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**EXAMINING WAYS TO STRENGTHEN RESEARCH
AND DEVELOPMENT IN INNOVATIVE TRANSPOR-
TATION TECHNOLOGIES, WITH A FOCUS ON
SOLUTIONS THAT DECREASE EMISSIONS, RE-
DUCE OUR RELIANCE ON FOREIGN SUPPLY
CHAINS, AND INCREASE MANUFACTURING IN
THE UNITED STATES**

**HEARING
BEFORE THE
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
ONE HUNDRED SEVENTEENTH CONGRESS**

FIRST SESSION

MARCH 16, 2021



Printed for the use of the
Committee on Energy and Natural Resources

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TUESDAY, MARCH 16, 2021

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The Committee met, pursuant to notice, at 9:34 a.m. in Room SD-366, Dirksen Senate Office Building, Hon. Joe Manchin III, Chairman of the Committee, presiding.

**OPENING STATEMENT OF HON. JOE MANCHIN III,
U.S. SENATOR FROM WEST VIRGINIA**

The CHAIRMAN. The Committee will come to order.

Before we get started, I would like to recognize my dear friend, Senator Heinrich. He has a little announcement he wants to make.

**OPENING STATEMENT OF HON. MARTIN HEINRICH,
U.S. SENATOR FROM NEW MEXICO**

Senator HEINRICH. Thank you, Chairman.

I wanted to just take a brief moment to recognize my long-time Senior Legislative Assistant on this Committee, Dr. Dan Alpert, who is retiring after a distinguished 23-year career here in the Senate. We all know that our work on this Committee and for our constituents would be absolutely impossible without the dedicated and knowledgeable staff that we have here on this Committee and that is especially true in the case of Dan Alpert.

Dan has been absolutely essential to my work on this Committee in support of our national labs where, by the way, he worked for 20 years before he worked for the Senate for 23. He has allowed me to really invest in the development and deployment of innovative clean energy technologies with his knowledge and just as important, I think, Dan has been a really wonderful mentor and friend to a countless number of colleagues and constituents here in the Senate.

His whip-smart intelligence and dry sense of humor are fully matched by his kind heart, and I know I speak for my entire team, as well as Senator Jeff Bingaman's office before us, and many others on this Committee in saying that we will miss you terribly, Dan, but I am so happy to congratulate you on your retirement and we all wish you well as you set off on new adventures and more time spent with your sweetheart, Ann.

Thank you, Dan.

[Applause.]

The CHAIRMAN. Thank you, Doctor. We really do appreciate you. I was wondering why Martin was so smart. Now I know.

Senator HEINRICH. You weren't supposed to tell anyone.

[Laughter.]

The CHAIRMAN. The United States has been a leader of innovation in the transportation sector since Robert Fulton created the first commercially successful steamboat in 1807. From the Wright Brothers and Henry Ford's assembly line to the successful flight of the Apollo 11 spacecraft, American ingenuity has been leading the way to transform how our society moves people and goods. As we face the climate challenge, American innovation in transportation technologies will once again lead the way in the vehicles and fuels of the future.

The transportation sector accounts for nearly 30 percent of the United States' energy consumption and it is responsible for the largest share—28 percent—of the country's greenhouse gas emissions. And that is something we do not talk about much, but needs to be known. Last Congress, this Committee considered the many bills that formed the bipartisan American Energy Innovation Act, which was ultimately largely enacted as the Energy Act of 2020. While I am so proud of all the things we were able to get done in the final bill, not everything made it across the finish line, including our vehicle's titles. If we want to reach any climate goal, we need to look at where the emissions are coming from and seek out solutions. At 28 percent of our emissions, it is clear that we have got to get to work on the transportation sector, and it is disappointing that we were not able to move the legislation last year.

So today, we begin attending to important unfinished work because our Committee has a critical role to play in ensuring that we have the technologies, the materials, and the domestic manufacturing needed to decarbonize our transportation sector. Whether it is electrolyzers that produce hydrogen from water or the batteries that power electric vehicles, we have to advance the technologies needed for the vehicles of the future and their supply chains. The United States can and should be the leader in clean transportation with help from research and development at the Department of Energy and the national labs. In addition, the opportunities for manufacturing and sustainable transportation technologies are plentiful and can create good-paying jobs right here at home when we need them most.

My American Jobs in Energy Manufacturing Act would help foster that economic growth by reviving the 48C energy manufacturing tax credit and carving out \$4 billion for exclusive use in coal communities, driving those jobs into the areas that have seen the biggest economic impact of the transition to a cleaner energy fu-

ture. I also firmly believe that we need to decrease our reliance on foreign supply chains to build these next generation technologies. While I recognize the value of electric vehicles to help reduce emissions, I remain deeply concerned that just a handful of countries, some of which have questionable mining practices, are the gatekeepers for the critical minerals we need to build the batteries used to power them.

We cannot stick our head in the sand about that. We have stronger environmental and workforce protection laws domestically than many of the countries that we rely on for these critical minerals. I believe that responsible domestic sourcing of the critical minerals needed for these cleaner technologies has to be part of this transition to a clean energy future. I am also concerned that we are quickly approaching the first cycle of batteries reaching the end of their usable life in the EV without the ability to recycle them domestically. So I am working on legislation that would boost DOE's role in advancing the recycling of the second life applications for EV batteries.

Ultimately, there is a lot of work yet to be done to reduce emissions in the transportation sector. As the sector of our economy emitting the most, we have got to get to work—whatever the fuels and the vehicles of the future will be—to advance the technologies that are going to be needed and shore up those supply chains.

I would like now for Senator Barrasso to give his opening statement.

**OPENING STATEMENT OF HON. JOHN BARRASSO,
U.S. SENATOR FROM WYOMING**

Senator BARRASSO. Well, thank you very much, Mr. Chairman. Thanks for holding today's critical hearing.

Our transportation sector is critical to our economy, and it moves people and products reliably and affordably across a huge network of roads and rails and runways and rivers. The transportation sector is also a big energy user, consuming 28 percent of our nation's total demand. Now, there are a lot of exciting new technologies to make this sector cleaner and more efficient, and I believe that innovation, not regulation, is the best way to improve our country's mobility. We need to expand, not limit choices in the transportation sector. If we have learned anything, it is that the government does a pretty poor job when it comes to picking winners and losers. So we should encourage a variety of technologies that reduce costs for consumers, that lower emissions, and that take advantage of the vast energy and mineral resources that we have in this country. Now, it seems to me that President Biden is taking the opposite approach. I am concerned he wants to regulate the internal combustion engine out of existence and insist that all Americans use electric vehicles.

Too often, regulation raises costs, punishes people. These are people that are often those who can least afford it. In December, the President of Toyota pointed out that regulating the internal combustion engine out of existence could make automobiles "a flow-er," he said, "on a high summit." In other words, something out of reach of ordinary people. Well, he's right. In the United States, a typical Tesla owner has no children and makes an annual income

of more than \$140,000. Limiting consumer options to just expensive electric vehicles is bad for consumers and the economy. It is bad for the environment too, and it will just slow the turnover to a cleaner, more efficient fleet.

Requiring a shift to electric vehicles will also put America in the position of importing critical minerals, often from bad actors. We will need to import minerals like cobalt, lithium, graphite, manganese, and other rare earths. China, for example, controlled about 60 percent of the graphite and rare earths produced in 2020. At the same time, we must not pursue emission reduction strategies that contribute to child labor, human rights abuses, and environmental damage. For example, the Democratic Republic of the Congo produces about 70 percent of the world's cobalt supply. According to the United Nation's report, about 20 percent of the cobalt it produces comes from small mines where 40,000 children are at work.

In the lithium production area of Chile, mining consumed 65 percent of the area's water, causing soil contamination and harming local communities.

If President Biden and others in Congress are serious about promoting electric vehicles, they should encourage mining here at home. Expanding American mining would help secure our nation's supply chains and ensure minerals are produced responsibly. Instead, last month, the Biden Administration withdrew a land exchange for the Resolution Copper mine in Arizona, casting doubt on what would be North America's largest copper mine.

Electric vehicles are part of the solution. They are not the only solution. More efficient internal combustion engines and a diverse set of fuels will have to be a significant part of the solution. That is especially true for heavy trucks, buses, trains, and vessels. And in trucking and rail, diesel engines are likely to remain the technology of choice for decades. We can reduce emissions through the use of clean diesel and even renewable diesel.

We can also reduce emissions through the use of natural gas. The United States produces more natural gas than any other country in the world. We should look for ways to use compressed or liquefied natural gas to power trucks, trains, and vessels. Additionally, we can convert natural gas to hydrogen for use in fuel cells. Natural gas is a great opportunity to keep costs low for consumers, to improve air quality, and to use the resources that America is blessed with.

The people of Wyoming drive greater distances than people in any other state, by far. We depend on our vehicles in ways people from other states do not. Our cars and trucks must be reliable and affordable. When alternative vehicles and fuels can pass the test in Wyoming, we will know we have hit upon great technologies. Until then, consumers in Wyoming and across the country need to be able to drive the cars and trucks they require for them to get to work and for their families.

Thank you, Mr. Chairman. I look forward to the testimony.

The CHAIRMAN. Thank you, Senator.

It is now my pleasure to introduce our panel to us. We have a distinguished panel and I think it is going to be quite informative. I thank each and every one of you.

We have Ms. Kelly Speakes-Backman, Principal Deputy Assistant Secretary and Acting Assistant Secretary for Energy Efficiency and Renewable Energy at the Department of Energy.

Mr. Adam—and I hope I don't destroy the last names here, but I am going to do the best I can—Muellerweiss, who is the Chief Sustainability Officer at Clarios, a battery supplier and manufacturer.

We have Mr. Janvier Nkurunziza, Officer-in-Charge of the Commodities Branch and Chief of the Commodity Research and Analysis Section of the Division of the International Trade and Commodities at the United Nations Conference on Trade and Development. And Mr. Nkurunziza, based on your affiliation with the United Nations, I would also like to note that you are appearing voluntarily today as a courtesy to this Committee.

Mr. Tony Satterthwaite, Vice Chairman of Cummins Inc.

And Mr. Robert Wimmer, Director of the Energy and Environmental Research Group at Toyota Motor North America.

I want to thank you all. First, I apologize if I did not get the names, last names, correctly pronounced, but I want to thank you for being here in person and also virtually. I look forward to the discussion today.

With that, I am going to turn to our first witness here and panelist, Mrs. Speakes-Backman, for her opening statement.

STATEMENT OF KELLY SPEAKES-BACKMAN, ACTING ASSISTANT SECRETARY, ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY

Ms. SPEAKES-BACKMAN. Chairman Manchin and Ranking Member Barrasso, thank you so much for the opportunity to testify on transportation technologies today. As you mentioned, I'm Kelly Speakes-Backman. I am the Acting Assistant Secretary for the Office of Energy Efficiency and Renewable Energy (EERE). As Acting Assistant Secretary, I oversee a broad portfolio of energy efficiency and renewable programs. The technologies in my portfolio advance America's economic growth and energy security while enhancing the reliability and the resilience of the U.S. energy system.

Climate change is one of the greatest challenges facing our nation and our planet today. DOE stands ready to work to address the climate emergency by doing its part to support the U.S. to build a 100 percent clean energy economy and reach net zero emissions, no later than 2050. We must also ensure that the benefits from a clean energy future are equitably shared by all Americans for clean air and good-paying jobs, from farmers to factory workers, and from cities to the rural economy. EERE is well-positioned to drive the research and development, and I will underscore the demonstration and the deployment needed to overcome these challenges while reducing harmful emissions that disproportionately affect lower income and minority populations. EERE-led demonstrations and deployments can also show how we can integrate new technologies to expand access to transportation for underserved communities.

Transportation has become the largest source of greenhouse gas emissions in the U.S., surpassing the power sector in 2017. Transportation is central to our economy. It supports millions of U.S.

jobs and is part of everyday life for all Americans. We are committed to developing the technologies needed to decarbonize the transportation sector and to do so in a way that is affordable, expands mobility options for underserved communities, keeps us globally competitive and our nation secure, and creates good-paying, middle class, American jobs.

Our sustainable transportation strategy to decarbonize the sector includes all modes. That is air, sea, rail, and road. It encompasses activities in the fuel streams of electricity, electrification, hydrogen and fuel cells, and biofuels. We must deploy technologies in all of these resources to be successful in our efforts. For this reason, today I will focus on work underway with the electric vehicles, biofuels, and hydrogen offices. These are not stand-alone topics and they bring up important conversations, I should add, about critical material supply chains and grid integration.

Electrification is one of the most effective ways that we can combat climate change. Our success with electric vehicles is largely dependent upon advancements in battery technologies. Our Vehicle Technologies Office R&D investments throughout the past decade have yielded breakthroughs in battery cost and performance, reducing lithium-ion EV battery costs by about 85 percent, from \$1,000 a kilowatt-hour in 2008 to only \$144 a kilowatt-hour in 2020; and driving down weight and enhancing manufacturability as well. DOE's goal is to lower the battery pack cost to below \$80 per kilowatt-hour, and cell cost to \$60 per kilowatt-hour, allowing EVs to reach cost competitiveness with future internal combustion engine vehicles. It's important that EVs are not just a luxury, but the most affordable and accessible choice for all Americans.

Biofuels are also a crucial part of the nation's energy system, and we see growing opportunities for biomass in the low-carbon transportation system, especially for aviation. In 2019, the U.S. produced over 19 billion gallons of biofuels and supported over 106,000 domestic jobs. The vast majority of these biofuels are ethanol and biodiesel, which are blended into petroleum gasoline and petroleum diesel fuel, respectively. The domestic biofuels industry faced significant challenges this past year due to reduced demand for transportation fuels as a result of the global pandemic. There are important opportunities to recover from this setback and expand the role of biomass for our rural farm economies. Supporting these communities and expanding job opportunities from biorefineries of the future is an important part of the President's plan.

Hydrogen is also a key part of our transportation strategy, as a versatile fuel that can play an important role to decarbonize key industrial sectors, provide new energy storage options, and support the move to 100 percent clean energy electricity production. Realizing the potential for hydrogen is going to require continued research and development as well as accelerated demonstrations and deployments with the private sector to achieve scale. That's the basis of our "H2@Scale" efforts to reduce hydrogen production costs to benefit all end-users, including industrial and transportation applications.

Thank you for this opportunity to appear before you today. I look forward to working with you to address the climate crisis and providing American families and businesses with a wider range of en-

ergy and mobility options that offer more affordability, more reliability, and more security of our nation's energy.

I look forward to your questions.

[The prepared statement of Ms. Speakes-Backman follows:]

Testimony for the Record

**Kelly Speakes-Backman
Acting Assistant Secretary
Energy Efficiency and Renewable Energy
U.S. Department of Energy**

**FOR A HEARING ON
Transportation Technologies**

**BEFORE THE
UNITED STATES SENATE
ENERGY AND NATURAL RESOURCES COMMITTEE**

**Tuesday, March 16, 2021
Washington, D.C.**

Introduction

Chairman Manchin and Ranking Member Barrasso, thank you for the opportunity to testify before the committee today. As the Acting Assistant Secretary of the Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE), I oversee a broad portfolio of renewable energy, energy efficiency, and sustainable transportation programs.

Our program's primary focus is on funding technology research, development, demonstration and deployment (RDD&D) through competitive solicitations open to the public and through support for the National Laboratories, which play a central role in advancing America's leadership in science and technology and developing innovative solutions for the future. Additionally, academic institutions, such as universities and colleges, are a resource for innovation, R&D, and training sponsored by EERE. The knowledge generated by EERE research, development, demonstration, and deployment drives down the costs of new technologies, supporting the efforts of U.S. industries, businesses, and entrepreneurs in growing and commercializing innovative energy technologies. These technologies also reduce harmful emissions that disproportionately affect lower income and minority populations. The demonstrations and deployments show how we can use new technologies to expand access to transportation for underserved communities.

Climate change is one of the greatest challenges facing our nation and our planet today. DOE stands ready to work to address the climate emergency and lead through the power of example, by doing its part to ensure that the U.S. builds a 100% clean energy economy and reaches net-zero emissions no later than 2050. We must also ensure that the benefits from a clean energy future are equitably shared by all Americans, from clean air to good-paying jobs, from farmers to factory workers and from cities to the rural economy.

Transportation is the largest source of greenhouse gas emissions in the United States, surpassing the power sector in 2017¹. It is also central to the economy, supports millions of U.S. jobs and is part of everyday life for all Americans. We are committed to developing the technologies needed to decarbonize transportation and to do so in a way that is affordable, provides improved mobility options for underserved communities, keeps us globally competitive and our nation secure, and grows good paying, middle-class American jobs. This includes opportunities to sustainably grow the role of biomass, address vulnerabilities with respect to critical material supply chains, and create jobs in the rural economy.

DOE's sustainable transportation strategy to decarbonize transportation includes all modes: air, sea, rail, and road. It encompasses activities in the fuel streams of electrification, hydrogen and fuel cells, and biofuels. We will need to deploy solutions from all three of these technologies to be successful in our efforts. In addition, we need to recognize the dramatic changes that are occurring in mobility itself, how people are accessing transportation and how e-commerce and the shipments of goods are changing. Our work includes understanding the transportation system as a whole and how promising mobility options like automation, connectivity and last-mile service – which is the last leg of a journey from a transportation hub to a final destination –

¹ <https://usafacts.org/articles/transportation-now-largest-source-greenhouse-gas-emissions/>

can help achieve both GHG reductions while also providing more and better mobility choices for underserved communities.

We are working closely with other agencies to achieve our goals, including the U.S. Department of Transportation, the U.S. Environmental Protection Agency, and the U.S. Department of Agriculture. I appreciate the opportunity today to share a bit on our work on electric vehicles (EVs), biofuels, and hydrogen fuel cell technologies.

Electric Vehicles

Electrifying transportation is one of the most effective ways we can combat climate change. Our success with electric vehicles is largely dependent on advancements in battery technologies.

At DOE, through our Vehicle Technologies Office (VTO) our research and development investments throughout the past decade have yielded breakthroughs in battery cost and performance; reducing lithium ion EV battery pack costs by about 85% from approximately \$1000/kWh in 2008 to \$144/kWh in 2020; and driving down weight and enhancing manufacturability. DOE's goal is to lower the battery pack cost to below \$80/kWh from the \$144/kWh level today, and cell cost to \$60/kWh, allowing EVs to reach cost competitiveness with future internal combustion engine vehicles. It's important that EVs are not a luxury, but the most affordable and accessible choice for all Americans.

Although initial costs of EVs are currently more expensive than internal combustion engine vehicles, they offer savings over the life of the car in fuel, maintenance and repair costs. Today, the average EV driver saves approximately \$600 in fuel costs each year, and about \$6000 in maintenance costs over the average 13,500 miles per year life of the car. By bringing down the upfront cost of EVs through our battery cell and battery pack research and development, EVs will be the clear choice for Americans in the coming years. The total fuel and maintenance cost savings are even greater for work trucks that often have higher mileage per year.

We are also working to improve convenience for EV owners, by decreasing recharge time to less than 15 minutes for a 300-mile range vehicle. Further, we are exploring new battery chemistries with less reliance on rare, critical minerals such as cobalt, to minimize the environmental impacts of production. Our most recent batteries have already reduced cobalt by 60% (vs 2010) and our goal is a 95% reduction.

In addition to light-duty cars and trucks, there has been tremendous progress made on electrifying medium and heavy-duty trucks and buses. This includes both battery electric and hydrogen fuel cell vehicles. Just in the last year, manufacturers have started to make medium and heavy duty electric trucks and electric school buses available for general sales and have demonstrated hydrogen fuel cell long-haul tractor trailer trucks. Demand for electric transit buses has also grown. There is growing consensus that these technologies will play a major role in the future of transportation.

Electrifying vehicles - and especially large trucks - whether powered by batteries or hydrogen fuel cells, can bring significant air quality benefits. These zero-emission vehicles can reduce the pollution in communities near ports, factories, and roadways. In ports for example, as vehicles

and other gas-powered machines idle, air pollutants are being inhaled by the on-site workers. Electric school buses also reduce the exposure to students from harmful emissions and particulates. Electrifying these vehicles and systems can bring important health benefits for many Americans.

We are working with a variety of industry partners and fleets to solve problems and address technology barriers to safely accelerate the development and deployment of electric vehicles and charging infrastructure. Our EV infrastructure work focuses on grid integration and smart charge management, high power charging systems, and cyber-physical security of charging infrastructure.

Battery Technology

As we advance battery technologies, we want to make sure that these batteries are being made domestically, so that we continue to see the growth of battery manufacturing jobs in the U.S. To meet the forecasted demand from light and heavy-duty EVs, the United States will need over one hundred (100) battery cell manufacturing locations in the U.S. by 2035. There is clear consensus that electrification of our economy and specifically in the transportation sector will expand, and other countries and regions such as China, South Korea and Europe are investing to have an economic stake in this industry. The United States currently manufactures only 9% of global battery cells. With the right combination of technological advances and policy signals, we can support U.S. manufacturing and workers.

Growing the domestic EV industry will require a secure and resilient domestic supply chain, “from minerals to markets.” DOE is leading the way to reduce U.S. dependence on imported critical materials like lithium, nickel, graphite and cobalt by reducing the amount of these materials needed for battery production, developing substitute materials, improving reuse and recycling, and exploring domestic sources that can be developed in an environmentally responsible manner.

The last critical piece of this supply chain is reusing and recycling the materials. Our research shows that up to 40 percent of the materials for future batteries can come from recycled vehicle batteries and our National Laboratories are conducting research on such efforts, such as the ReCell Center at Argonne National Lab which is also supported by the National Renewable Energy Lab (NREL).

Our commitment aligns with President Biden’s recent Executive Order, emphasizing the need to strengthen these supply chains in recognition of their importance to our economy. We want to focus on the entire supply chain, including mining, processing, and manufacturing, which again will translate to a series of good-paying, middle class jobs distributed across the country. At each level of the chain, we want to partner with the private sector.

Biofuels

Biofuels are a crucial part of the Nation’s energy system—now and in the future. We see additional and growing opportunities for biomass in a low carbon transportation system. While petroleum currently provides over 90 percent of our transportation energy mix, biofuels provide

almost 10 percent.² In 2019, the United States produced over 19 billion gallons of biofuels and supported over 106,000 domestic jobs.³ The vast majority of these biofuels are ethanol and biodiesel, which are blended into petroleum gasoline and petroleum diesel fuel, respectively. The domestic biofuels industry faced significant challenges over the past year due to reduced demand for transportation fuels as a result of the global pandemic. There are important opportunities to recover from this setback and expand the role of biomass for our rural, farm economies. Supporting these communities and growing job opportunities from bio-refineries of the future is an important part of the President's plan.

The Department of Energy's Bioenergy Technologies Office (BETO) conducts RDD&D activities in support of low-carbon drop-in biofuels that are compatible with existing fuels and infrastructure. These technologies can use traditional feedstocks, such as corn or soy oil, as well as agricultural wastes, forest biomass, algae biomass, municipal solid waste, sludge from farms or wastewater treatment—to make gasoline, diesel, and jet fuel. These technologies will produce direct hydrocarbon replacements for petroleum, which will help the industry overcome the blend limitations on ethanol and biodiesel while also delivering climate benefits. Our bioenergy office funding has helped to lower the cost of these fuels by over 47 percent since 2012 and has strategies in place to continue the pursuit of cost competitiveness with traditional fuels. There are a variety of biofuel production pathways in the BETO portfolio, most delivering 70 percent lower greenhouse gases than petroleum fuels. It will be critical to work closely with the existing bio-fuels industry to leverage their expertise and the lessons learned from the past 20 years to achieve these benefits.

The aviation fuel market is a particularly attractive market for new biofuel solutions. The aviation sector is important to the American economy but is a significant and growing source of greenhouse gas emissions. U.S. commercial aviation consumes approximately 10 percent of transportation energy and is one of the fastest growing uses of transportation energy. Aviation also drives 6 percent of the U.S. gross domestic product and just under 9 percent of national employment. The 106-billion-gallon global commercial jet-fuel market (21-billion-gallon domestic) is projected to grow to over 230 billion gallons by 2050⁴.

The aviation sector is difficult to decarbonize because of the need for a high energy density liquid fuel to meet the mission needs for efficiency, long range, safety, and space for passengers and cargo. Current battery technologies do not have the energy density required for a commercial aircraft fully loaded with passengers, fuel, and freight to take off and travel long distances.

The aviation industry considers drop-in advanced liquid biofuels, often called Sustainable Aviation Fuel (SAF), to be the only feasible solution to reducing greenhouse gas emissions and decoupling their market growth from carbon emissions. BETO is particularly focused on the

² <https://www.eia.gov/todayinenergy/detail.php?id=43096>

³ <https://www.eesi.org/papers/view/fact-sheet-jobs-in-renewable-energy-energy-efficiency-and-resilience-2019#:~:text=USEER%20reports%20that%20the%20woody%20stable%20from%202017%20to%202018>

⁴ <https://www.eia.gov/todayinenergy/detail.php?id=41913#>

development of innovative SAF technologies that can address this challenge and position the U.S. as a global leader in the emerging aviation biofuels market.

The “Billion Ton Study,” a joint study by DOE and the U.S. Department of Agriculture in 2016, estimates that the United States can grow and harvest about 1 billion dry tons/year of biomass economically and sustainably by 2030, which is sufficient to produce 50-60 billion gallons of advanced biofuels without impacting agriculture, trade, and current uses of biomass. By our analysis, this is sufficient to meet the projected needs of the U.S. aviation industry (35 billion gallons by 2050), produce additional volumes of biofuels and bioproducts for other applications, and reduce CO₂ emissions by 450 million metric tons - all while employing over one million people in good-paying jobs.

Hydrogen

Hydrogen is also a key part of our transportation strategy, and a versatile fuel that can play an important role to decarbonize key industrial sectors, provide new energy storage options and support the move to 100% clean electricity production by 2035. Realizing the true potential for hydrogen requires continued research and development, as well as accelerating demonstrations and deployments with the private sector to achieve scale. That is the basis of our ‘H2@Scale’ efforts to reduce hydrogen production costs to benefit all end-uses, including industrial and transportation applications. The U.S. currently produces 10 million metric ton of hydrogen, mostly in the south-central U.S. As the hydrogen economy grows, we will need to build upon this existing infrastructure and expertise. As renewable energy grows across the U.S., this will also provide new opportunities for green hydrogen production through electrolysis.

In transportation, hydrogen is particularly well-suited for heavy-duty applications that need both the energy density stored hydrogen can provide and centrally located fueling. This includes long-haul heavy-duty trucks, maritime and rail. Last year we launched the Million Mile Fuel Cell Consortium with industry and National Labs to develop fully cost-effective and durable technologies that can demonstrate a class 8 long haul truck by 2025. We are also working to reduce the cost of hydrogen storage on trucks and to develop improved high-pressure fuel stations that can quickly and safely refuel these trucks.

We have also launched the H2NEW consortium to reduce the cost of electrolyzers, which directly ties into the need to achieve low cost, carbon-free hydrogen. Our hydrogen efforts also involve a greater integration of renewable and nuclear energy systems, and it will take an integrated approach from multiple energy sectors to realize the full potential and benefits of hydrogen. We have several projects being conducted jointly with the DOE Office of Nuclear Energy to demonstrate how electrolysis can be coupled with nuclear energy sites to provide benefits both to the nuclear plant and to reduce the cost of hydrogen production. This type of integrated energy systems approach is a key part optimizing resources and achieving large scale, low cost production of clean hydrogen.

Grid Integration

The Energy Act of 2020 (the “Act”) directed DOE to establish a research, development, and demonstration program to advance the integration of electric vehicles onto the electric grid. The Act also requires an EV-grid integration assessment report and roadmap of how to best integrate electric vehicles (EVs) for both grid reliability and grid resiliency services. This is an important priority for the Department as we look to the future of the power system. As more and more of electric vehicles come on the road, integrating their charging into the power system becomes an additional consideration in grid planning and operation. Greater vehicle electrification poses both a challenge and an opportunity: a challenge both because it requires more power overall, and because the speed and timing of that additional demand can be difficult to predict; and an opportunity because vehicle charging can provide an additional source of flexibility that can be used to integrate variable generation like wind and solar. DOE is investigating technologies that maximize that flexibility and could effectively allow vehicle chargers to be managed as a grid asset. Vehicles can even be a source of resilience and backup power: for example, during the 2021 Texas ice storms and power outages, previously charged EVs served as a refuge from extreme cold, and, in some cases, provided emergency back-up power to affected households.

The Department is currently conducting a scenario analysis to better understand the national impact of electrifying the transportation sector and understand the impacts this will have on generation. We are also investigating how EVs can provide more system flexibility through managed charging and vehicle-to-grid. Finally, we are investigating the implications of necessary grid upgrades at the distribution level where fleet electrification will be taking place in the near future (e.g. UPS or Amazon).

Conclusion

Thank you for the opportunity to appear before the Committee today. I look forward to working with you to address the climate crisis by providing American families and businesses with a wider range of energy and mobility options that offer more affordability, reliability, and security of our nation's energy.

I look forward to your questions.

The CHAIRMAN. Thank you, Ms. Speakes-Backman.

And now we will have Mr. Muellerweiss for his opening statement.

STATEMENT OF E. ADAM MUELLERWEISS, PRESIDENT, RESPONSIBLE BATTERY COALITION, AND CHIEF SUSTAINABILITY OFFICER, CLARIOS

Mr. MUELLERWEISS. Chairman Manchin, Ranking Member Barraso, and distinguished members of the Committee, thank you for the invitation to testify today. I am Edmund Adam Muellerweiss, President of the Responsible Battery Coalition and Chief Sustainability Officer for Clarios.

As part of our nation's critical infrastructure, my company, Clarios, is the world's largest producer of low-voltage batteries essential for vehicles to start, perform efficiently, and keep people safe. Every vehicle requires the types of batteries we make, no matter if they are internal combustion, hybrid, or fully electric. Clarios is a member of the Responsible Battery Coalition, a leading group of companies, academics, and organizations dedicated to the responsible management of the batteries of today and tomorrow.

There are three key points I will highlight today: Number one, modern life requires batteries, and the U.S. needs more of them. But there is no single technology that can satisfy these demands. Number two, to meet this need, we will need to take into account every stage of a battery's life, especially end of life and recycling. Number three, this creates opportunities for domestic job creation, material efficiency, and system-wide carbon reductions.

Meeting increasing demand for transportation and stationary storage batteries is especially critical. The combined demand for transportation and stationary batteries is expected to increase four-fold by 2030. Projections suggest that by 2040, as many as two billion vehicles will be on the road globally, including both internal combustion and electric vehicles, with each requiring batteries. The batteries used in electric vehicles may look different than stationary storage, or bear little resemblance to the ones NASA used in the rover now on Mars, yet all of these batteries have one thing in common—they are a contained chemical reaction. Each battery chemistry has different characteristics and tradeoffs suitable for some applications and not others. Some use abundant, readily available, and recyclable materials, and others use rare materials with limited supply. That's why every aspect of a battery's life, from mining and manufacturing to end of life and recycling, must be considered as we work to protect supply chains, decrease greenhouse gas emissions, and reduce risk to human health and the environment.

At Clarios, we do this every day. We make new batteries from the used batteries we collect and recycle. Our supply chain does not start around the world, but around the corner at your local car dealer, repair shop, or auto parts store, when a used lead-acid battery is exchanged for a new one. We design to maximize recyclability. For example, up to 99 percent of a used lead-acid battery from the plastic case to the active materials can be recycled to make new ones. This results in 90 percent lower greenhouse gas emissions. Because of this approach, the U.S. has nearly a 100 per-

cent recycling rate ensuring reliable and secure domestic supplies to manufacturing new lead-acid batteries. Developing recycling for next generation batteries is equally critical, especially those that use materials that are in limited supply or come from unstable regions.

Over the next 20 years, more than two million metric tons of used lithium-based batteries from electric vehicles will reach end of life in the U.S. alone. These batteries must be considered a critical resource, not a waste. Together, the Responsible Battery Coalition and Argonne National Lab are modeling to help design batteries for maximum recyclability before they go into production. Through the DOE's lithium-ion recycling prize, Clarios is applying our decades of experience in battery recycling to the challenge of recycling lithium batteries at scale. The ultimate goal is to capture 90 percent of discarded lithium-based batteries in the U.S. to recover key materials and reintroduce them into the supply chain to make new batteries. Establishing these critical supply chains will require U.S. jobs for recovery, processing, and recycling that are by definition local jobs.

In closing, a life-cycle approach, from mining and manufacturing to end of life and recycling, is critical to protect supply chain, reduce emissions, and create new jobs. Responsible recycling is essential to complement the Administration's effort to ensure the supply of critical battery materials for the United States.

Thank you again for this opportunity. I look forward to answering your questions.

[The prepared statement of Mr. Muellerweiss follows:]

**Written Testimony of E. Adam Muellerweiss
President of the Responsible Battery Coalition
Chief Sustainability Officer for Clarios**

**Prepared for the U.S. Senate Committee on Energy and Natural Resources
Hearing on Transportation Technologies
March 16, 2021**

Introduction

Chairman Manchin, Ranking Member Barrasso, and distinguished members of the Committee:

Thank you for the invitation to provide testimony to the Energy & Natural Resources Committee as part of your examination of ways to strengthen research and development on innovative transportation technologies. I appreciate the opportunity to share solutions that leading companies in the private sector are embracing to decrease emissions, reduce our reliance on foreign supply chains, and increase manufacturing in the United States.

I am Edmund Adam Muellerweiss, President of the Responsible Battery Coalition and Chief Sustainability Officer for Clarios.

The Responsible Battery Coalition (RBC) is a leading coalition of companies, academics and organizations dedicated to the responsible management and environmental sustainability of the batteries of today and tomorrow. The RBC mission is to advance the responsible production, transport, sale, use, reuse, recycling, and resource recovery of batteries primarily used for transportation and stationary storage applications.

As part of our nation's critical infrastructure, my company, Clarios, supplies batteries that ensure that the majority of cars, trucks and emergency services vehicles on our country's roads stay on the move and that the country's agricultural equipment and military transport vehicles remain operational in the field. Clarios is the world's largest producer of low-voltage batteries that are essential for vehicles to start, perform efficiently, and keep people safe. Every vehicle requires the type of batteries we make – no matter if they are internal combustion, hybrid, or fully electric.

Securing the future transportation and energy systems of the United States requires addressing the following three priorities:

1. We need more batteries – but there is no silver bullet.
2. A different approach is required – one that takes into account every stage of a battery's life.
3. Embracing a lifecycle approach creates opportunities for domestic job creation, material efficiency, and system-wide carbon reductions.

A Battery-Driven Society Needs More Batteries

Every aspect of our daily lives is tied to batteries. If this morning you have used your cell phone, made coffee, used the internet, or turned on a computer, you have already engaged with multiple batteries.

The combined demand for transportation and stationary batteries is expected to increase fourfold by 2030 to more than 2,500 GWh, from a 2018 baseline.¹

Recent analysis from the International Energy Agency predicts that 125 million electric vehicles will be on the road around the world by 2030, and other projections suggest that a total of 2 billion combustion engine and electric vehicles will be on the road globally by 2040, each requiring batteries.²

No one-size-fits-all or silver bullet

Yet, there is no single battery type, design, or chemistry that meets all these needs. Commonly used consumer batteries differ greatly from those used to provide back-up power to the grid. The batteries used in electric vehicles or to store wind and solar energy bear little resemblance to the ones NASA used in the rover now on Mars.

Despite these differences, all batteries are a contained chemical reaction. This means every stage of the battery's life – from mining and manufacturing to end-of-life and recycling – must be considered to decrease greenhouse gas emissions and reduce risk to human health and the environment.

This becomes a national imperative as the demand for batteries accelerates exponentially.

A Different Approach is Required

The batteries needed to secure our future transportation and clean energy systems must be developed, designed, and deployed differently. Every aspect of a battery's life, especially its end-of-life must be considered from the very beginning.

Each battery chemistry has specific characteristics and tradeoffs that make it suitable for some applications and not others. Some chemistries have higher energy density while others have higher life expectancy. Some use abundant, readily available and recyclable materials, and others use rare materials with limited supply.

¹ Energy Storage Grand Challenge - Energy Storage Market Report, December 2020, https://www.energy.gov/sites/prod/files/2020/12/f81/Energy%20Storage%20Market%20Report%202020_0.pdf
² <https://www.responsiblebatterycoalition.org/rbc-u-of-m-publish-first-green-principles-for-ev-battery-management/>

Factors such as resource availability, geopolitical implications, supply-chain risk, human and environmental impacts, domestic manufacturing capacity, and recyclability should be as important in the choices we make today as performance and cost.

Typically batteries have been designed, made, and used following a linear process. The selection of materials was tied primarily to performance and price instead of the sustainability of its supply. End-of-life was rarely considered upfront, leaving environmental managers to address the impacts later in the process.

Critical Role of End-of-Life Recovery and Recycling

Recycling is too often viewed as something to do out of altruism or moral obligation. In fact, battery recycling is an economic driver, a risk reducer, and is about protecting our supply chain. Using recycled materials can dramatically reduce energy consumption, greenhouse gas emissions, and potentially harmful pollutants.

Effective and responsible recycling can reduce conversion costs, increase domestic supply chain resilience, decrease dependence on foreign material sources, ensure better cost predictability, improve operational efficiency, and reduce the chance of production disruption.

A study on battery recycling by Argonne National Laboratory indicates that using recycled lithium, aluminum, and copper could theoretically reduce the embodied energy in these batteries by approximately 40 to 50 percent.³

Dr. Ramon Sanchez of the T.H. Chan School of Public Health at Harvard University and chair of the Responsible Battery Coalition's Science Advisory Board said, "The recycling of lead-acid vehicle batteries is one of the great achievements in protecting public and environmental health. With 99 percent of the vehicle batteries in North America currently being recycled, we are reducing pollution, including the greenhouse emissions caused from sourcing new battery materials."⁴

I was honored to be with Dr. Sanchez in 2018 when the RBC launched the "2 Million Battery Challenge" with the U.S. Senate Auto Caucus at our nation's capitol. The 2 Million Battery Challenge raises awareness with consumers on the importance of returning lead-acid batteries, and includes specific efforts for recovering used batteries from rural Alaska and Canada.

Developing similar recycling systems is critical for next generation battery chemistries, which rely on metals that are in limited supply or produced in unstable regions. Over the next 20 years, the projected global used battery volume from electric vehicles alone will increase to

³ Material and Energy Flows in the Materials Production, Assembly, and End-of-Life Stages of Automotive Lithium-Ion Battery Life Cycle; Argonne National Laboratory, 2012; <https://greet.es.anl.gov/publication-lib-lca>.

⁴ <https://www.responsiblebatterycoalition.org/rbc-launches-2-million-battery-challenge-at-u-s-senate-auto-caucus-briefing-on-sustainability/>

more than seven million metric tons annually, with more than two million metric tons of used battery waste produced in the United States alone.⁵

Current Initiatives Supporting a Complete Lifecycle Approach

As an affiliate member of the Department of Energy's Joint Center for Energy Storage Research led by Argonne National Laboratory, the Responsible Battery Coalition is engaged to help identify opportunities to accelerate the development of recycling and circular supply chains for future battery chemistries.

Recognizing the significant energy, environmental, and economic benefits of battery recycling, our coalition has entered into a joint research project to further advance battery innovation and ensure that the batteries of tomorrow are designed for maximum recyclability. The project goal is to generate detailed information to help battery manufacturers design batteries with reuse and recycling in mind.

The project provides a platform for the battery industry to assess the full lifecycle attributes of various battery technologies before they go into production. By modeling the complete lifecycle in advance, a manufacturer has the opportunity to compare and contrast different battery chemistries "in the lab."

This helps proactively identify risks, reduce production costs, and enable environmentally-responsible battery design from materials selection through end-of-life recycling. This work will lead to tangible, real-world solutions, benefiting industry and consumers alike.

At my own company, Clarios, we have had the privilege to work alongside the Department of Energy's Joint Center for Energy Storage Research as the only battery company in the first phase helping shape this public-private partnership to accelerate advance battery research and development.

Through the Department of Energy's Lithium-Ion Battery Recycling Prize, we have assembled a private sector team working with national labs to apply the lessons learned through our decades of experience in battery recycling to the challenge of recycling lithium ion batteries at scale.

Clarios collects and converts used batteries into materials to build new batteries. We convert 8,000 used lead-acid batteries every hour of every day across our network to help feed our plants that build new batteries with up to 90 percent recycled content. This innovative circular supply chain starts and ends when a consumer replaces a used vehicle battery with a new one at a dealer, repair shop, or auto parts store. By considering end-of-life in the design of our batteries, up to 99 percent of the materials in our batteries can be recovered and reused.

⁵ <https://www.responsiblebatterycoalition.org/rbc-argonne-national-laboratory-partner-on-advanced-design-recycling-programs-for-new-battery-technologies/>

Green Battery Principles

The Responsible Battery Coalition is working with battery manufacturers, recyclers, the automotive industry, fleet owners, and academia to advance responsible lifecycle management of all batteries.

Foundational to this work is translating science and making it usable in the real world, informing battery technology through sharing best practices and principles.

A team led by Dr. Gregory A. Keoleian, director of the University of Michigan's Center for Sustainable Systems and a member of the Responsible Battery Coalition's Scientific Advisory Board, developed new "Green Principles for Vehicle Energy Storage." These principles define best practices applicable for both current and emerging battery technologies – from initial raw materials extraction, battery-in-use, through to end-of-life.⁶

These green principles establish a comprehensive set of recommendations to guide mobile battery technology development and deployment minimizing the environmental impact of electric vehicle (EV) batteries – most notably lifecycle energy consumption and greenhouse gas impact.

As batteries play an ever-larger role in meeting our energy needs, applying these principles supports the creation of a sustainable domestic battery economy.

Conclusion

If I could leave you with one take away – Every stage of the battery lifecycle presents opportunities for domestic job creation, material efficiency, and system-wide carbon reductions.

While much attention has rightly focused on ensuring supplies of critical minerals in the United States, to complement these efforts we need to adopt a whole lifecycle approach to battery design that includes end-of-life recovery and recycling.

In closing, advancing a comprehensive lifecycle approach to battery innovation is critical for this Committee to consider as it strives to create a sustainable, domestic battery economy to decrease emissions, reduce our reliance on foreign supply chains, and increase manufacturing in the United States.

Senators, I thank you again for this opportunity to appear before you today. I look forward to taking your questions.

⁶ <https://www.sciencedirect.com/science/article/abs/pii/S2352152X19302956?dgcid=coauthor>

The CHAIRMAN. Thank you, sir.

And now we have Mr. Nkurunziza for his opening statement.

STATEMENT OF JANVIER DÉSIRÉ NKURUNZIZA, OFFICER-IN-CHARGE, COMMODITIES BRANCH, AND CHIEF, COMMODITY RESEARCH AND ANALYSIS SECTION, DIVISION ON INTERNATIONAL TRADE AND COMMODITIES, UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Mr. NKURUNZIZA. Mr. Chairman and Ranking Member Barrasso, it is an honor to be with you. I thank you for reminding everyone that we are here on a voluntary basis. This should not be understood to be a waiver, express or implied, of the privileges and immunities of the United Nations and its officials under the 1946 Convention on the Privileges and Immunities of the United Nations. I am speaking in my personal capacity, and the opinions expressed here are my own.

My intervention is structured around three points. The first point is to look at U.S. activity in the lithium and cobalt value chains. The key ingredient in the current innovative mobility paradigm is the electric rechargeable battery, particularly the lithium-ion battery. Two key natural resources are central to the production of these batteries. These are lithium and cobalt. Known reserves of these resources are in a few countries. Fifty-eight percent of lithium reserves are in Chile and 50 percent of cobalt reserves are in the Democratic Republic of Congo. Currently, production of cobalt and lithium from within United States is relatively limited, but things could change. There are opportunities found on the commodities value chains beyond extraction that could be taken advantage of and this takes me to the second point.

What are these opportunities? I think the first is exploration. Some regions, particularly in Africa, are way underexplored. So there must be more deposits of these strategic resources in every region of the world. Extraction: There are technologies that are inefficient, opening the door for firms with better technologies. Lithium extraction in Chile, for example, is inefficiently extracted. Deposits in Bolivia are stranded due to technological issues. So new, more efficient technologies are being introduced and these will bring to bear a number of otherwise stranded assets. The other aspect is recycling and disposal. This area is underdeveloped and we think there are opportunities there.

The United States has two advantages, its R&D capabilities and its financial industry. Developing countries, where these resources are located, just lack these two resources. They lack the technology. They lack the financial resources. So the U.S. can leverage these two advantages to be able to access these resources. These countries also need a new business model. They need a win-win joint venture model based on an impact investing model, as opposed to the traditional predatory model, especially in the mining sector. In this model, investment is judged not only by rate of return but also its impact where it takes place, especially its impact on the environment. U.S. firms can champion this emerging trend, even in these developing countries, not just within the U.S. U.S. firms can also procure the raw materials and develop a value chain in the U.S. This is what other countries have been doing up to now. After

all, the countries dominating lithium and cobalt value chains are not the major producers.

The third point is fostering frictionless international trade. International trade allows developing countries to transform their natural resources into physical, human, and financial capital that they need for their development. Trade also allows importers like the United States to access the raw materials. So it is thanks to international trade that, except for Chile, no major producer-country is an exporter of lithium and cobalt-based products. China and Belgium account for 87 percent of total cobalt oxide and hydroxide exports despite the fact they are not major producers of cobalt. The United States is the second largest exporter of lithium oxide and hydroxide, 13 percent, behind China, 50 percent, and before Chile, 12 percent. Thanks to its R&D and financial industry and relying on a small international trading system, the U.S. can develop a home-grown industry, feeding a greener and innovative transportation system.

Thank you for the opportunity and I look forward to your questions.

[The prepared statement of Mr. Nkurunziza follows:]

Janvier Désiré Nkurunziza
 Officer-in-Charge, Commodities Branch
 Chief, Commodity Research and Analysis Section
 Division on International Trade and Commodities
 United Nations Conference on Trade and Development (UNCTAD)
 Palais des Nations, 6-14 Avenue de la Paix
 CH-1211 Genève 10
 Switzerland

**Testimony before the United States Senate
 Committee on Energy and Natural Resources
 16 March 2021**

Senator Joe Manchin III, Chairman of the Senate Energy and Natural Resources Committee
 Senator John Barrasso, Ranking member of the Senate Energy and Natural Resources Committee
 Senate members of the Energy and Natural Resources Committee
 Ladies and gentlemen,

I am honored to be here to testify at this hearing examining ways to strengthen research and development in innovative transportation technologies with a focus on solutions that decrease emissions, reduce America's reliance on foreign supply chains, and increase manufacturing in the United States.

Allow me, from the outset, to make it clear that I am speaking in my personal capacity and that the opinions expressed in this testimony are my own, not those of my employer, the United Nations Conference on Trade and Development (UNCTAD). My testimony draws from my 30-year research experience as a development economist, including the last ten years researching the interaction between natural resource dependence and development. The material I present today is based on three main sources: *Commodities at a Glance: Special issue on strategic battery raw materials* (UNCTAD, 2020, New York and Geneva); *Commodities at a Glance: special issue on rare earths* (UNCTAD, 2014, New York and Geneva); *La guerre des métaux rares: la face cachée de la transition énergétique et numérique—The war over rare metals: the hidden face of the energy and digital transition* (my own translation)—(Guillaume Pitron, 2018, Les Liens qui Libèrent). I use this opportunity to thank my colleagues Alexandra Laurent and Rachid Amui, who worked on UNCTAD's two reports. My presence here is that our work is relevant and useful for policymaking, which is the overarching objective of UNCTAD's research.

My testimony is presented in three parts. First, I highlight the key natural resources associated with innovative transportation technologies as we know them today, focusing on rechargeable electric batteries as this is arguably the key ingredient for successful green mobility. I also show where these natural resources are found, and what is the United States position in this space. Secondly, I argue that the United States does not need to have deposits of such natural resources in its ground to be a key player in the energy transition. Most opportunities lie in downstream segments of the value chain. Stronger United States involvement in commodity value chains especially through joint ventures with producer countries could help diversify US supply sources and reduce the country's strong reliance on foreign supply chains. Indeed, the few countries holding most of the strategic natural resource reserves are developing countries in need of partners and a different business model that could allow them to capture more value from their natural resources. The third aspect of my testimony briefly touches on the importance of frictionless international trade as a way of ensuring steady and predictable supply.

1. Natural resources associated with innovative transportation technologies

The world is going through an energy transition. There is a strong movement towards decarbonization of energy consumption with the introduction of renewable energy systems such as photovoltaic solar panels, wind turbine systems, and more recently rechargeable energy storage batteries. Batteries are used to provide energy for household use, and power electric vehicles, appliances and gadgets used in day-to-day life, such as mobile telephones. Batteries are also used in military, industrial, and several commercial applications.

Natural resources that fuel transportation systems associated with low Greenhouse Gas (GHG) emissions are mainly those used in the production of rechargeable electric batteries, particularly lithium-ion batteries (LIBs). The LIB is particularly prized thanks to its high technical performance; it has the highest energy and power density of all rechargeable battery types. LIBs are also lighter and smaller than other rechargeable batteries, allowing them to be most suitable for use in the fast-growing market of electric vehicles (EVs). Furthermore, the LIB offers a higher number of charge and discharge cycles in the battery's life than nickel-based batteries, for example. In addition, LIBs have the potential for further improvement in costs and performance with respect to battery chemistry, energy storage capacity, manufacturing scale and charging speeds, suggesting that they are likely to remain dominant parts of EV manufacturing for the seeable future.

The current and evolving battery technology relies on a limited number of raw materials. The main are lithium, cobalt, manganese, and natural graphite. Most have few substitutes and are not widely globally distributed. Therefore, rapid growth in the demand for LIBs, largely driven by environmental concerns, coupled with LIBs cost and efficiency advantages over other rechargeable battery types, is expected to boost demand for the commodities used to manufacture them. This is an opportunity that countries producing these raw materials should take advantage of. However, exploitation of these commodities may also present a challenge. Experience shows that their exploitation has often been associated with an undesirable environmental footprint, poor human rights, and poor worker protection. The commodities' low substitutability and limited geographical distribution also raise the question of sustainability of supply, particularly in view of rising demand for them.

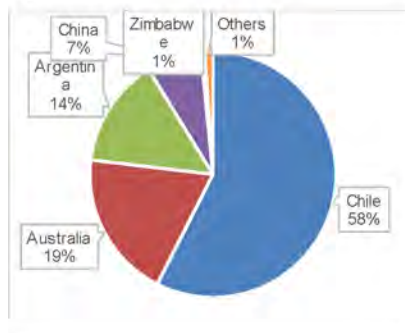
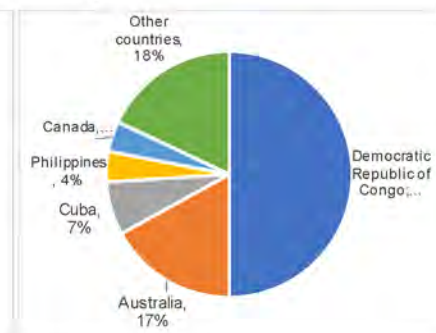
Many countries classify these commodities as strategic raw materials because they serve an essential function in the manufacturing of many products that are considered of high importance for a country's economic and/or national security. As these natural resources have few or no substitutes, some countries may put in place measures to control their conservation and/or distribution. The list of strategic raw materials may depend on each country's specific interest. Moreover, the list may vary over time depending on technology advances, new discoveries, changes occurring in their global supply and demand, concentration of production, and current policy priorities.

There are five different types of lithium-ion batteries (Table 1). Lithium Cobalt Oxide has the highest capacity as well as the highest cobalt content. The table shows what types of natural resources are needed to manufacture LIBs required for the transportation industry. Lithium and cobalt come out as two essential raw materials in the production of these batteries.

Table 1: Types of lithium-ion battery chemistries

Name	Abbreviation	Chemical Formula	Cobalt content	Properties and applications
Lithium Cobalt Oxide	LCO	LiCoO ₂	60%	High capacity. Mobile phones, tablets, laptops, cameras
Lithium Manganese Oxide	LMO	LiMn ₂ O ₄	0	Safest; lower capacity than LCO but high specific power and long life. Power tools, e-bikes, EVs, medical devices
Lithium Iron Phosphate	LFP	LiFePO ₄	0	
Lithium Nickel Manganese Cobalt Oxide	NMC	LiNiMnCoO ₂	10 – 30%	
Lithium Nickel Cobalt Aluminium Oxide	NCA	LiNiCoAlO ₂	10 – 15%	High capacity; gaining importance in electric power train and grid storage; industrial applications, medical devices

Lithium and cobalt are central to the manufacturing of rechargeable batteries used in electric vehicles, trains, and bicycles, according to Table 1. Given the United States interest in this sector, the question is where is it going to find these raw materials? The following figures provide the answer.

Figure 1: Lithium reserves**Figure 2: Cobalt reserves**

Figures 1 and 2 show that only two countries account for more than half of world reserves of lithium (Chile with 58%) and cobalt (the Democratic Republic of Congo with 50%).¹ This level of concentration suggests that these two countries are key players in the ongoing energy transition. It is also relevant to note that, apart from Australia, the two natural resources are found in their natural form in developing countries. The third take away from the two figures is that the United States does not appear as a producer of lithium and cobalt.

Figures 3 and 4 extend the discussion to manganese and natural graphite, the latter being the commonly used battery anode material. While these two commodities are more widely geographically distributed relative to lithium and cobalt, developing countries dominate the distribution.² Moreover, the United States does not appear in the distribution, again.

Figure 3: Manganese reserves

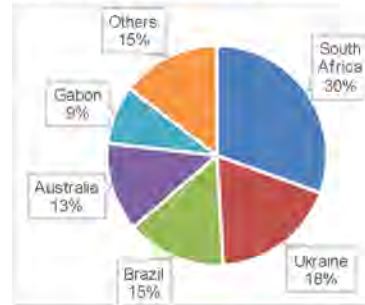


Figure 4: Graphite reserves



Other natural resources of interest to the so-called “green mobility” are rare metals or rare earths.³ A typical electric and hybrid car may contain 9 to 11 kilograms of these natural resources. They include lanthanum and cerium in a hybrid battery; cerium/zirconium and lanthanum in the catalytic converter; several neodymium-based magnets in the electrical engine; neodymium in lamps; cerium in windshield, windows and mirrors; europium, yttrium, and cerium in ACL screens; yttrium for captors; and neodymium, praseodymium, dysprosium and terbium in the engine and electric generator of a hybrid car. In addition to hybrid and electric cars, these natural resources are used in all sectors of modern technologies including mobile telephones, television screens, satellites, oil refining, military and defense sector, green energy technologies, etc.

¹ Bolivia is part of the “Lithium Triangle” (Argentina, Bolivia, Chile). However, it is not ranked in Figure 1 as its reserves remain undeveloped due to technical, geographic, and political challenges. But the country is considered as having the largest reserves of lithium and it may soon become a key player in the lithium market if the current challenges are overcome.

² Graphite is either synthetically produced (artificial graphite) or mined from the ground (natural graphite). Extracted graphite is heavily processed to serve as anode. Both types of graphite are used for Li-ion anode material with about 55% being synthetic and 45% natural graphite. Synthetic graphite has been preferred to natural graphite because of its superior consistency. However, the trend is changing. Modern chemical purification processes and thermal treatment have made it possible to achieve a purity of 99.9% from natural graphite compared to 99.0% for synthetic graphite. Purified natural graphite has a higher crystalline structure and offers better electrical and thermal conductivity than the synthetic material. Unprocessed natural graphite is not only cheaper, lowering production cost with the same or better Li-ion performance, but also more environmentally friendly than the synthetic type.

³ Rare earths and rare metals are used interchangeably in this document.

The distribution of these rare metals and rare earths is also concentrated but not in the same countries as the four natural resources discussed above. Even though exact information on these highly strategic materials is difficult to gather, it is widely accepted that one country, China, accounts for the largest share of rare earth resources, ranging from 23% to 55% of world reserves, depending on the source used. The United States is also in a good position as a producer of rare metals; it may account for 11% to 13% of world reserves, depending on the source used. The United States may hold 90% of beryllium and 73% of helium reserves.

In view of the information discussed above, the second section of the testimony focuses on how the United States could position itself in the growing lucrative market for innovative transportation systems. What are the challenges and opportunities?

2. Opportunities in the green transportation value chain

The discussion in Section shows that the United States does not appear to have any of the four commodities central to the manufacturing of electrical batteries, namely lithium, cobalt, manganese, and natural graphite. Therefore, the United States needs to rely on supplies from the countries shown in Figures 1-4.

Regarding rare earths deposits, the United States is relatively well endowed. In fact, the United States dominated the rare earth sector between 1965-1985. It was the largest producer of these materials, mainly from one production site, the Mountain Pass Mine in California, exploited by Molycorp, an American mining company. The country lost its leadership position in the 1990s and early 2000s due to two factors. First, China got seriously involved in the production of rare metals at about this time. With production costs that were a fraction of the United States' production from the US became uncompetitive. Second, the high cost to the environment and a series of environmental accidents at the gigantic Mountain Pass Mine invited scrutiny from the government. Molycorp judged that the mine would not be profitable if it were to modernize its equipment to comply with environmental regulations, amid stiff competition from China. The mine was eventually closed in early 2000s.

The case of Mountain Pass Mine is instructive in several ways. A country may have deposits of a natural resource, but this does not mean that it can be extracted profitably. Lithium in Bolivia is another illustrative case. The extraction of rare metals is particularly tricky. Even though some countries extract rare earths directly, most of the quantities commercialized come from mines where rare earths are in small concentration, in combination with another less rare metal such as nickel or copper. Therefore, it might not make economic sense to exploit a nickel or copper mine for the sake of extracting rare earths if market conditions are not jointly conducive for the two or three commodities.

Environmental concerns that led to closure of the Mountain Pass Mine had the same effect in Europe. Mining of rare metals in countries such as France was discontinued for the same reasons environmental. By discontinuing mining in Europe and the United States, the negative environmental effects associated with rare metal mining in Europe and the United States were externalized to countries that did not have the same level of environmental standards at the time. The consequence was that Europe, and the United States, became strongly dependent on external suppliers.

Figure 5 illustrates how the standing of the United States in the production of rare metals waned from the 1990s to the 2000s, with some recovery starting in early 2010s. From 28% of total world production in 1995, the share of the United States dropped to nil in 2005. By 2012, the United States re-appeared in the list of producing countries, with a share of 6.4% in 2012. In contrast, China's shares in total production increased from 60% in 1995 to 97% in 2005. By 2012, China was still comfortably in the leading position, accounting for 87% of total world production.

Figure 5: Rare metals producing countries



More recently, in 2019, the United States produced 26,000 MT of rare earths, up 44% from 2018. The United States rare earths come exclusively from the Mountain Pass mine discussed above. After it went bankrupt, the mine was purchased by MP Mine from Molycorp. Data from the US Geological Survey shows that The United States has become again one of the world's largest producers of rare earths, second only to China. This suggests that the United States was able to find solutions to the problems that had plagued the sector in the 1990s. Technological developments can indeed make an otherwise unprofitable operation to be economically feasible. The United States has an opportunity to become, again, a key player in the strategic sector of rare metals.

As stated earlier, opportunities in the context of innovative transportation systems that reduce America's reliance on foreign supply chains and increase manufacturing in the United States do not materialize only in areas where the country has its own natural resources. In fact, most opportunities lie with operations that take place after the extraction of the natural resource. Indeed, the United States might not have its own deposits of lithium, cobalt, manganese, and natural graphite, but it can benefit from opportunities that these raw materials offer along their relatively long value chains. The lifecycle of the metals of interest may be summarized as follows: exploration, extraction, basic treatment (e.g., grinding), production of intermediary or basic material after primary transformation (e.g., anodes and cathodes), further transformation (e.g., pipes, cables, tubes), use in final product (e.g., cars, wind turbines), and disposal or recycling (e.g., waste and its eventual treatment).

Two main factors put the United States in a privileged position in terms of the benefits it could derive from the natural resources discussed above: technology and financial capital. Each segment of the lifecycle requires specific technologies and investments. The United States is a leader in research and development and the country sits on the technology frontier. The United States can leverage its unique technological position to enter any of the segments of the value chains of the commodities we are discussing, from exploration to recycling. Similarly, the country has a financial industry and financial resources that could help it position itself as the investor of choice in the sector. The current reality shows that he who controls the technology and capital controls the value chain, irrespective of where the resources are extracted.

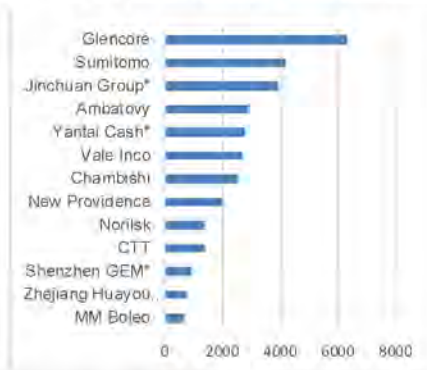
It is useful to recall that most resources associated with electric battery technologies are in developing countries: Chile and Argentina for lithium; Democratic Republic of the Congo, Cuba, and Philippines for cobalt; South Africa, Brazil, and Gabon for manganese; and Brazil, Turkey, Mozambique, and Tanzania for natural graphite. Many of these countries may well hold important reserves of these

strategic commodities, but they generally lack the technologies and investments required to extract them efficiently and economically, let alone transforming them domestically. To illustrate, Figure 6 shows that the companies that refine cobalt are not from the DRC even though 66% of world production takes place there.

Figure 6: Refined cobalt—chemicals (tons), 2017



Figure 7: Refined cobalt—metal (tons), 2017



Foreign countries have been able to capture the opportunities offered by the refining segment of the value chain for cobalt—the picture is similar for most commodities produced in developing countries. For example, out of 13 companies involved in cobalt refinery to derive cobalt chemicals, seven are Chinese; and all seven Chinese companies are among the top eight in terms of production. Finland's Freeport Cobalt comes five, with companies from Belgium, Russian Federation, South Africa, DRC, and France accounting for smaller amounts. The United States does not feature in the list. A comparable picture emerges with respect to cobalt refineries extracting metal. Four out of 13 are from China and the United States does not have any of the 13 companies.

Cobalt refineries are rarely located near cobalt mines. Refiners purchase cobalt concentrate from various mines and ship to their own locations for transformation. Generally, refiners buy cobalt ore, ship it to their countries where they undertake the refining and other upstream transformation processes. This starves producing countries of opportunities to add value and internalize at least some of the benefits accruing to these activities. Upstream transformation generates positive spillover effects in the economies where it takes place: job creation, tax payment, technological development, etc. These forgone benefits may explain why some countries well-endowed continue to have some of the highest levels of poverty in the world. The Democratic Republic of the Congo is one of them.

The absence of the United States from the value chains of strategic commodities imply that the country is forgoing benefits that should accrue to its technological and financial leadership. At the very least, buying ore and transforming it in the United States, as other countries are doing, would also remedy the lack of natural resource within its boundaries, reducing its dependence on external suppliers. Most of the countries in Figures 6 and 7 do not have a single domestic cobalt mine but they become important players in the sector by procuring the commodity where it is.

It is important to note that the extractive model pursued by most foreign companies has created frictions and even serious problems in their host countries. There are recent well-known cases of large-scale environmental damage, human rights violations with impunity, and child labor in mining operations. These practices have created tensions in host communities, particularly in countries with

weak institutions where these multinational companies are not held to account. No host country appreciates these practices but most of the times, affected communities are powerless when they face unscrupulous large and powerful companies. This business approach may generate maximum short term financial returns for company shareholders, but it based on a model that is more and more decried across the world. It is also important to note that developing countries caught in this extractive model do not appreciate the fact that the benefits from their natural resources are limited to selling the raw commodity. These countries would also like to internalize at least some segments of the value chain as a way of capturing more revenue from their natural resources. With the current model, natural resources benefit more foreign companies and the countries where value is added. This system perpetuates underdevelopment of natural resource-rich countries.

Should United States firms engage more in natural resource value chains, they could adopt a model that does not consider their engagement as a zero-sum game. The world is moving towards more responsible investment models, where sharing benefits more fairly with host countries does not prevent profit making. Key investors, particularly institutional investors, have been pushing for more sustainable investing. To be clear, the relatively new concept of "impact investing" is gaining traction in investment circles. Impact investing implies that an investment is not assessed just by its rate of return. Other considerations including the investment's impact on the community where it takes place, its environmental footprint, and its social impact, are equally important. Impact investment does not mean that profit is not important. It simply means that profit should be made but respecting environmental and social sustainability principles.

Incumbent investors will probably find it difficult to change their old business model. This is an opportunity for entrants interested in following the new trend. Moreover, there are many untapped opportunities in natural resources that American companies might consider taking advantage of. Exploration is key among them. The fact that regions such as Africa are highly under-explored offers immense opportunity to companies that have the modern technologies used in natural resource exploration elsewhere. Even sectors already in development might need more efficient and less polluting technologies that American firms may possess or develop. For example, the extraction of Chilean lithium is so inefficient and polluting that new extraction technologies are needed. They are apparently under development and could be deployed soon, drastically reducing extraction time and cutting the ecological footprint of current operations. There are also opportunities in recycling. To date, the rate of recycling of rechargeable batteries and electronic products that use the raw materials discussed here is very low. Developing the relevant recycling technologies would provide an advantage to firms interested in this segment of the commodity lifecycle.

3. Importance of frictionless international trade

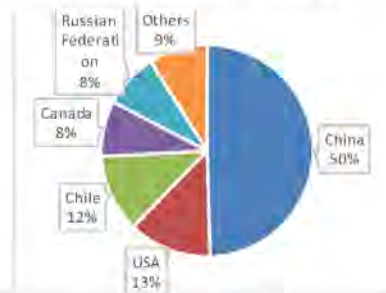
No country in the world can depend on its own natural resources for all its needs, no matter how well it is endowed with natural resources. Even for the most endowed countries such as China and Australia, self-reliance has its limits. Countries, including the United States should, therefore, foster a frictionless international trading system. Countries should be able to access strategic commodities through international markets. Ironically, some countries that procure through trade ores from developing countries for refining and further processing into intermediary and final products have sometimes imposed export restrictions on processed goods derived from the imported raw materials hurting importing country industries. Developing countries supplying these raw materials do not benefit either. Therefore, should not trading in strategic natural resources be governed by the same rules governing international trade?

Thanks to international trade, developing countries transform their natural capital (natural resources) into other forms of capital (physical, financial, human) needed for their development. Countries importing natural resources also owe the revenues they derive from transforming them to international trade. Figure 7 and 8 show, for example, the top five exporters of oxide and hydroxide from cobalt and from lithium. They are mainly developed countries that import the raw materials.

Figure 7: Cobalt (% share)



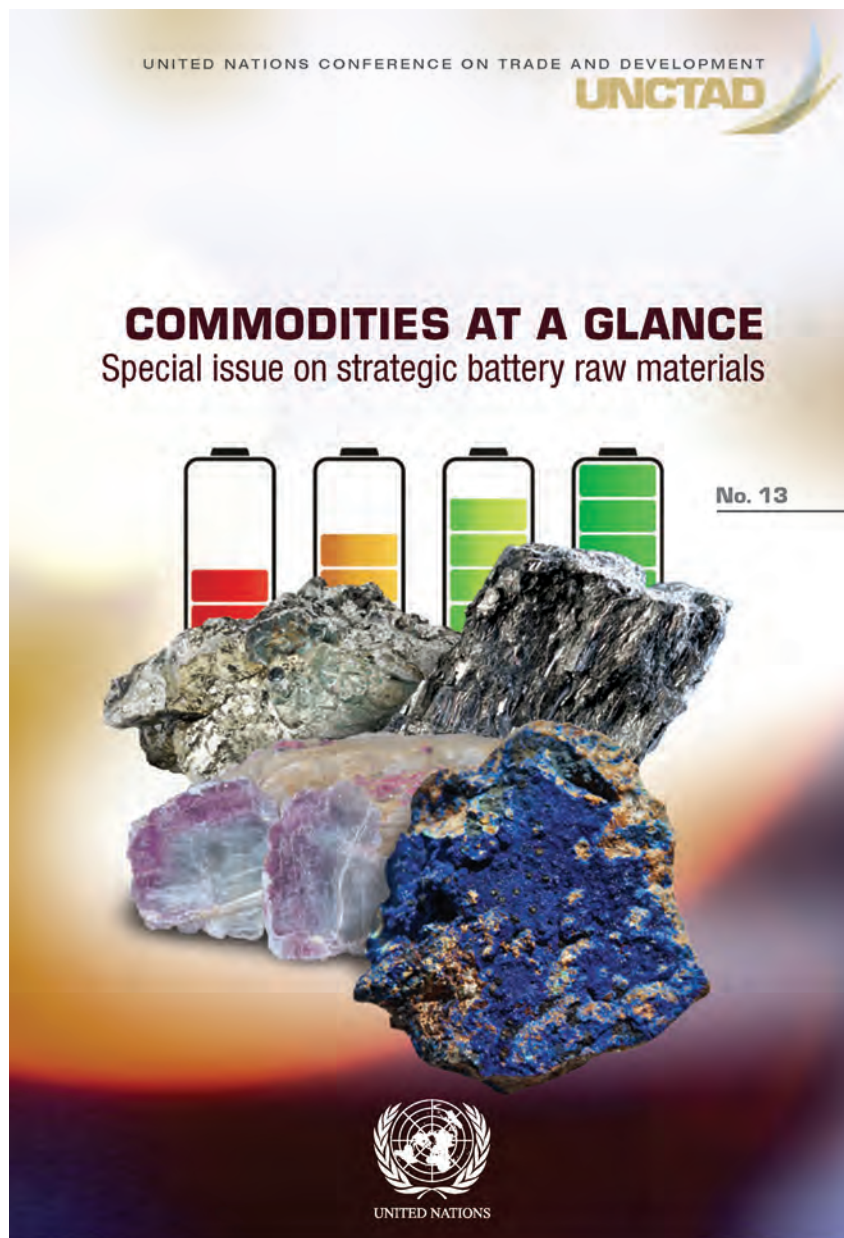
Figure 8: Lithium (% share)



Except for Chile (for lithium), no other exporter is a major producer of cobalt or lithium. Belgium and China dominate cobalt exports, despite the fact they are not cobalt producers. China, again, dominates lithium oxide and hydroxide exports despite not being a major producer of lithium. This confirms a point made earlier: a country does not need to have important deposits of a natural resource to dominate its value chain and trade.

In conclusion, as the United States does not possess some of the natural resources needed to fuel its green mobility, it would benefit by fostering an international system that guarantees access to such resources. Frictionless trade is one avenue. Another opportunity is to leverage America's technological and financial leadership to actively get involved in commodity value chains, from exploration to recycling. The United States could lead by adopting and spreading a new business model that is more sustainable, seeking profit while at the same time making a positive impact in host countries. Sustainability should be pursued at every segment of the commodity cycle the country is involved in.

[THE END]



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This edition of *Commodities at a Glance* was prepared by Rachid Amui, Economic Affairs Officer at the Commodities Branch, Division on International Trade and Commodities, UNCTAD, under the overall guidance of Janvier Nkurunziza, Chief, Commodity Research and Analysis Section, Commodities Branch.

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CONTACTS

For further information about this publication, please contact the Division on International Trade and Commodities, Commodities Branch, UNCTAD, Palais des Nations, CH-1211 Geneva 10, Switzerland, email: commodities@unctad.org, tel. +4122 917 6286/1648

NOTE

Reference to "dollars", or use of the dollar symbol (\$), signifies United States dollars, unless otherwise specified.

The term "tons" refers to metric tons.

Unless otherwise stated, all prices in this report are in nominal terms.

Data sources are indicated under each table and figure.

ACRONYMS AND ABBREVIATIONS

BC	before Christ
C	carbon
CAGR	Compound Annual Growth Rate
CE	circular economy
CH₄	methane
Co	cobalt
CO₂	carbon dioxide
CTL	coal-to liquid
GHG	greenhouse gas
GTL	gas-to liquid
EV	electric vehicle
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LCE	lithium carbonate equivalent
LCO	lithium cobalt oxide
LED	light-emitting diode
LFP	lithium Iron Phosphate
Li	lithium
LiAlSi₄O₁₀	Lithium silicate (petalite)
LIB	lithium-ion battery
LiBF₄	lithium tetrafluoroborate
LiClO₄	lithium perchlorate
Li-ion	Lithium-ion
LiPF₆	lithium hexafluorophosphate
LMO	Lithium Manganese Oxide
m	million
Mn	manganese
N₂O	nitrous oxide
NCA	Lithium Nickel Cobalt Aluminum Oxide
NiCd	Nickel-Cadmium
NIMH	Nickel-Metal Hydride
NMC	Lithium Nickel Manganese Cobalt
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
USGS	United States Geological Survey

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INTRODUCTION

Anthropogenic greenhouse gas (GHG) emissions since the industrial revolution have driven large increases in the atmospheric concentrations of carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). According to scientists, these gases along with other sources of GHG emissions, are extremely likely to have been the dominant cause of the observed warming of the climate system since the mid-19th century.¹ In response to the rising temperature, parties to the United Nations Framework Convention on Climate Change (UNFCCC) reached a landmark agreement in 2015 (The Paris Agreement) to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. Some estimates show that failure to stabilize or reduce global emissions of CO₂ and other greenhouse gases will lead to economic losses amounting to at least US\$2 billion per day by 2030.² Moreover extreme weather events and patterns associated with the warming climate system are likely to impact the achievement of the Sustainable Development Goals, particularly Goal 13 – “Take urgent action to combat climate change and its impacts.”³

Fossil fuel use is the primary source of anthropogenic GHG emissions. The Intergovernmental Panel on Climate Change (IPCC) estimated that CO₂ emissions from fossil fuel combustion and industrial processes contributed about 65 per cent to total GHG emissions in 2010.⁴ Therefore, attempts to reduce fossil fuel-based energy emissions and mitigate effects on the climate will require, inter alia, transformation of energy consumption by drastically reducing fossil-based energies to greener sources of energy. A transition to decarbonization of energy consumption is already underway with the introduction of renewable energy systems such as photovoltaic and wind turbine systems and more recently rechargeable energy storage batteries that are used to produce energy for household use and to power electric vehicles.

Some of the raw materials used in these renewable energy systems as well as in key industry sectors

such as aerospace, defense, health, automotive and consumer electronics currently have few substitutes and are not widely globally distributed. They are defined as strategic and critical raw materials because they serve an essential function in the manufacturing of a product, the absence of which would have substantial consequences for a country's economy or national security.⁵ Since there are few or no substitutes to these raw materials, strict measures are employed to control their conservation and distribution. The term strategic and critical raw materials is relative to their importance for major importing countries because what is critical to one country may not be critical for another. Moreover, the list of these raw materials is not static. It evolves depending on technology advances, changes occurring in their global supply and demand, concentration of production, as well as current policy priorities.

A broad array of minerals and metals are classified as strategic and critical. These raw materials are making a contribution towards reducing greenhouse gas emissions and achieving a low carbon future. For example, rare earth metals such as the Platinum Group of Metals are mostly mined in a few countries (South Africa and Russia) and there are few or no good substitutes to them. Thus supply disruption could constrain the production of critical components in the catalytic converters found in most vehicles that reduce harmful emissions or disrupt key industrial processes that use these metals as catalysts in petroleum refining; high-temperature processing of abrasive materials such as glass; disc drives and electronic components; medical and dental implants and devices; and electrochemistry.⁶ Similarly, metals such as cobalt, lithium, manganese, copper, and minerals like graphite play a significant role in energy-related technologies such as rechargeable batteries that are used in a variety of applications ranging from electronics to electric vehicles as well as in renewable energies such as nuclear, wind, and solar power.

The market for rechargeable batteries, particularly for lithium-ion batteries (LIBs), is growing rapidly owing to its cost and efficiency advantages over other rechargeable battery types. It has been largely driven by environmental concerns, a growing market

¹ https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf

² <https://www.nationalgeographic.com/science/2019/11/nations-miss-paris-targets-climate-driven-weather-events-cost-billions/>

³ https://unctad.org/en/PublicationsLibrary/ditcocom2019d3_en.pdf

⁴ <https://pubs.usgs.gov/of/2018/1021/of20181021.pdf>

⁵ <http://www.thinftr.com/platinum-group-metals-report-2018.htm>

for electric vehicles and support from governments. Rechargeable batteries open opportunities to boost supplies for the raw materials used in manufacturing them: lithium, nickel, manganese, cobalt and natural graphite, but they also present challenges in ensuring that the raw materials are sustainably sourced given that their exploitation is often associated with undesirable environmental footprints, poor human rights and worker protection. It also raises questions on whether there is enough supply of these raw materials to meet rising demand given that available quantities are low for some of the raw materials, they are not widely geographically distributed in high concentrations and they have low substitutability.

The aim of this report is to provide information on the critical raw materials used in LIBs with respect to production, consumption, trade and prices. The report also analyses the influence of supply and demand of these battery raw materials on market prices in view of the growing role of LIBs in energy storage and electric vehicles. Furthermore, the study examines the varying stages of transformation from ores/brines into value added products and their

implications for producing countries. The scope of the report will be limited to a few battery raw materials that are considered as strategic and critical: Cobalt (Co), lithium (Li), manganese (Mn) and natural graphite (C), given that these materials are essential to the production of rechargeable batteries, which are expected to have a high market growth and will play an important role in mitigating GHG emissions from the use of fossil fuels.

The report is divided into six chapters. The first chapter discusses the different types of rechargeable batteries, their performance and chemistries. The second chapter presents an overview of the selected battery raw materials considered in this report. The third chapter discusses the upstream and downstream value chains of the LIB. The fourth chapter discusses supply, demand with respect to production and consumption, and price evolution of the selected raw materials used in LIBs. The fifth chapter discusses the social and environment effects related to exploitation of the selected battery raw materials discussed in this report. The final chapter draws some policy implications from the report.



1.1. RECHARGEABLE BATTERIES AND CLIMATE CHANGE

Rechargeable batteries are energy storage devices that allow for recharging after the store charge has been drained – i.e. the chemical reactions that produce the charge can be reversed to store a new charge.⁶ They offer a reliable source of electricity which can be used when renewable sources of power such as wind and solar are not available due to their variable nature. Rechargeable battery technology is also very important for the transport sector because it can contribute to reducing GHGs that are emitted from burning fossil fuels in internal combustion engines. In 2010, the transport sector accounted for 14 per cent of global greenhouse gas emissions⁷ and is expected to almost double by 2050 due to increasing transport demand per capita in developing and emerging economies.⁸ Scientists warn that without mitigating these transport emissions, the increasing concentrations of GHGs in the atmosphere will have a profound effect on the climate. In this regard, rechargeable batteries are likely to make a significant contribution to mitigating transport emissions.

1.2. TYPES OF RECHARGEABLE BATTERIES AND PERFORMANCE

There are different types of rechargeable batteries available on the market for different purposes (eg. lead acid, Lithium-ion (Li-ion), Nickel-Metal Hydride (NiMH), Nickel-Cadmium (NiCd) batteries), but Lithium ion batteries are the most commonly used because they have the highest technical performance (i.e. the highest energy and power density).⁹ LIBs are lighter and smaller than other rechargeable batteries¹⁰ allowing them to be most suitable for use in the fast-growing market of electric vehicles (EVs). In addition, the LIB offers a higher number of charge and

discharge cycles in the battery's life than the NiCd and Ni-MH batteries. By contrast, lead acid batteries have superior cycles but they are less efficient compared to LIBs.¹¹ Lithium ion batteries also have the potential for further improvement in costs and performance with respect to battery chemistry, energy storage capacity, manufacturing scale and charging speeds, suggesting that they are likely to remain dominant in EVs into the next decade (IEA, 2018).¹²

1.3. BATTERY COMPONENTS AND BATTERY CHEMISTRIES

There are four principal components of a lithium-ion battery: cathode and anode active materials, electrolytes, and separators. Each plays a different role to generate repeated energy outputs. Their functions are detailed as follows:

The cathode is the positive electrode of a rechargeable battery. It plays an essential role in providing the chemical reactions that generate the electric current. Within the lithium ion battery technology, various cathode chemistries exist at commercial level such as Lithium Cobalt Oxide (LCO), Lithium Manganese Oxide (LMO), Lithium Iron Phosphate (LFP), Lithium Nickel Manganese Cobalt (or NMC) and Lithium Nickel Cobalt Aluminum Oxide (or NCA) (see table 1).¹³ Owing to the high cost and limited availability of the principal materials used in LIBs such as cobalt, research is ongoing for different cathode chemistries that have less reliance on the critical materials currently used in manufacturing cathodes. Furthermore, improvement has been made to the materials currently used in cathodes which has led to increased battery life through some combination of NMC. The improvements to cathode combinations enable lithium ions to be stored more efficiently and facilitates movement of ions through the cathode to the anode easier than other materials.¹⁴ The NMC takes different forms based on the amount of the three elements' atoms (eg. NMC 111, NMC532/622, NMC 811).¹⁵ The NMC chemistries is favoured by battery makers because of its high performance and relatively

⁶ <https://courses.lumenlearning.com/introchem/chapter/other-rechargeable-batteries/>

⁷ <https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>

⁸ https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_chapter8.pdf

⁹ Energy density is the amount of energy the battery can store per unit mass. A device with a higher energy density can supply an electronic load for longer than one with a low energy density and the same mass/volume. Power density is the amount of power that can be generated by the battery with respect to its mass. See <https://www.energy.gov/eere/articles/how-does-lithium-ion-battery-work>

¹⁰ Lowe M., Tokucka S., Trigg T., Gereffi G. (2010). Lithium-ion batteries for electric vehicles: the U.S. value chain, Technical report, DOI: 10.13140/RG.2.1.1421.0324

¹¹ <https://news.energysage.com/lithium-ion-vs-lead-acid-batteries/>

¹² IEA (2018), Global EV outlook 2018 – Towards cross-modal electrification.

¹³ Azevedo M., Campagnol N., Hagenbruch T., Lala A., Ramsbottom O. (2018). Lithium and Cobalt – A tale of two commodities, McKinsey & Company.

¹⁴ <https://qz.com/1360234/a-silicon-valley-startup-is-giving-lithium-ion-batteries-a-much-needed-silicon-boost/>

¹⁵ The NMC 811 combination is a cathode composition with 80 per cent nickel, 10 per cent manganese and 10 per cent cobalt.

Table 1 - Types of lithium-ion battery chemistries

Name	Abbreviation	Chemical Formula	Cobalt content	Properties and applications
Lithium Cobalt Oxide	LCO	LiCoO ₂	60%	High capacity. Mobile phones, tablets, laptops, cameras
Lithium Manganese Oxide	LMO	LiMn ₂ O ₄	0	Safest; lower capacity than LCO but high specific power and long life. Power tools, e-bikes, EVs, medical devices
Lithium Iron Phosphate	LFP	LiFePO ₄	0	
Lithium Nickel Manganese Cobalt Oxide	NMC	LiNiMnCoO ₂	10 – 30%	
Lithium Nickel Cobalt Aluminium Oxide	NCA	LiNiCoAlO ₂	10 – 15%	High capacity; gaining importance in electric power train and grid storage; industrial applications, medical devices

Source: Dias et al (2018)¹⁶

low cost. In 2018, NMC batteries accounted for nearly 28 per cent of global EV sales and the market share is expected to grow to 63 per cent by 2027.¹⁷

The anode's role is to store and release lithium ions to the cathode thus allowing current to pass through an electrical circuit. The common anode material used is graphite, either synthetically produced (artificial graphite) or mined from the earth's crust (natural graphite). The extracted graphite is heavily processed to serve as anodes. Both types of graphite are used for Li-ion anode material with 55 per cent gravitating towards synthetic and the balance to natural graphite.¹⁸ Synthetic graphite is preferred to natural graphite because of its superior consistency but this is changing because modern chemical purification processes and thermal treatment have made it possible to achieve a purity of 99.9 per cent from natural graphite compared to 99.0 per cent for the synthetic equivalent.¹⁹ Purified natural graphite has a higher crystalline structure and offers better electrical and thermal conductivity than the synthetic material. Switching to unprocessed natural graphite, which is a much cheaper graphite, not only lowers production cost with same or better Li-ion performance but is also more environmentally friendly than the synthetic type.²⁰

The electrolyte is a core component of the lithium ion battery. It provides a suitable medium for the conduction of ions (flow of lithium ions between the cathode and anode), adequate thermal and chemical stability and compatibility with electrode materials.²¹

The most commonly used electrolyte is lithium salts such as a combination of lithium hexafluorophosphate (LiPF₆), lithium tetrafluoroborate (LiBF₄) or lithium Perchlorate (LiClO₄) in an organic solvent such as ether.²² Solid electrolytes have been investigated but challenges such as low conductivity have limited their commercial viability.

The separators are permeable membranes that provide a barrier between the anode and cathode while enabling the exchange of lithium ions from one side to the other. Table 2 presents a summary of components and materials used in the manufacture of the Lithium ion battery and their functions.

All lithium ion batteries comprise of the four main components discussed and they work broadly in the same way. When the battery is discharging, lithium ions tied to electrons within the structure of the anode are released. These lithium ions travel through the electrolyte to be absorbed in the cathode and the free electrons created at the anode flow through an external wire to provide the electric current used to do work.²³ This process is reversed during the charging phase. An external electric charge applied to the LIB initiates an oxidation reaction at the cathode that pushes lithium ions through the electrolyte back into the anode. Negatively charged electrons are also released from the cathode to tie up the lithium ions absorbed by the anode.²⁴ Figure 1 presents a schematic view of the LIB. The four principal elements (Cobalt, lithium, manganese and natural graphite) used in the manufacturing of compounds for anodes, cathodes and electrolytes in an NMC battery are discussed in the next section.

¹⁶ https://publications.jrc.ec.europa.eu/repository/bitstream/JRC112285/jrc112285_cobalt.pdf

¹⁷ <https://www.mining.com/nmc-batteries-dominating-ev-sales-reach-63-global-market/>

¹⁸ https://batteryuniversity.com/learn/article/bu_309_graphite

¹⁹ Ibid

²⁰ Ibid

²¹ Mosa J., Vélez J.F., Aparicio M. (2019). Blend hybrid solid electrolytes based on LTFSi doped silica-polyethylene oxide for lithium-ion batteries.

²² Lowe M., Tokucka S., Trigg T., Gereffi G. (2010). Lithium-ion batteries for electric vehicles: the U.S. value chain, Technical report, DOI: 10.13140/RG.2.1.1421.0324

²³ <https://www.science.org.au/curious/technology-future/lithium-ion-batteries>

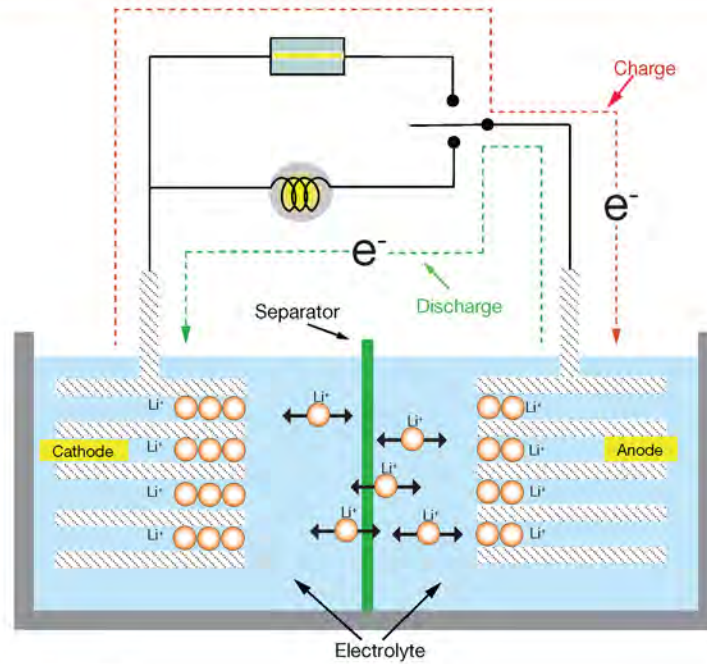
²⁴ Ibid

Table 2: Components of a lithium ion battery, functions and materials

Components	Functions	Materials
Cathode	Emit lithium-ion to anode during charging Receive lithium-ion during discharging	Lithium metal oxide powder
Anode	Receive lithium-ion from anode during charging Emit lithium-ion during discharging	Graphite powder
Electrolyte	Pass lithium-ions between cathode and anode	Lithium salts and organic solvents
Separator	Prevent short circuit between cathode and anode Pass lithium ions through pores in separator	Micro-porous membranes

Source: Lowe et al (2010)²⁸

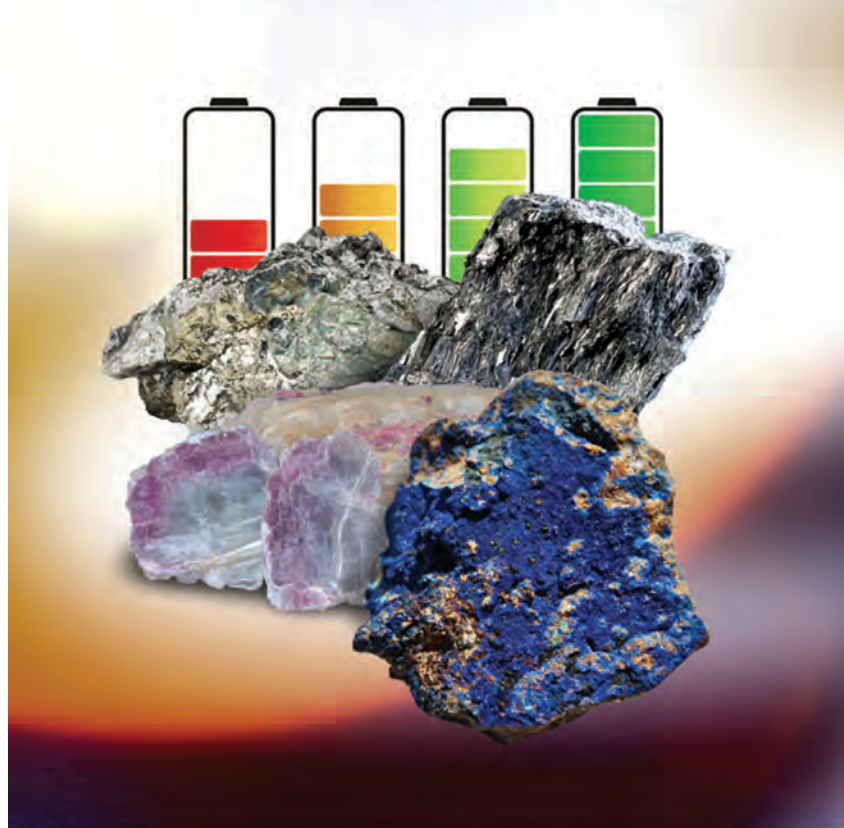
Figure 1: Schematic of a lithium ion battery

Source: Huang P. et al (2015)²⁹

²⁸ Lowe M., Tokuda S., Trigg T., Gereffi G. (2010). Lithium-ion batteries for electric vehicles: the U.S. value chain, Technical report, DOI: 10.13140/RG.2.1.1421.0324

²⁹ Huang P., Wang Q., Ping P., Sun J. (2015). The combustion behavior of large-scale lithium titanate battery.

CHAPTER 2

**OVERVIEW OF LITHIUM ION
BATTERY RAW MATERIALS**

2.1. HISTORICAL BACKGROUND

The principal materials used in LIBs are cobalt, lithium, manganese and graphite (allotrope of carbon). These chemical elements are among 118 known chemical elements, metals and minerals, listed in the periodic table. They were discovered either independently or by two or more scientists working independently of each other at different periods in history. A synopsis of the principal materials used in LIBs with respect to their origins, properties, formation, reserves and geographical distribution, and uses is presented in this section.

Cobalt

Cobalt was first used in the production of pigments in Egypt during the late Bronze age around the 18th century BC. Between 770 - 475 BC, it was used in China as a colouring agent in glazed beads, then later in low-firing glazes on Tang sancai and blue glazed earthenware's. There are many instances of cobalt used as a pigment in ceramic technology during the Han and Yuan dynasties. (Giannini et al, 2017). The distinctive blue hue to porcelain represents one of the most successful and influential developments in the history of ceramic technology.²⁷ In the form of metal, Cobalt was first isolated in 1735 by Swedish chemist G Brandt but its metallic uses became more common towards the end of the century when fellow Swedish scientist confirmed Brandt's findings, and in the 1930s due to studies and patents by Elwood Haynes (Boland and Kropshot, 2011).²⁸

Cobalt is the 27th element of the periodic table with an atomic mass of 58.9332 grammes per molecule. It is a brittle silvery grey coloured metal with a high melting point that is valued for its wear resistance and ability to retain its strength at high temperatures. It also has naturally occurring magnetic metals that maintain its permanent magnetic properties at temperatures up to 2012 Fahrenheit (1100 degrees Celsius).²⁹ Iron and nickel are the only naturally occurring metals that exhibit similar properties.

Cobalt also has valuable catalytic properties³⁰ so it finds use in several industrial applications. Cobalt, iron and nickel are described as transition elements because of their remarkable ability to combine with several other atoms and molecules at the same time to form coordination compounds. Cobalt's electrons can participate in the formation of chemical bonds in two shells instead of one allowing it to form several different oxidation states.³¹

Cobalt occurs in the earth crust or sometimes relatively near the surface, mostly in combination with nickel and/or copper. There are several principal cobalt bearing minerals but the most common cobalt minerals are cobaltite (cobalt sulfoarsenide mineral), linnaeite (sulfide mineral), skutterudite (series of cobalt and nickel mineral), and smaltite (cobalt, nickel arsenide).³² Large quantities of cobalt also occur on the sea floor, contained within manganese nodules and cobalt-rich crusts, although they are not economically viable with current technology and economic conditions.³³ See Table 3.

The world terrestrial cobalt resources³⁴ are estimated to be about 25 million tons. Most of these resources are in sediment-hosted stratiform copper deposits in the Democratic Republic of the Congo and Zambia (Africa's copper belt); nickel-bearing laterite deposits in Australia and nearby island countries and Cuba; and magmatic nickel-copper sulfide deposits hosted in mafic and ultramafic rocks in Australia, Canada, Russia, and the United States.³⁵ In 2018, the world total reserves were estimated at 6.9 million tons (United States Geological Survey (USGS, 2019)

²⁷ Ibid

²⁸ <https://www.britannica.com/science/transition-element>

²⁹ <https://periodic-table.com/cobalt/>

³⁰ <https://www.cobaltinstitute.org/cres-containing-cobalt.html>

³¹ The terms resources and reserves have different meanings. Resources are a concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible. Resources are sometimes classified as 'identified resources'. This refers to resources whose location, grade, quality, and quantity are known or estimated from specific geologic evidence. Identified resources include economic, marginally economic, and sub-economic components. Reserves refer to that part of an identified resource, which could be economically extracted or produced at the time of determination. USGS (2019), Mineral commodity summaries

³² https://www.cia.gov/library/publications/the-world-factbook/appendix/print_appendixh.html

²⁷ http://discovery.ucl.ac.uk/1540125/1/Freestone_European%20cobalt%20sources.pdf

²⁸ Giannini R., Freestone I.C. and Shortland A.J. (2017). European 'cobalt' sources identified in the production of Chinese famille rose porcelain. *Journal of Archaeological Science*, Volume 80, pp 27-36.

²⁹ <https://www.thebalance.com/metal-profile-cobalt-2340131>

Table 3: Summary of main cobalt deposit types

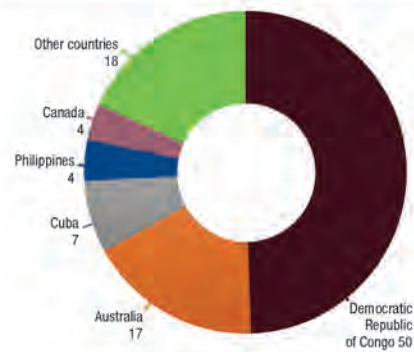
Deposit type	Genetic process of formation	Typical economic grades	Major examples
Sediment hosted	Diagenetic processes in near-shore or saline lagoon environment convert sea water sulphates to sulphides and concentrate metallic elements sourced from sediments.	0.1-0.4 per cent	Tenke Fungurume, Democratic Republic of the Congo; Mt Isa, Australia
Hydrothermal and volcanogenic	Precipitation of minerals from hydrothermal fluids passing through the host rock.	0.1 per cent	Bou Azzer, Morocco; Keretti, Finland
Magmatic Sulphide	An immiscible liquid sulphide phase is concentrated in magmas. This phase preferentially collects and concentrates metallic elements such as cobalt.	0.1 per cent	Norilsk, Russia; Sudbury, Ontario, Canada; Kambalda, Australia
Laterite	Tropical weathering causes the breakdown of cobalt silicates and sulphides in ultramafic bodies causing cobalt to become enriched in residual weathered rocks.	0.05 – 0.15 per cent	Koniambo Massif, New Caledonia
Manganese nodules and cobalt rich crusts	Ferromanganese oxide concretions on the sea floor become enriched in cobalt by extraction from sea water and pore fluids from muds	Up to 2.5 per cent	None currently economic

Source: The Cobalt Institute®

See Appendix 1. The Democratic Republic of the Congo has the largest reserves of cobalt in the world (3.4 million tons). Australia and Cuba have the second and third largest cobalt reserves, estimated at 1.2 million and 0.5 million tons respectively, followed by the Philippines, and Canada with approximately 0.3 million tons each. (see figure 2). More than 120 million tons of cobalt

resources have been identified in manganese nodules and crusts on the floor of the Atlantic, Indian, and Pacific Oceans (USGS Statistics, 2019) at water depths of up to 6,000 meters. However, legal, technological and environmental challenges as well as the economic viability of such projects makes it difficult to exploit these resources (Slack et al, 2017).

Figure 2: Cobalt reserves, 2018



Source: USGS National Minerals Information Center (2018)

ibid

Cobalt has diverse commercial and industrial uses as well as military applications. It is widely used in the manufacture of superalloys, which have a wide range of aviation and industrial uses because of their resistance to corrosion at very high temperatures. For example, cobalt is used to make parts for gas turbines, aircraft engines, and other components used in aircraft and space vehicles, chemical and petroleum plants, and power plants that depend on the high-temperature strength of superalloys.³⁷ Cobalt's magnetic properties makes it a valuable component in a range of applications that use hard magnets³⁸ such as electric motors or soft magnets such as transformer cores. Cobalt is also the key element in several forms of clean energy production technology applications including gas-to liquid (GTL) and oil desulfurization, coal-to liquid (CTL), clean coal, solar panels, wind and gas turbines, and fuel cells (Rufe, 2010)³⁹; about half of the world's cobalt production is consumed in the manufacture of cathode material in the fast-growing market of rechargeable LIBs commonly used in electronic devices such as laptops, smart telephones, camcorders, toys, power tools and other technology devices, and in hybrid and electric vehicles (EVs) (Felter, 2018).⁴⁰ The use of cobalt in EV batteries supports the climate change initiatives for mitigating greenhouse gases. However, due consideration must be given to minimizing GHG emissions during the extraction of battery raw materials, the electricity consumed in manufacturing the battery, and the type of electricity that is used to charge the battery.⁴¹

Lithium

The origins of lithium are traced to the discovery of the mineral petalite ($\text{LiAlSi}_4\text{O}_{10}$) at a mine on an island in Sweden in 1800 by a Brazilian chemist, José Bonifácio de Andrade de Silva. The presence of lithium in petalite was later detected by the Swedish chemist Johan August Arfwedson in 1817. It had similar properties to

sodium and potassium metals discovered in 1807, but its carbonate and hydroxide were less soluble in water and more alkaline. Further studies by Arfwedson on various minerals showed that lithium was contained in minerals such as spodumene and lepidolite but it could not be separated until 1821 when an English Chemist, William Brande, obtained a tiny amount by electrolysis. In 1855, German chemist Robert Bunsen and the British chemist Augustus Matthiessen obtained lithium in bulk by the electrolysis of molten lithium chloride.⁴²

Lithium is the third element of the periodic table with an atomic number of 3 and atomic weight 6.941 grammes per molecule. It is a soft silvery metal with a low melting point and the lowest density of all metals.⁴³ Lithium is highly reactive with water and forms strong hydroxide solutions, yielding lithium hydroxide and hydrogen gas. Lithium hydroxide is used in the production of cathode materials for lithium ion batteries.

Lithium does not occur as a metal in nature but is found in hard rock forms in crystals that are hosted in Pegmatites which form when mineral rich magma is cooled in fissures in continental plates.⁴⁴ The lithium found within the pegmatite formations is in the mineral forms of spodumene, petalite, lepidolite, and amblygonite.⁴⁵ Because of the high reactivity of lithium with water, it is always found bound with one or more other elements or compounds. Lithium is also formed in brine deposits as lithium chloride salts. The main type of brine deposit mined for lithium is found in interior saline drainage basins. These basins originally contained water, but high rates of evaporation that exceed precipitation leave behind concentrates of minerals containing lithium washed from rock by floods discharging into the basin. The dry saline lake beds are commonly referred to as salt pans, salt flats, salt marsh, alkali flats, playas or, most commonly, salars.⁴⁶ Other types of brine deposits containing lithium include liquid brine reservoirs located beneath salt flats, which are a principal source of lithium extracted today; geothermal brines originating from volcanic

³⁷ <https://pubs.usgs.gov/fs/2011/3081/pdf/fs2011-3081.pdf>

³⁸ Hard magnets materials are difficult to magnetize, but once magnetized are difficult to demagnetize while soft magnetic materials are easily magnetized and demagnetized. <https://astarmathsandphysics.com/o-level-physics-notes/292-uses-of-hard-and-soft-magnetic-materials.html>

³⁹ Rufe P.F. (2010). Testimony for the United States Senate on Energy and Natural Resources. https://www.energy.senate.gov/public/index.cfm/files/serve?File_id=6308A3D0-E21E-442A-445C-9F0803776F80

⁴⁰ Felter C. (2018). The Cobalt Boom. Council on foreign relations.

⁴¹ <https://www.weforum.org/agenda/2017/11/battery-batteries-electric-cars-carbon-sustainable-power-energy/>

⁴² <http://www.rsc.org/periodic-table/element/3/lithium>

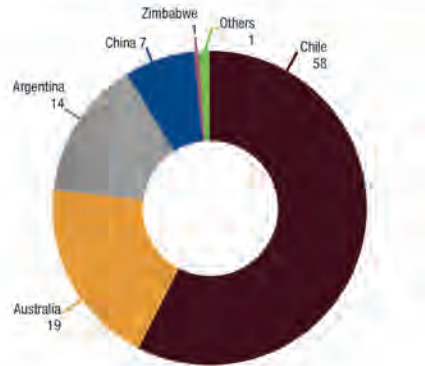
⁴³ <http://www.rsc.org/periodic-table/element/3/lithium>

⁴⁴ <https://tsxmedia.com/2018/07/17/not-all-lithium-mining-is-equal-hard-rock-pegmatites-vs-lithium-brine/>

⁴⁵ <https://www.sciencedirect.com/topics/materials-science/spodumene>

⁴⁶ Kavanagh L., Keohane J., Cabellos G.C., Lyod A. and Cleary J. (2018). Global lithium sources – Industrial use and future on the electric vehicle industry: A review, Resources volume 7 issue 3.

Figure 3 Lithium reserves: 2018
(Percentage)



Source: USGS National Minerals Information Center (2018)

activity, weathering of silicates, and leaching from lake sediments such as found in the Reyknes geothermal field in Iceland, the Hatchobaru and Ogoni geothermal fields in Japan and the Wairakei in New Zealand (Kavanagh et al, 2018).⁴⁷ Brines produced as a waste product of some oil extraction processes may also possess economic resources of lithium. In seawater, the low concentrations of lithium, approximately 0.1 part per million (ppm), makes it difficult to extract the metal efficiently and economically (Kavanagh et al, 2018).⁴⁸ Although lithium is found in many rocks and several natural brines, commercial exploitation is only possible in a few deposits with high concentration that make exploitation feasible.⁴⁹

Lithium resources are mainly concentrated in Chile, Bolivia and Argentina, also known as the lithium triangle. Over 50 per cent of lithium resources are believed to be located in the lithium triangle.⁵⁰ Total world resources are estimated to be about 62 million tons.⁵¹ Lithium brine deposits represent about 66 per cent of global lithium resources. Pegmatites account for approximately 26 per cent and hectorites in the

form of clay, potentially a source of lithium, represent 8 per cent of the resources.⁵² Total world reserves of lithium calculated from brines and pegmatites are estimated at 14 million tons.⁵³ The largest lithium reserves are in Chile, which holds approximately 58 per cent of the world total, Australia and Argentina hold approximately 19 per cent and 14 per cent in the form of rock and brine deposits respectively (see figure 3).⁵⁴ Bolivia is known to have identified resources estimated at 9 million tons⁵⁵ but there is no available data on its reserves. Rock deposits of lithium are more evenly distributed across the earth with deposits found on each continent.

Lithium is used in improving the physical and chemical properties of metals and alloys (metallurgy). For example, lithium is alloyed with aluminum or magnesium to reduce density and increase stiffness and this has important uses in the aerospace industry. Other uses of lithium in compound states include Lithium oxide for manufacturing ceramics and glass; lithium chloride and lithium bromide for air conditioning and industrial drying systems; Lithium stearate for lubricants; lithium carbonate for medicinal drugs; and; lithium hydride

⁴⁷ Ibid

⁴⁸ Ibid

⁴⁹ <https://www.sciencedirect.com/topics/engineering/lithium-deposits>

⁵⁰ <https://resourceworld.com/lithium-triangle/>

⁵¹ <https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mcs-2019-lithi.pdf>

⁵² www.sciencedirect.com/topics/engineering/lithium-deposits

⁵³ Ibid

⁵⁴ <https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mcs-2019-lithi.pdf>

⁵⁵ Ibid

as a means of storing hydrogen for use as a fuel.⁵⁵ A substantial part of lithium is used in the fast-growing sector of rechargeable batteries. For example, lithium salt, such as LiPF₆ in an organic solution, is used as an electrolyte⁵⁷ in lithium-ion battery technology. The application of lithium in batteries ranges from small rechargeable batteries used for electronic devices such as mobile phones, laptops, cameras to high power rechargeable lithium storage batteries for electric vehicles and power storage. The important role lithium plays in the manufacture of rechargeable batteries makes the element critical in supporting the climate change initiatives for reduction of greenhouse gases, but as in other battery raw materials used in these batteries, due consideration must be given to minimizing GHG emissions during their production (see discussions on environmental impacts).⁵⁸

Natural graphite

Natural Graphite was first discovered in Cumbria in North England at the beginning of the sixteenth century. It was initially used as a pigment for marking sheep, but gradually its application for writing developed. By the end of the sixteenth century, graphite was well known throughout Europe for its superior line-making qualities, its erasability, and the ability to re-draw on top of it with ink, which is not possible with lead or charcoal.⁵⁹ In 1855, English chemist Sir Benjamin Brodie proved that graphite was made of carbon. By the end of the century, Canadian miners began exploring deposits and became important graphite producers.⁶⁰ In 1893, Charles Street, an engineer working for Le Carbone (now Mersen), discovered and patented a process for converting carbon to artificial graphite of high purity. In the mid-1890s, American chemist Edward Goodrich Acheson manufactured graphite by high-temperature heat treatment of carborundum⁶¹, a compound of silicon and carbide that he had discovered earlier.⁶²

Natural Graphite is a naturally occurring allotrope of Carbon⁶³ (C) which is the sixth element of the periodic table. It is grey to black in color, soft and crystalline, opaque, and has a metallic luster.⁶⁴ Graphite cleaves with very light pressure, has a very low specific gravity⁶⁵ and exhibits properties of a metal and a non-metal, which make it suitable for many industrial applications. Its metallic properties include thermal and electrical conductivity and the non-metallic properties comprise of inertness, high thermal resistance, and lubricity.⁶⁶ Graphite ores are classified as microcrystalline and crystalline based on the ore's crystallinity, grain-size, and morphology.⁶⁷ The unique physical and chemical properties of graphite, particularly coarse crystalline graphite, make it difficult to find suitable substitutes for some industrial applications. The higher-grade natural graphite has lower processing costs but lower grades can also be attractive even though they have higher processing costs when they contain a low level of impurities that makes it possible to obtain good quality material.⁶⁸

Natural Graphite is formed when carbon is subjected to heat and pressure in the earth's crust and in the upper mantle. Pressures and temperatures needed to produce graphite are in the range of 75,000 pounds per square inch and 750 degrees Celsius respectively.⁶⁹ Natural graphite comes in three different forms: amorphous, flake and vein. The amorphous type is the most abundant form of naturally occurring graphite making up about 60 per cent of the market. It is formed from metamorphism of carbonaceous sedimentary rocks and has a carbon content of 70 to 80 per cent.⁷⁰ Amorphous carbon consists of micro graphite flakes that are a result of low-grade metamorphism of coal. Flake graphite is a less common form of graphite, which is characterized by its coarse flakes and crystallinity form usually mined from carbonaceous metamorphic rocks. It is formed as a result of medium to high grade metamorphism of carbonaceous metamorphic rocks and has a carbon content of

⁵⁵ <http://www.rsc.org/periodic-table/element/3/lithium>

⁵⁶ The electrolyte plays a key role in transporting the positive lithium ions between the cathode and anode.

⁵⁷ <https://www.weforum.org/agenda/2017/11/battery-batteries-electric-cars-carbon-sustainable-power-energy/>

⁵⁸ <http://museumofeverydaylife.org/exhibitions-collections/current-exhibitions/visual-history-of-the-pencil>

⁵⁹ <https://www.internationalgraphitetechnology/graphite/>

⁶⁰ Carborundum is a highly effective abrasive in manufacturing, which played an important role in advancing the industrial era.

⁶¹ <https://www.invent.org/inductees/edward-goodrich-acheson>

⁶² Three naturally occurring allotropes of carbon known to exist are: Amorphous, Diamond and Graphite.

⁶³ <https://www.usgs.gov/centers/nmic/graphite-statistics-and-information>

⁶⁴ <https://geology.com/minerals/graphite.shtml>

⁶⁵ <https://www.usgs.gov/centers/nmic/graphite-statistics-and-information>

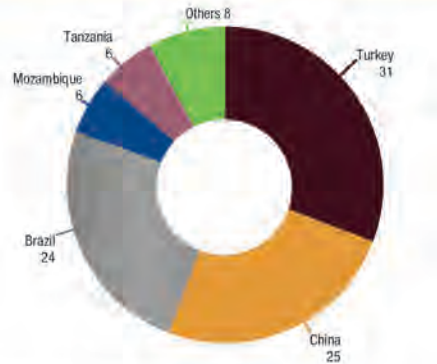
⁶⁶ <https://pubs.usgs.gov/pp/1802/pp1802.pdf>

⁶⁷ Ibid

⁶⁸ <https://geology.com/minerals/graphite.shtml>

⁶⁹ <http://www.focusgraphite.com/technology/>

Figure 4 Graphite reserves, 2018⁷¹
(Percentage)



Source: USGS National Minerals Information Center (2018)

85 to 98 per cent.⁷¹ The vein or lump type of graphite is the rarest and most valuable form of graphite. It is formed in the veins of high-grade metamorphic rock⁷² resulting from deposits from carbon bearing fluids.⁷³ The veins are a few millimeters to over a meter thick in places, although usually less than 0.3 meter thick. Vein graphite has a carbon content of 90 to 99 per cent carbon⁷⁴ and it appears as large lumps of solid graphite. Sri Lanka is the only country that produces commercially viable vein graphite.⁷⁵ Vein graphite is highly sought after by both miners and suppliers because the higher the grade, the lower the milling and refining cost. Synthetic graphite is made by high temperature treatment of amorphous carbon from feedstock such as petroleum coke, and coal tar pitch. It is more expensive to produce than natural graphite⁷⁶ but it is a more consistent and predictable product than processed natural flake.

The total identified world graphite resources are estimated to be approximately 1.5 billion tons⁷⁷ of

which approximately one-half is flake graphite. Global graphite reserves are estimated at 300 million tons.⁷⁸ The largest reserves of natural graphite are in Turkey, China and Brazil accounting for about 31 per cent, 25 per cent and 24 per cent respectively of the world total (see figure 4).

The principal use of Graphite is in steelmaking and refractory applications in metallurgy. Other major end uses of graphite include semiconductors, light-emitting diodes (LEDs), high-temperature lubricants, brushes for electrical motors and friction materials, and lightweight high-strength composite applications.⁷⁹ The use of graphite is growing in emerging renewable technology such as large-scale fuel cell, anodes in rechargeable batteries, solar cells and nuclear reactors, which indirectly contributes to the mitigation of GHGs.

Manganese

Manganese was used by pre-historic cave painters as a pigment for their paintings in the Lascaux region of France around 30,000 years ago in the form of manganese dioxide, but was discovered as a metal in 1774 by Swedish chemist and mineralogist

⁷¹ Ibid.

⁷² <https://pubs.usgs.gov/pp/1802/j/pp1802j.pdf>

⁷³ https://eprints.ucm.es/45150/2/art_10_1007_s00126-013-0499-912.pdf

⁷⁴ <http://www.focusgraphite.com/technology/>

⁷⁵ <https://www.gk-graphite.com/en/products-services/vein-graphite/>

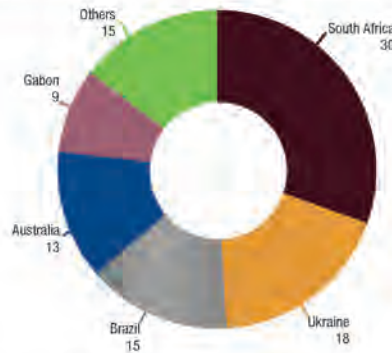
⁷⁶ <https://www.gk-graphite.com/en/products-services/vein-graphite/>

⁷⁷ <https://pubs.usgs.gov/pp/1802/j/pp1802j.pdf>

⁷⁸ <https://prid-wriet.s3-us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/atoms/files/mcs-2019-graph.pdf>

⁷⁹ <https://pubs.usgs.gov/pp/1802/j/pp1802j.pdf>

Figure 6: Manganese reserves, 2016 (Percentage)



Source: USGS National Minerals Information Center (2018)

Johan Gottlieb Gahn.⁶⁰ In the 19th century, scientists established its usefulness in increasing the hardness of iron, without reducing its malleability or toughness. By the end of the century, the demand for manganese dioxide increased because of the invention of the "Leclanché cell" in 1866 and the subsequent improvement of batteries containing manganese dioxide as a cathodic depolarizer.⁶¹ A wide range of metallurgical and chemical applications were developed in the 20th century. At present, nearly 90 per cent of all the manganese produced each year is used in the production of steel, and the rest is mainly used in the production of batteries and chemicals.⁶²

Manganese is the 25th element of the periodic table with an atomic mass of 54.938 grammes per molecule. It is a hard and brittle metal with similar chemical and physical properties to iron. It is silvery in colour with a high melting point of 1246 degrees Celsius. Manganese is reactive in its pure form and the metal oxidizes in air and corrodes in moist air. Like iron, manganese burns in oxygen/air at increased temperatures, and decomposes water gradually when cold but quickly on heating.⁶³

Manganese is not found as an element in nature. It occurs in many minerals such as manganite, purpurite, rhodonite, rhodochrosite, and pyrolusite. It is also found in many mineraloids such as psilomelane and wad.⁶⁴ Manganese rocks and ores are formed in basins of sedimentation of various types and are represented by carbonates as well as various types of oxides and hydroxides of manganese.⁶⁵ The formation of manganese ores requires specialized geologic conditions that concentrate manganese at several hundred times its average crustal abundance.⁶⁶ The dominant processes in forming the world's principal deposits take place in the oceans. As a result, most important manganese deposits occur in ancient marine sedimentary rocks that are now exposed on continents as a result of subsequent tectonic uplift and erosion.⁶⁷ Modern seabed resources of ferromanganese nodules cover vast areas of the present ocean floor and are still forming by complex interactions of marine microorganisms, manganese dissolved in seawater, and chemical processes on the seabed.⁶⁸

⁶⁰ <http://www.rsc.org/periodic-table/element/25/manganese>

⁶¹ <http://metallpedia.asiametal.com/metal/manganese/history.shtml>

⁶² Ibid

⁶³ <https://www.azom.com/article.aspx?ArticleID=13027>

⁶⁴ <https://geology.com/usgs/manganese/>

⁶⁵ <https://pubs.usgs.gov/pp/1802/l/pp1802l.pdf>

⁶⁶ Ibid

⁶⁷ Ibid

⁶⁸ Ibid

The total world land-based manganese resources including reserves and rocks sufficiently enriched in manganese to be ores in the future are large but unevenly distributed across the earth.⁸⁹ The largest resources of land based manganese are in South Africa accounting for about 74 per cent of the world total, and Ukraine accounts for about 10 per cent.⁹⁰ The total identified world land based manganese resources are estimated to be approximately 17 billion tons. Manganese resources in seabed deposits of ferromanganese nodules and crusts are larger than those on land and have not been fully quantified. Land-based world manganese reserves are estimated at 760 million tons, with South Africa, Ukraine and Brazil accounting for almost 63 per cent of the total (see figure 5).⁹¹ Manganese is rarely found in high enough concentrations to form an ore

deposit. Only about ten out of hundreds of minerals containing manganese are of mining significance.⁹²

Manganese is mainly used as a purifying agent in iron-ore refining and as an alloy that converts iron into steel. Although the quantity consumed to make a ton of steel is small (about 6 to 9 kilograms), it has no satisfactory substitute.⁹³ It is also used in alloys to improve resistance to corrosion, as a pigment in paint and for decolourizing glass.⁹⁴ The most important non-metallurgical application of manganese is in disposable and rechargeable batteries. It is favoured in cathode chemistries in the LIB because it offers energy density, power output, thermal stability, faster charging time, and shelf life. More recently manganese is increasingly being used in making cathode materials in NMC lithium ion batteries.

⁸⁹ <https://pubs.usgs.gov/pp/1802/pp1802L.pdf>

⁹⁰ https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mcs2019_all.pdf

⁹¹ <https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/atoms/files/mcs-2019-manga.pdf>

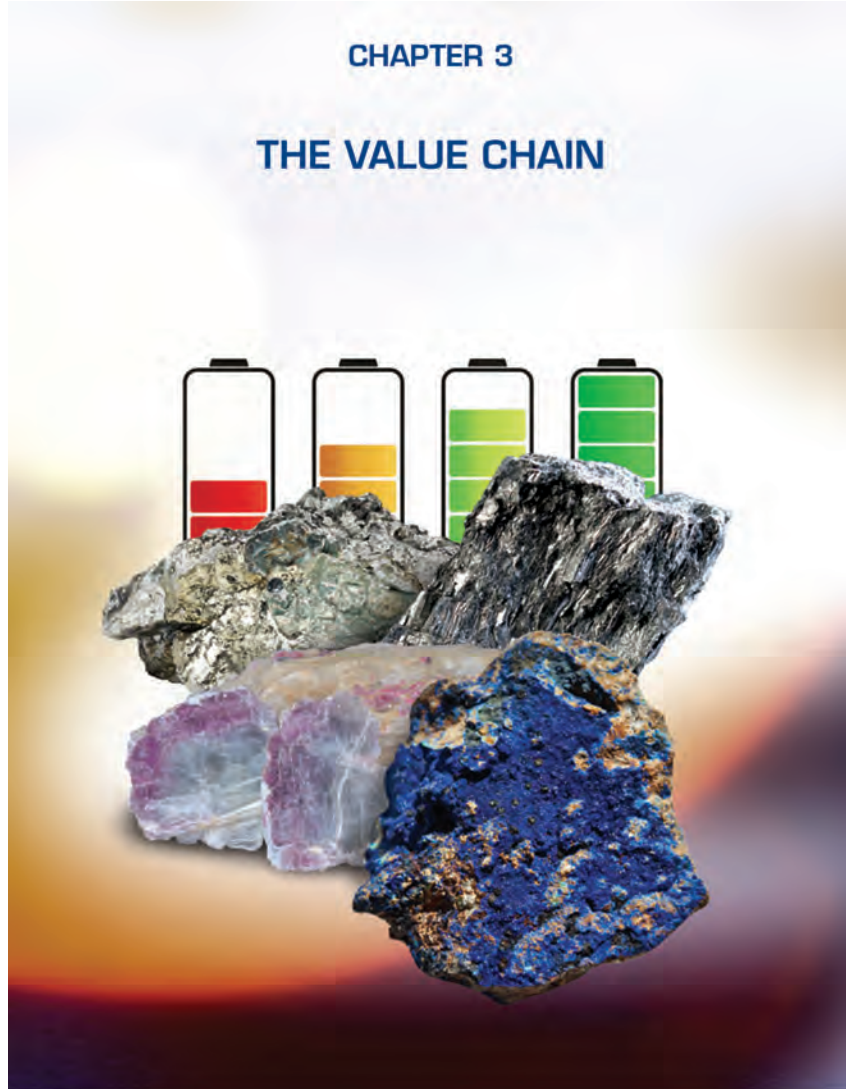
⁹² <https://www.theassay.com/technology-metals-edition-insight/manganese-no-longer-just-an-input-on-steel/>

⁹³ <https://pubs.er.usgs.gov/publication/pp1802L>

⁹⁴ <https://byjus.com/chemistry/manganese/>

CHAPTER 3

THE VALUE CHAIN



3.1. THE MINING VALUE CHAIN

The generic mining value chain essentially consists of three segments: mine initiation activities, mineral extraction and beneficiation, refining and recycling. It involves multiple players, some of which are vertically integrated firms, in a chain of activities that is linked to each other to deliver intermediate and final products.

At the mine initiation segment, the first activities consist of exploration and mine development. The exploration activities require a variety of technical skills and feasibility studies to identify economic deposits. This is followed by planning and development of the mine.

The mineral extraction and beneficiation segment include activities that lead to liberating ores from surrounding rock, usually by employing a range of high and low-level technologies. For example, scrapers and explosives are used to break up rock overburden when the deposits lie close to the surface. More sophisticated technology processes are used to mine deep underground ores. Sometimes surface ore deposits are identified and mined by artisanal miners using low technology equipment and hand sorting, with the high-grade ore sold to local cooperatives, who proceed to sell to local merchants and traders, to be part of the supply chains of companies producing concentrates for refining companies.⁹⁵ The extracted ores are processed by crushing, grinding and separating grains of ore minerals from the gangue minerals to form more concentrated saleable intermediate products of the raw metal. This is achieved by combining ground raw materials with chemical reactants and converting into slurry, followed by filtering and evaporation (hydrometallurgy) or using high temperature processes that stimulate chemical reactions to separate metals from ores (pyrometallurgy).

The refining and recycling segment involve refining concentrates (at local or foreign depots) into high quality mineral/metallic compounds or pure forms of the mineral or metal, which finds its use in a variety of applications. High quality compounds used as active cathode and anode materials in LIBs are derived from concentrates at this stage of the value chain. Activities in this segment of the value chain may include recycling of waste materials and transforming

the recycled materials (secondary raw materials) to produce high quality new metals. Recycling involves different stakeholders (collectors, dismantlers, metal merchants, shredders, transport-related organizations etc.) linked to each other to create value for the final recycled product. The recycling process begins with recovering the metal from scrap or waste and re-melting the metal, then refining to ensure the final product is free of contaminants. Recycling can be less expensive and less energy intensive than creating a new metal from mining deposits, but challenges remain with respect to recovering sufficient material for recycling followed by processing and then refining.

In general, the transformation from ores to intermediate products and to pure metals and minerals, or from scrap to recyclable metals can be a laborious process where countries are not well equipped to participate in all activities. Therefore, some activities are located across different countries wherever the necessary skills and materials are available at competitive cost and quality.⁹⁶ This fragmented process has been enhanced largely due to improved information and communication technologies, trade liberalization and lower transports costs.

The value chain specific to raw materials used in manufacturing the LIB, namely cobalt, lithium, graphite and manganese, is discussed in the following section. The scope of analysis in this section will be limited to specific segments of the LIB value chain due to lack of supporting data on distribution of value at every node of the chain.

Cobalt value chain

Most of cobalt production around the world comes from copper/nickel ore bodies. The ores are extracted and processed domestically into intermediate products in the form of cobalt oxides and hydroxides and cobalt carbonates to lower the high cost of shipping bulky, low value ores/concentrates. A typical cobalt extraction process may include pressure acid leaching⁹⁷ to separate nickel or copper from the laterite ore and then followed by hydrometallurgical

⁹⁵ <https://www.oecd.org/st/ind/global-value-chains.htm>

⁹⁷ In pressure acid leaching, slurred ore is preheated and mixed with a sulfuric acid solution in high temperature and pressure for 90 min. After this, primary and secondary metals are converted into sulfate salts. These sulfate salts are then washed using a counter-current decantation circuit (CCD) which produces a clear nickel and cobalt solution, and residue; <https://www.sciencedirect.com/science/article/pii/S2300396018301836>

⁹⁶ <http://www.mining.com/congo-miners-buying-cobalt-artisanal-operators-balance-market/>

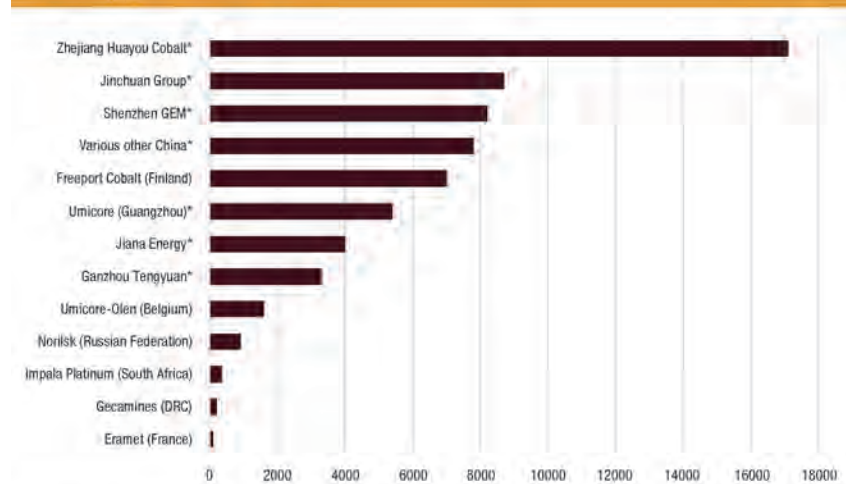
or pyrometallurgical processing, to separate the metals. The copper-associated cobalt ores found in the Democratic Republic of the Congo and Zambia are processed in this conventional way to produce a copper-cobalt concentrate. Processing of cobalt mined by artisanal workers is sometimes done locally by operating mines in the country to support their own mined supply.²⁹

The top 5 cobalt mining companies in 2017 were Glencore (27,400 tons), China Molybdenum (16,419 tons), Fleurette Group (7,595 tons), Vale (5,811 tons), and Gecamines (4,167 tons), which is a state controlled cobalt mining company in the Democratic Republic of the Congo.³⁰

Major refineries purchase intermediate products of cobalt from various mines and ship them to their own

locations to produce value added compounds of cobalt for use in a variety of applications.³¹ Because there are different feed materials (intermediates) used in refining the ores, the processes to recover cobalt differ and produce a range of cobalt products including metals such as cathodes, ingots, briquettes, powder and chemicals such as sulfate, chloride, carbonate, oxalate, oxide, tetroxide. Cobalt chemicals are used to combine with other metals like nickel and manganese to make the cathode element of LIBs while cobalt metal and powder are mostly used to make superalloys used in jet engines.³² As EVs become more integrated into global transportation, refineries will grow proportionally to avoid supply bottlenecks in the LIB supply chain. The top cobalt chemical refineries are in China (see figure 6).

Figure 6: Top refined cobalt – chemicals, 2017
(Tons)



*Refineries based in China

Source: Bloomberg³²

²⁹ <http://www.mining.com/congo-miners-buying-cobalt-artisanal-operators-balance-market/>

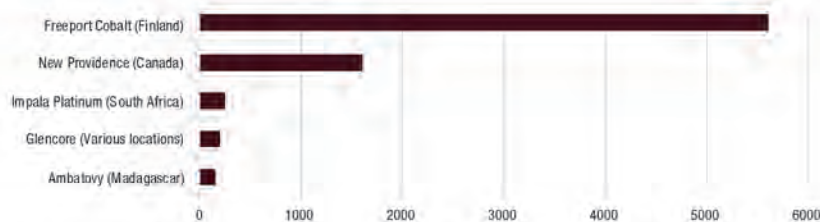
³⁰ <https://investingnews.com/daily/resource-investing/battery-metals-investing/cobalt-investing/top-cobalt-producing-companies/>

^{31,32} Refiners are rarely located near cobalt mines, instead, major refiners purchase cobalt concentrate from various mines and ship to their own locations <https://www.thebalance.com/the-biggest-cobalt-producers-2339726>

³¹ <https://www.bloomberg.com/graphics/2018-china-cobalt/>

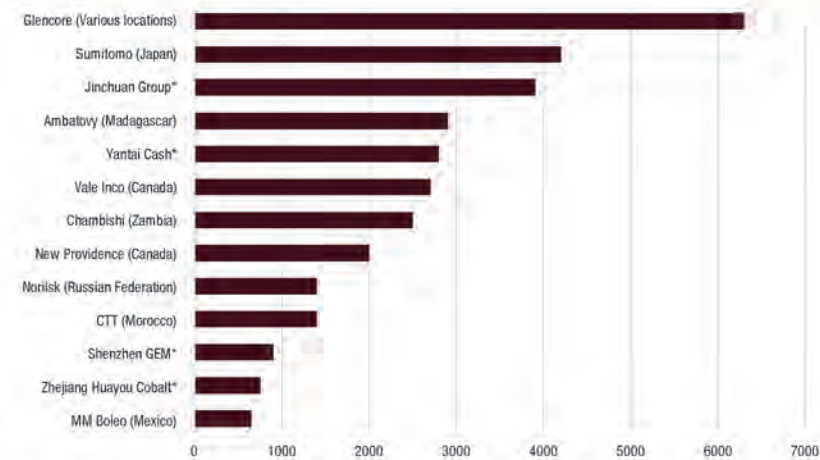
³² Bloomberg taken from Darton Commodities Limited; See <https://www.bloomberg.com/graphics/2018-china-cobalt/>

Figure 7 Refined cobalt – powder, 2017
(t/year)



Source: Bloomberg¹⁰³

Figure 8 Refined cobalt – metal, 2017
(t/year)



*Refineries based in China

Source: Bloomberg¹⁰⁴

¹⁰³ Bloomberg taken from Darton Commodities Limited; See <https://www.bloomberg.com/graphics/2018-china-cobalt/>

¹⁰⁴ Ibid

Lithium value chain

Lithium is mined from petalite/pegmatite rock deposits at open pits or underground mines. In open pits, it generally involves stripping overburden with scrapers, digging the ore or blasting with explosives then transporting the ore to designated areas for processing.¹⁰⁹ Underground mining methods are used when economic open pit mines are depleted, and it becomes efficient to access deposits through shafts. The recovered ores are crushed, and the lithium minerals are separated on the basis of their physical, electrical and magnetic properties to form a concentrate.¹¹⁰ Further concentration is achieved by froth floatation,¹¹¹ followed by hydrometallurgy and precipitation from an aqueous solution.¹¹² Depending on the end use, the producer will typically create either lithium hydroxide or lithium carbonate, which is sent to refineries to be purified and manufactured into its final form. Lithium is also mined from salt lakes or from underground brine water. In underground mining, boreholes are drilled into saline aquifers and the brine is pumped into evaporation ponds at the surface. The brine is kept in the ponds to evaporate until an optimum level of concentration is attained, then it is pumped to a lithium recovery facility where it is pretreated to remove contaminants or unwanted constituents. The concentrates from mines or lithium-rich saline solution from underground lakes in South America is concentrated into a silvery-gray powder that is purified and refined into lithium hydroxide and lithium carbonate. Lithium extraction from rock is more exhausting than extracting the metal from brines and the cost is double than that extracted from brines containing the metal.¹¹³

At refineries, the lithium content (the value of lithium) in the concentrates is enhanced to battery grade lithium hydroxide or lithium carbonate, which is used to make cathode material for lithium-ion batteries and lithium chemicals. These chemicals are subsequently processed with materials such as nickel or cobalt to produce battery electrodes, or with solvents to

make electrolytes.¹¹⁴ The type of ore mined may yield profitable by-products of the refining process such as tantalum, beryllium and caesium.¹¹⁵ The pure metallic Lithium is produced by the electrolysis of molten lithium chloride and potassium chloride but its use in batteries is limited due to potential dangers of exploding.

The top 5 lithium mining companies in terms of global market share are Albemarle (18 per cent); Jiangxi Ganfeng Lithium (17 per cent); Sociedad Química y Minera S.A. (14 per cent); Tianqi Lithium Industries Inc. (12 per cent) and FMC/Livent (5 per cent).¹¹⁶ These companies are engaged in either rock or brine lithium projects, or both. For example, Albemarle has lithium projects in Chile and Argentina (brine), and in Australia (rock). Livent has extracted lithium brine at its operations in Argentinian salars for more than 20 years and has been producing lithium compounds for more than 60 years.¹¹⁷

The top producers of refined lithium are in Chile, where the world's largest lithium sources are located. The U.S, Argentina and China are also major producers of refined lithium. Four companies dominate the market for refined lithium: Sociedad Química y Minera de Chile, Australia's Talison, Chemetall in Germany and FMC in the United States. Lithium carbonate is generally sold on three- to five-year contracts from miners to refiners — including those listed above — that produce and market downstream chemicals and lithium metal.

Graphite value chain

Graphite occurring naturally as flakes and veins within rock fractures or as amorphous lumps is extracted through open pit mining by breaking rocks either with explosives or drilling (also referred to as quarrying) when the ore is near to the surface. When the graphite ore is located deep underground, more sophisticated methods such as underground mining is used to liberate the ore (eg. vein/lump graphite). The extracted ore is sorted, crushed and ground into fine particles, and then immersed in flotation tanks so that gangue minerals and impurities can be separated. As crystalline flake graphite has the best floatability,

¹⁰⁹BGS, 2016, Lithium; MineralsUK, Centre for sustainable mineral development (www.MineralsUK.com)

¹¹⁰Ibid

¹¹¹Froth floatation is a process that selectively separates materials based upon whether they are water repelling (hydrophobic) or have an affinity for water (hydrophilic); <https://www.sciencedirect.com/topics/earth-and-planetary-sciences/flotation-froth>

¹¹²<http://www.mining.com/web/lithium-supply-demand-story/>

¹¹³<https://www.thebalance.com/lithium-production-2340123>

¹¹⁴<https://www.bloomberg.com/news/features/2019-06-03/lithium-miners-australia-chile-see-riches-as-ev-battery-makers>

¹¹⁵<http://www.mining.com/web/lithium-supply-demand-story/>

¹¹⁶<https://seekingalpha.com/article/4241060-top-5-lithium-producers-growing-producers-consider>

¹¹⁷<https://seekingalpha.com/article/4241060-top-5-lithium-producers-growing-producers-consider>

followed by vein graphite (amorphous graphite has the poorest floatability), flotation is the most commonly used method in graphite beneficiation.¹¹⁴ However, the purity levels that can be achieved for flake graphite after flotation ranges from 80 to 98 per cent, therefore further purification is required.

At the refineries, the concentrates are treated using chemical and thermal based methods to reach 99.9 per cent purity needed to generate battery-grade spherical graphite used as anodes in LIBs. The leading producers of refined graphite are in China, Mexico and Canada.

Manganese value chain

Manganese is mostly extracted from open pits and then transferred to a processing plant where it is treated. The ores may contain different physical characteristics and mineral associations. For example, in some ores the manganese minerals occur as relatively large aggregates whereas in others, impurities are distributed throughout the manganese minerals. Low grade ores are transformed into concentrates by methods such as washing, screening, separation, pyrometallurgy enrichment and chemical mineral processing.¹¹⁵ The concentrates are sent to refineries to produce pure manganese. The ores may also be sent directly to refineries for smelting.

At the refineries, pure manganese is produced by hydrometallurgical and electrolytic processes, while ferromanganese and silicomanganese, which are materials used in making steel alloys, are produced by the smelting of ores in a blast furnace or, more commonly, in an electric furnace.¹¹⁶ The important chemical compounds that are derived from refining concentrates is manganese dioxide, which is used in non-metallic applications such as battery cathodes in rechargeable batteries and in dry cell batteries.

The leading manganese ore companies, manufacturers/players are: BHP Billiton, Eramet Comilog, Vale, OM Holdings, Braken International Mining, MOIL Ltd, Dharni Sampda Private Ltd, Kaboko, and Gulf Minerals Corp.¹¹⁷

¹¹⁴<https://pdfs.semanticscholar.org/3e06/e260f32a1933562facc4846de118fd6b3f58.pdf>

¹¹⁵Grigorova I. (2011), Studies and possibilities of low grade manganese ore beneficiation

¹¹⁶<https://www.britannica.com/technology/manganese-processing>

¹¹⁷<https://www.marketwatch.com/press-release/manganese-ore-market-2018-global-industry-size-demand-growth-analysis-share-revenue-and-forecast-2023-2019-04-10>

3.2. RECYCLING OF RAW MATERIALS USED IN LITHIUM ION BATTERIES

Recycling of raw materials used in LIBs is increasing in importance because it reduces waste and impact on the environment. Furthermore, valuable scrap metals can be recovered from end of life products because their physical properties do not degrade over time.

Currently cobalt and manganese are the major raw materials that are of most interest to metal recyclers. The end of life recycling rate for cobalt is above 68 per cent and for manganese is 53 per cent.¹¹⁸ Cobalt can be recovered from end-of-life products such as spent rechargeable batteries (the lithium ion battery cell comprises of between 5 to 20 per cent cobalt¹¹⁹), petrochemical catalysts and alloys used in aerospace applications. Depending on the type and quality of the scrap, it might be recycled within the industry sector that generated it, processed to reclaim the cobalt as a cobalt chemical or metal powder, downgraded by using it as a substitute for nickel or iron in an alloy with a lower cobalt content, or processed to an intermediate form that would then either be further refined or downgraded. The products of recycled cobalt scrap include alloys, mixed metal residues, pure cobalt metal, metal powder, or chemicals; and tungsten carbide-cobalt powders.¹²⁰ Manganese is mainly recovered from scrap of iron and steel. The quantity of manganese used in batteries is relatively small in comparison to metallurgical applications, but as the EV market continues to expand, it raises the potential for recycling spent LIBs.

Depending on the battery manufacturer, spent LIBs could contain between 5 to 10 per cent of lithium as well as other metals such as copper, aluminum and iron.¹²¹ Both pyrometallurgical and hydrometallurgical processes¹²² can be employed to recycle LIB waste into lithium. Lithium can also be recycled an unlimited number of times, but no recycling technology exists

¹¹⁸UNEP, 2011, Recycling rates of metals – A status report

¹¹⁹<https://www.sciencedirect.com/science/article/pii/S2095809917308226>

¹²⁰<https://investingnews.com/daily/resource-investing/battery-metals-investing/cobalt-investing/recycling-cobalt-sustainable-and-affordable/>

¹²¹<https://www.sciencedirect.com/science/article/pii/S2095809917308226>

¹²²Pyrometallurgical processes involves smelting in furnaces, incineration, combustion and pyrolysis; In hydrometallurgy involves using strong inorganic/organic acids or caustic watery solutions to effectively dissolve and precipitate metals.

today that can produce pure enough lithium for a second use in batteries.¹⁰² The end of life recycling rate for lithium is estimated at less than 1 per cent.¹⁰⁴ Similarly, not much recycling of natural graphite (flake) is done due to limitations in current technologies even though the potential exists to recover waste resources from, inter alia, LIBs, steel furnace refractories, casting processes, and brake lining. The challenge in graphite recycling is to segregate the used graphite from other materials and ensure they are not contaminated. The end of life recycling rate for lithium and natural graphite is estimated at less than 1 per cent.¹⁰⁵

3.3. ADVANTAGES AND DISADVANTAGES OF RECYCLING

All metals can be recycled without degrading their properties; but choosing to recycle and the success of such initiatives may depend on a variety of factors, inter alia, the geographical location in relation to markets for reprocessing materials, volume of recyclable materials and efficiency of the collection methods.¹⁰⁶ Many components of rechargeable batteries end up in dump sites at the end of their life cycles. It has been estimated that today's typical passenger vehicle car manufactured with an NMC 622 cathode 55kWh battery pack will contain 7.4 kg Lithium Carbonate Equivalent (LCE)¹⁰⁷ and 12kg refined cobalt. In the future a similar car with a 77kwh battery pack equipped with an NMC 811 cathode will contain 8.4 kg LCE and 6.6 kg refined cobalt.¹⁰⁸ Although the potential recoverable quantity of metals in the LIB is relatively high and could present recycling business opportunities, they are often combined with several different elements in a complex mix making recycling extremely difficult. Furthermore, not all retrieved materials may reach battery-grade quality when recycled but the recovered resources can be used for less demanding purposes.¹⁰⁹

The recycling of raw materials used in LIBs has significant advantages. For example, it contributes to

reducing waste destined for landfill sites and as a result helps to reduce land and groundwater pollution, since landfills contribute to environmental degradation. In addition, using secondary raw materials means less use of energy to develop primary raw materials, a reduction in GHG emissions, conservation of resources and environmental protection.¹¹⁰ Furthermore, recycling contributes to the Circular Economy (CE) model, which entails a gradual decoupling of economic activity from the consumption of finite sources and designing waste out of the system.¹¹¹ Recycling also contributes to the creation of jobs ranging from collection and delivery of recyclable materials to setting up recycling plants. The constraints to recycling are the high upfront capital costs such as building the recycling plant. Recycling may make a small contribution to conserving the resource but if the growth rate of global production of the raw material is greater than consumption, recycling may not be able to delay the inevitable depletion of deposits.¹¹²

3.4. THE LITHIUM ION BATTERY MANUFACTURING CHAIN

The manufacture of rechargeable batteries involves three main steps: Electrode manufacturing, cell assembly and cell finishing. The different segments are either part of a vertically integrated company or a manufacturing supply chain where the different components are supplied for the manufacture of the final product.

In electrode manufacturing, the active components are mixed with some additives and transformed by a series of different processes into cathodes or anodes. The cathode is the positive electrode of the LIB. The worldwide Lithium Ion Battery cathode market was estimated at US\$7 billion in 2018 and is expected to reach US\$58.8 billion by 2024.¹¹³ The manufacture of cathode active materials is dominated by Asia. In 2015, China manufactured approximately 39 per cent (by weight) of the total amount of cathode materials, followed by Japan (19 per cent) and Republic of Korea

¹⁰² https://batteryuniversity.com/learn/article/availability_of_lithium

¹⁰³ UNEP, (2011), Recycling rates of metals – A status report.

¹⁰⁴ UNEP, (2011), Recycling rates of metals – A status report.

¹⁰⁵ https://www.sustainabilityexchange.ac.uk/factors_affecting_recycling

¹⁰⁶ Lithium Carbonate Equivalent refers to the different lithium compounds and production quantities used in the battery

¹⁰⁷ Azevedo M., Campagnol N., Hagenbruch T., Hoffman K., Lalá A., Ramsbottom O. (2018), Lithium and cobalt – a tale of two commodities, McKinsey & Company.

¹⁰⁸ https://batteryuniversity.com/learn/article/recycling_batteries

¹⁰⁹ <https://www.conserve-energy-future.com/advantages-and-disadvantages-of-recycling.php>

¹¹⁰ <https://www.ellenmacarthurfoundation.org/circular-economy/concept>

¹¹¹ <https://www.conserve-energy-future.com/advantages-and-disadvantages-of-recycling.php>

¹¹² <https://www.globenewswire.com/news-release/2019/03/14/1752966/0/en/Worldwide-Lithium-Ion-Battery-Cathodes-Market-Report-2019-Market-is-a-7-Billion-Market-in-2018-and-is-Expected-to-Reach-58-8-Billion-by-2024.html>

(7 per cent).¹³⁴ Leading manufacturers of cathode materials for lithium-ion battery includes Umicore, BASF, and Johnson Matthey, among others.¹³⁵

The anode is the negative electrode of the LIB. The worldwide market for Lithium-ion Battery Anode Materials is expected to grow at a Compound Annual Growth Rate (CAGR) of roughly 13.6 per cent over the next five years, reaching US\$ 2.99 billion in 2024, from US\$ 1.39 billion in 2019.¹³⁶ Anode materials are mostly manufactured in Asia by manufacturers including Hitachi Chemical, BTR, Shanshan Technology, JFE, Mitsubishi Chemical Holdings, and Nippon Carbon.¹³⁷ In 2016, the market share of the top six manufacturers was estimated at about 41 per cent.¹³⁸

In the cell assembly segment, the process is usually highly automated but manual assembly methods may be used by smaller manufacturers. This stage involves building the power-generating compartments called cells. Each cell is essentially made of a positive electrode (connected to the battery's positive or + terminal), a negative electrode (connected to the negative or - terminal), and an electrolyte in between them. The cells are built by first making the electrode sub-assembly in which the separator is sandwiched between the anode and the cathode.¹³⁹ This is followed by connecting the electrode structure to the terminals together with any safety devices and to insert this sub-assembly into a can. The can is then sealed in a laser welding or heating process, depending on the case material, leaving an opening for injecting the electrolyte into the can. The last stage involves filling the cell with the electrolyte and then sealing.¹⁴⁰

At the cell finishing stage, the cells are tested, graded and sorted. The finished and sorted cells are supplied to battery assembly pack manufacturers where they are assembled into battery pack products that are cost effective, environmentally safe and meet specifications demanded by the end user. In 2018, the battery pack market was estimated at US\$20.6 billion

and is forecast to reach US\$36.2 billion by 2023, at CAGR of 12 per cent.¹⁴¹

Manufacturers from three countries in Asia, China, Japan and Republic of Korea dominate the rechargeable battery market. In 2018, less than 3 per cent of the total global demand for EV batteries was supplied by companies outside these three countries, and only approximately 1 per cent was supplied by European companies.¹⁴²

3.5. ECONOMIC IMPLICATIONS OF THE LITHIUM ION BATTERY VALUE CHAINS

The various stages outlined in the LIB value chain and the value chains of raw materials used in LIBs highlight various activities that are conducted to transform ores into finished products. Very often, the largest producers of the raw materials used in manufacturing LIBs exit the value chain at a very early stage, focusing on the first saleable product that is extracted from the deposits (ores). Due to the relatively low price of ores per ton and fixed shipping charges per unit weight, ore undergoes at least some processing at or near the extraction site in order to increase its value per unit weight prior to shipment.¹⁴³ For example, the battery raw materials discussed in this report are sometimes transformed into intermediate products through chemical and physical transformations before being traded.

The largest producer of cobalt, the Democratic Republic of the Congo, exports most of its cobalt in ores, oxides and hydroxides. In 2017, cobalt exports comprised of 26.2 per cent of total exports from the DRC. The value of Cobalt oxides and hydroxide exported was estimated at US\$721m and cobalt ore at US\$512m.¹⁴⁴ The ores are produced by both artisanal and large-scale mining activities. Ores originating from artisanal miners in the DRC contribute to the livelihood of about 100,000 miners¹⁴⁵ including diggers, sorters and washers, many of whom include child workers. Artisanal miners sell most of their ore to middlemen who

¹³⁴https://ec.europa.eu/jrc/sites/jrcsh/files/jrc105010_161214_li-ion_battery_value_chain_jrc105010.pdf

¹³⁵<https://www.batterypoweronline.com/news/embracing-lithium-ion-battery-euphoria-innovations-in-cathode-materials/>

¹³⁶<https://www.reuters.com/brandfeatures/venture-capital/article?id=87198>

¹³⁷ *Ibid*

¹³⁸ *Ibid*

¹³⁹ https://www.mpoweruk.com/battery_manufacturing.htm

¹⁴⁰ *Ibid*

¹⁴¹ <https://www.businesswire.com/news/home/20181114005414/en/Global-Battery-Packaging-Market-Type-Battery-Level>

¹⁴² <https://www.mckinsey.com/industries/oil-and-gas/our-insights/recharging-economies-the-ev-battery-manufacturing-outlook-for-europe>

¹⁴³ <https://pdfs.semanticscholar.org/930e/841dc74dt2736184a16f7bbec98d9d07e03d.pdf>

¹⁴⁴ <https://oec.world/en/profile/country/cod/>

¹⁴⁵ <https://www.mining.com/congo-miners-buying-cobalt-artisanal-operators-balance-market/>

sell the raw material to operators for semi processing. Artisanal miners accounted for between 14 to 16 per cent of the country's annual production in 2017.¹⁴⁶ The value added to cobalt ores by the Democratic Republic of the Congo is limited to intermediate products or concentrates, mainly composed of hydroxide with a cobalt content of between 20 and 40 per cent.¹⁴⁷ End products that require further processing/refining for use in rechargeable batteries as well for other uses are mostly produced from refineries in China, Finland, Norway, Belgium and Zambia.¹⁴⁸

Unlike other metals that can be used with limited processing after they are extracted, raw lithium must undergo extensive chemical treatment to be used in batteries.¹⁴⁹ For example, lithium carbonates from Australian spodumene deposits and from brine are processed further to produce lithium chloride and lithium hydroxide and lithium carbonates, then processed further to produce lithium metal. In 2018, the revenues earned by the top exporters of lithium oxide and hydroxide were as follows: China (US\$398m), the United States (US\$102m), Chile (US\$95m), the Russian Federation (US\$87.3m) and Belgium (US\$38m). The main exporters of lithium carbonates were Chile (US\$948m), China (US\$164m), Belgium (US\$104m), Germany (US\$45m), and the United States (US\$23m) (see discussion on international trade).

Manganese is mostly exported as ores and concentrates, and natural graphite is exported in the form of powder or flakes. The bulk of manganese ores is processed into ferromanganese and silicomanganese. Only a small fraction of manganese ores and concentrates is refined into high purity manganese metal and high purity manganese sulphate for use in the battery industry. The revenues earned from the top exporters of manganese ores and concentrates, in 2018 was: South Africa (US\$3.5bn), Brazil (US\$406m), Ghana (US\$288m), Kazakhstan (US\$33m) and Malaysia (US\$23m). The revenues from

top exporters of Natural graphite in powder or flakes were: China (US\$315m), Brazil (US\$31.2m), Germany (US\$29.5m), United States (US\$21.1m) and Canada (US\$17m).

The global electric car fleet is growing rapidly. In 2018, it exceeded 5.1 million, up by 2 million (65 per cent) from the previous year and almost doubling the number of new electric car sales.¹⁵⁰ According to IEA projections, global electric car sales are expected to reach 23 million in 2030 with a stock exceeding 130 million vehicles (excluding two/three wheelers).¹⁵¹

The IEA forecast has implications for suppliers of raw materials and value added intermediate products used in rechargeable batteries. Some forecasts indicate that average annual global cobalt consumption will reach about 220 000 tons in 2025 and increase to 390 000 tons in 2030 if not alleviated by substitution mechanisms with the adoption of alternative battery chemistries requiring less cobalt.¹⁵² One area in which there is opportunity for resource owners is therefore in boosting supplies to meet rising demand as well as in refining to produce battery grade materials usable in rechargeable batteries. Their increased production could also meet consumption needs in the varied applications for cobalt highlighted in this report. The potential exists to increase domestic value addition in host countries where raw materials originate and processing is not advanced. However, lack of infrastructure (eg. electricity, communications), forward linkages (mineral beneficiation and manufacturing), backward linkages (local capabilities and suppliers), financing, and policies that encourage local value addition has made it difficult to maximize the economic benefits of moving further up the value chain. Other factors that have contributed to stifling value-added manufacturing include, low access to advanced materials technology, stringent environmental regulations, and elaborate product specifications in the fabrication of semi-finished and finished products.

¹⁴⁶<https://phys.org/news/2018-02-cobalt-prices-soar-congo-small.html>

¹⁴⁷Ibid

¹⁴⁸<https://www.thebalance.com/the-biggest-cobalt-producers-2339726>

¹⁴⁹<https://cdn2.hubspot.net/hubfs/4518141/Risks%20and%20Opportunities%20in%20the%20Battery%20Supply%20Chain.pdf>

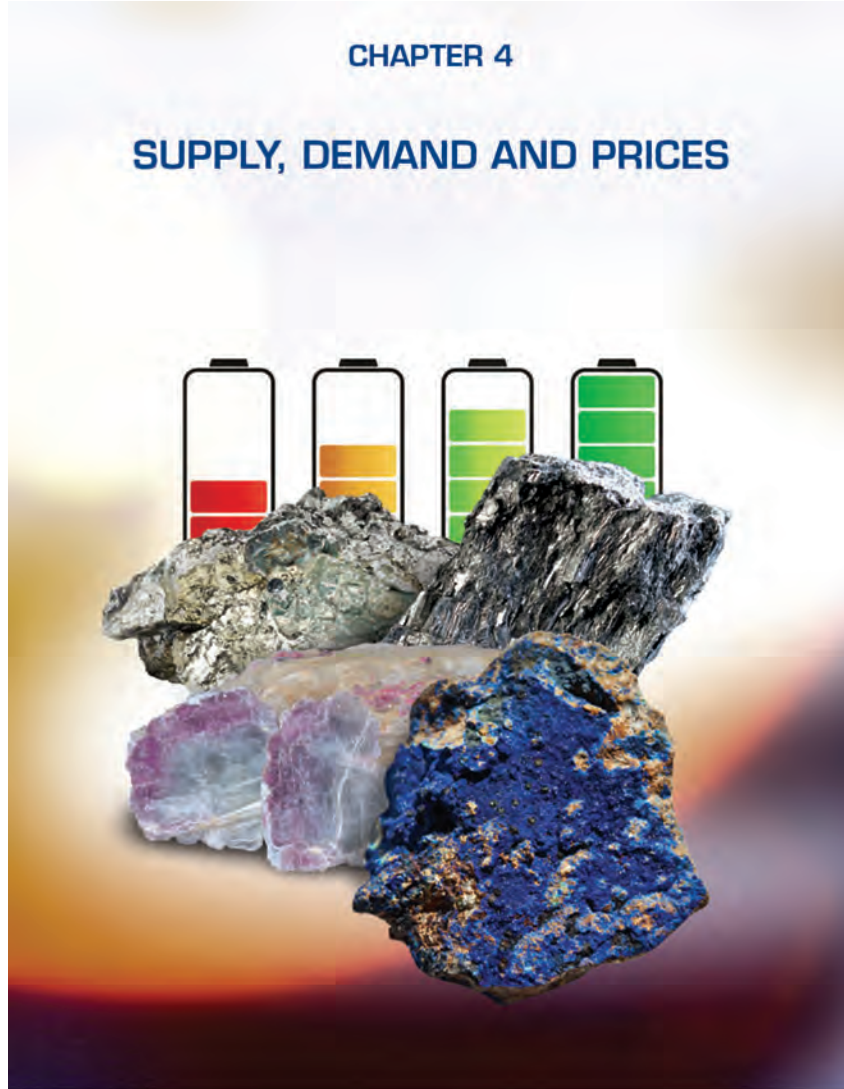
¹⁵⁰<https://www.iea.org/publications/reports/globalevoutlook2019/>

¹⁵¹Ibid

¹⁵²Dias A, Blagoeva D, Pavel C, Arvanitidis N. (2018). Cobalt: demand-supply balances in the transition to electric mobility, JRC Science for Policy Report.

CHAPTER 4

SUPPLY, DEMAND AND PRICES



4.1. PRODUCTION OF RAW MATERIALS USED IN LITHIUM ION BATTERIES

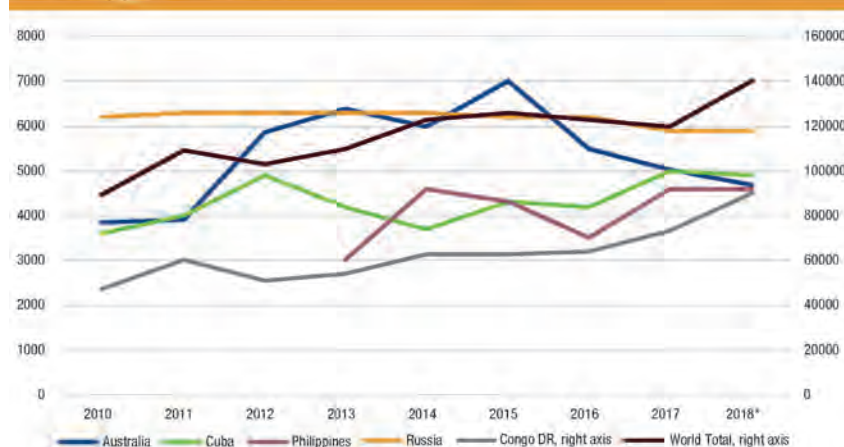
A few countries dominate production of the raw materials used in LIBs: cobalt is mainly produced in the Democratic Republic of the Congo, lithium in Australia and Chile, graphite in China and Brazil, and manganese in South Africa and Australia.

Given that cobalt is mostly mined as a by-product of either copper or nickel, the decisions made from exploration for and production of copper or nickel may affect the supply of cobalt on the market. For example, a period of low copper and nickel prices may discourage exploration activities and investment decisions and impact the expansion of cobalt production in the medium term. Currently, the only primary cobalt operation is from the Brou-Azzer mine in Morocco¹⁵³ where production over the last two years is estimated to be on average 2,250 tons per annum.¹⁵⁴

From 2010 to 2018, global production of mined cobalt increased from 89,500 tons to 140,000 tons. Most of the cobalt mined during this period came from copper cobalt

operations in the Democratic Republic of the Congo, with the bulk of the rest being attributed to nickel-cobalt operations. During this period, other leading producers had varied production patterns. For example, production volumes in Russia, the second largest producer of cobalt, remained relatively stable at around 6,000 tonnes, while production from Cuba, Australia and the Philippines followed a volatile path of rising and falling volumes. Between 2010 and 2013, production in Australia increased by 66 per cent largely due to rising demand, before falling by 27 per cent in 2018. The fall was due in part to the influence of declining nickel prices which led to a shutdown of nickel mines at a time when demand for cobalt was growing. Cobalt production in the Philippines also declined from 2014 to 2016 due in part to low nickel prices causing mines to be closed or suspended¹⁵⁵ but a combination of strong demand and increasing prices contributed to reversing the downward trend and pushed production upwards. In 2018, the Democratic Republic of the Congo increased production by approximately 23 per cent over the previous year to 90,000 tons and it has almost doubled since 2010 (an increase by 90 per cent over the period) largely due to rising demand (see figure 9).

Figure 9 Cobalt production, 2010 to 2018*



* Estimates for year 2018

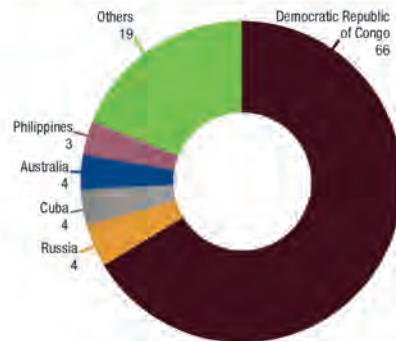
Data Source: USGS National Minerals Information Center (2018)

¹⁵³ <https://www.proactiveinvestors.co.uk/companies/news/212832/cobalt-set-for-bearish-2019-but-demand-fundamentals-remain-strong-212832.html>

¹⁵⁴ <https://www.usgs.gov/centers/nmic/mineral-commodity-summaries>

¹⁵⁵ <http://mgb.gov.ph/2015-05-13-02-02-11/mgb-news/181-metallic-production-value-suffers-deficit-in-q3-2015>

Figure 10. Cobalt production, 2018*
(Percentage)



*Estimates for year 2018

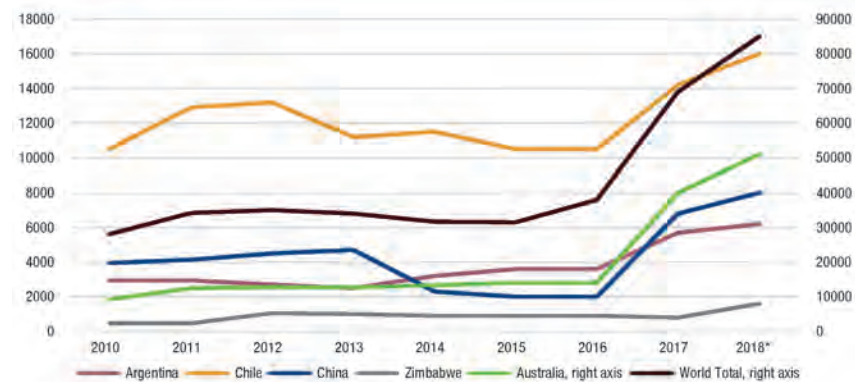
Source: USGS National Minerals Information Center (2018)

In 2018, the Democratic Republic of the Congo accounted for approximately 66 per cent of global production, with Russia, Cuba, Australia and the Philippines as the next largest producers, accounting together for 16 per cent of global production (see figure 10).

Lithium production comes mainly from rock and brine. Australia is the largest producer of lithium from rocks, while Chile and Argentina dominate

supplies originating from brines. From 2010 to 2018, global production of lithium increased from 28,100 tonnes in 2010 to 85,000 tonnes in 2018. Most of the increase occurred between 2015 to 2018 where production jumped by almost 170 per cent due in part to soaring demand for lithium compounds such as lithium hydroxide and lithium carbonate used in LIBs (see figure 11).

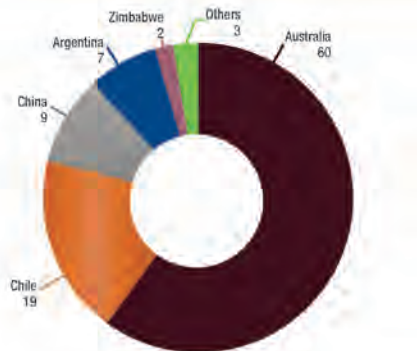
Figure 11. Lithium production, 2010 to 2018*
(Tons)



*Estimates for year 2018

Data source: USGS

Figure 12: Lithium production, 2014*
(Percentage)



*Estimates for year 2018

Source: USGS National Minerals Information Center (2018)

Latest available data shows that in 2018, five countries accounted for approximately 97 per cent of global lithium production: Australia, Chile, Argentina, China and Zimbabwe (see figure 12). Australia produced 60 per cent of lithium concentrate in the form of spodumene (rock); Chile produced 19 per cent from brine; Argentina produced 7.3 per cent from brine; China produced 9.4 per cent from rock and brine, and Zimbabwe produced 1.9 per cent from rock. Published production figures relating to lithium are often expressed as lithium carbonate equivalent LCE, a standard used to harmonize the different terminologies used to describe the quantities involved (eg. lithium content (Li), lithium oxide content (LiO₂), Lithium Carbonate content (Li₂CO₃)).¹⁵⁶ Lithium production has risen by over 200 per cent since 2010, and new rock and brine mines due to come on stream by 2022 in Australia, Argentina, Canada, Chile, United States and Mexico are expected to add to global capacity and double production.¹⁵⁷

Global manganese production increased by 29 per cent to 18,000 tons in 2018 from 3,900 tonnes in 2010 but recorded fluctuations on the way (see

figure 13). The iron and steel sector is the main consumer of manganese, but rising demand in the rechargeable batteries sector may also have contributed to rising production from 2016 to 2018. In 2018, five countries accounted for over three quarters of total global manganese production: South Africa (30 per cent), Australia (17 per cent), Gabon (13 per cent), China (10 per cent) and Brazil (7 per cent). The total global production increased by almost 15 per cent from 15,700 tons in 2016 to 18,000 tons in 2018 in response to high prices and robust demand.

In 2018, five countries accounted for over three quarters of total global manganese production: South Africa (30 per cent), Australia (17 per cent), Gabon (13 per cent), China (10 per cent) and Brazil (7 per cent).

Global production of natural graphite was relatively stable between 2011 and 2016 but dipped sharply by 22 per cent in 2017 to reach 897,000 tons largely due to environmental concerns in China, the largest producing country, which has resulted in closure of mines (see figure 15).¹⁵⁸ Plant inspections in China are ongoing and may lead to more closures if stringent pollution targets are not met.¹⁵⁹ The drastic drop in

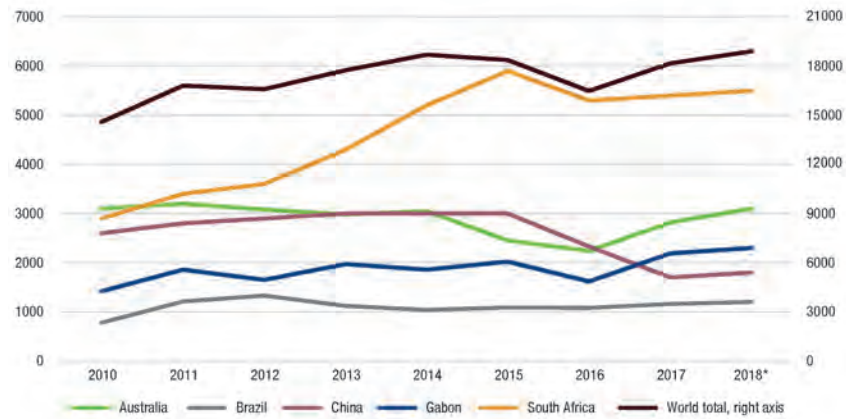
¹⁵⁶ British Geological Survey (2016), Lithium, June 2016

¹⁵⁷ <https://www.mining-technology.com/comment/global-lithium-production-double-next-four-years/>

¹⁵⁸ <https://roskill.com/news/graphite-chinese-flake-closures-to-continue-through-2018/>

¹⁵⁹ Ibid.

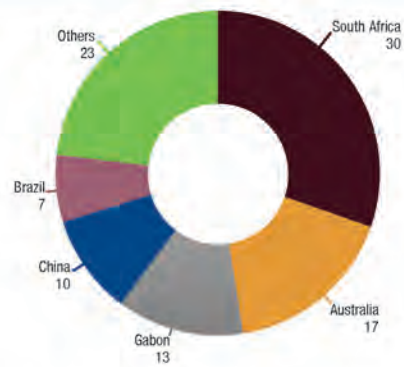
Figure 13. Global manganese production, 2010 to 2018*
(Tons)



*Estimates for year 2018

Source: USGS National Minerals Information Center (2018)

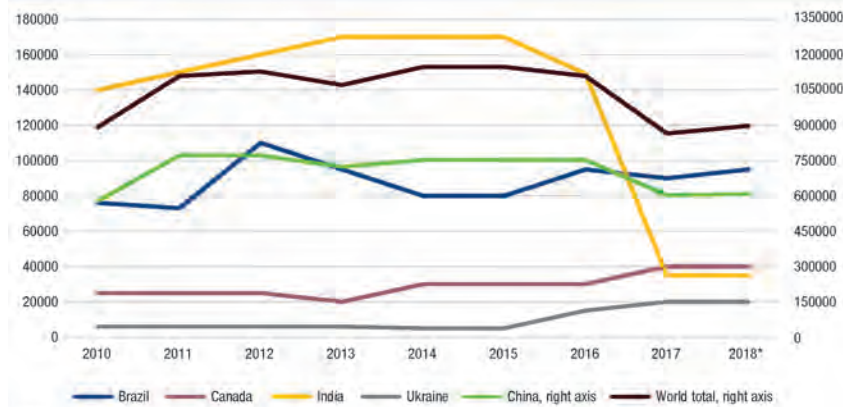
Figure 14. Manganese production, 2018*
(Percentage)



*Estimates for year 2018

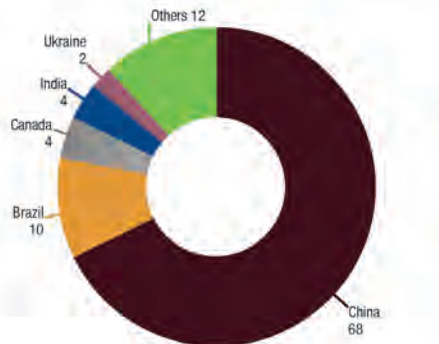
Source: USGS National Minerals Information Center (2018)

Figure 15. Natural graphite production, 2010 to 2018*
(Tons)



*Estimates for year 2018
Data source: USGS

Figure 16. Natural graphite production, 2018*
(Percentage)



*Estimates for year 2018
Source: USGS National Minerals Information Center (2018)

India's production from 2016 to 2017 is documented by different sources (USGS, British Geological Survey) even though no explanation is provided.

In 2018, China produced almost 70 per cent of the world's total graphite production of which approximately 44 per cent was amorphous graphite and about 56 per

cent was flake.¹⁶⁰ Other major producers were Brazil (10 per cent), Canada (4 per cent), India (4 per cent), Ukraine (2 per cent) (see figure 16).

¹⁶⁰ <https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/atoms/files/mcs-2019-graph.pdf>

4.2. DRIVERS OF PRODUCTION

The underlying factor influencing the increasing production of cobalt, lithium manganese and natural graphite is the rising demand for electric vehicles. The latter, in turn, is largely driven by policies that encourage the mitigation of greenhouse gases coupled with incentives for zero- and low-emissions vehicles, economic instruments that help bridge the cost gap between electric and conventional vehicles and support for the deployment of charging infrastructure (IEA, 2019).¹⁶¹ It is also being driven by policies that target banning future sales of internal combustion engines (e.g. in Norway and France) which are influencing the expansion of the EV market. Furthermore, technology advances are delivering more compact batteries that are able to cover longer distances, extra durability (the capacity to withstand many charge/discharge cycles without performance being affected) and substantial cost savings, thereby influencing EV adoption.¹⁶² This trend in policy actions, cost savings and higher efficiency batteries is contributing to escalating demand and supply of raw materials used in rechargeable batteries. Growth in consumer electronics, renewable based energy sources and energy storage systems are also expected to positively impact demand for rechargeable batteries¹⁶³ and in turn, drive growth in the extraction of raw materials for rechargeable batteries. The global rechargeable battery market size is expected to grow at a Compound Annual Growth Rate (CAGR) of around 7 per cent during 2019-2024.¹⁶⁴

Technology for raw materials production from deep ocean mineral deposits is still evolving but it has significant potential to expand supply to meet growth forecasts. It is driven by growing demand, potential supply disruptions and depletion of land-based resources. The International Seabed Authority (ISA), charged with regulating human activities on the deep-sea floor beyond the

continental shelf, has issued 27 contracts since its inception in 1982 for mineral exploration, encompassing a combined area of more than 1.4 million km², and continues to develop rules for commercial mining.¹⁶⁵ At the same time, some seabed mining operations are already taking place within continental shelf areas of nation states, generally at relatively shallow depths, while others are at advanced stages of planning. The first commercial enterprise expected to target mineral-rich sulfides in deep waters, at depths between 1,500 and 2,000m on the continental shelf of Papua New Guinea, is scheduled to begin in early 2019.¹⁶⁶

4.3. DEMAND FOR RAW MATERIALS USED IN LITHIUM ION BATTERIES

Demand for cobalt, lithium, natural graphite and manganese falls largely within two main categories: metallurgical and chemicals. The metallurgical category is dominated by the superalloys segment associated with, inter alia, power generation, hard metals and high-tech industries such as aerospace and defence.¹⁶⁷ The chemicals category is dominated by the rechargeable batteries segment.

As more automotive manufacturers are rolling out electric vehicles, the demand for raw materials used in rechargeable batteries is also rising. In recent years, the cobalt market expanded rapidly, with demand rising above 100,000 tonnes for the first time in 2017. In 2018, demand surged by 25 per cent from the previous year to 125,000 tonnes with about 9 per cent accounted for by the EV battery sector.¹⁶⁸ Some forecasts estimate that cobalt demand will reach 185,000 tonnes by 2023 with about 35 per cent accounting for the EV battery sector.¹⁶⁹ The rechargeable battery market is the fastest growing sector for cobalt demand largely due to expansion of electric mobility. The emergence of China as a major producer and consumer of refined cobalt since

¹⁶¹ IEA (2019). Global EV Outlook 2019, IEA, Paris. See <https://www.iea.org/publications/reports/globalevoutlook2019/>

¹⁶² <https://www.iea.org/topics/innovation/transport/gaps/advancing-technologies-and-reducing-battery-costs.html>

¹⁶³ IEA (2019). Global EV Outlook 2019, IEA, Paris; <https://www.iea.org/publications/reports/globalevoutlook2019/>

¹⁶⁴ <https://www.prnewswire.com/news-releases/world-rechargeable-battery-market-research-report-2019-2024---segmented-by-battery-type-capacity-application-and-region-300879849.html>

¹⁶⁵ Miller K.A., Thompson K.F., Johnston P., Santillo D. (2018). An overview of seabed mining including the current state of development, environmental impacts, and knowledge gaps, *frontiers in marine science*; <https://doi.org/10.3389/fmars.2017.00418>.

¹⁶⁶ *Ibid.*

¹⁶⁷ <https://www.globalenergymetals.com/cobalt/cobalt-demand/>

¹⁶⁸ http://publications.jrc.ec.europa.eu/repository/bitstream/JRC112285/jrc112285_cobalt.pdf

¹⁶⁹ <https://www.reuters.com/article/us-cobalt-prices-electric/cobalts-price-crash-bottoming-out-stocks-to-hinder-quick-rally-idUSKCN1Q11EP>

2007 has influenced the pattern of demand for mined cobalt (cobalt ores and concentrates). More cobalt is sourced from the largest producer, Democratic Republic of the Congo. Eight of the largest mines in the Democratic Republic of the Congo are Chinese owned, accounting for almost half of global cobalt supplies.¹⁷² Other major importers of cobalt ores and concentrates include Zambia, Morocco, Finland, Republic of Korea and Belgium.

Lithium has also benefitted from the growth of the global EV market and other battery applications such as portable electronic and energy storage applications. Demand growth for lithium has been significant since 2015, increasing by 13 per cent per year. Demand from rechargeable batteries exceeded 144,000 tons LCE in 2018 and is forecast to increase more than six-fold by 2028 if demand for EVs persists. A shift to higher nickel cathode materials in lithium-ion batteries is likely to accelerate demand for lithium hydroxide, as opposed to lithium carbonate, with battery-grade hydroxide demand forecast to grow by 35 per cent per year through to 2028, compared to 14 per cent per year for battery grade carbonate.¹⁷³

Demand for manganese is usually associated with steel making but manganese is also becoming an important component in the manufacture of LIBs. Since 2019, global output has increased largely due to iron and steel demand as well as the demand created in the battery market, as more automotive manufacturers are rolling out electric vehicles that require manganese and lithium compounds to create batteries.

Demand for natural graphite is rising slowly largely due to its cost advantages and its environmental friendliness compared to synthetic graphite. Natural graphite also forms the base for graphene, which promises to hold energy better than graphite anodes and also deliver faster charging times.¹⁷⁴ Although no commercial products of graphene are currently available, it is a potential substitute to the LIB graphite anode. Graphite for batteries currently accounts to only 5 per cent of global demand.¹⁷⁵

4.4. INTERNATIONAL TRADE¹⁷⁶

International trade in cobalt

Raw materials and intermediate products across the LIB value chain are traded internationally for further processing and use in downstream industries. The major upstream product categories of cobalt traded are ores and concentrates, oxides and hydroxides, as well as chlorides. In 2018, the top 5 importers of cobalt ores and concentrates in terms of value were China (US\$601.6m), Zambia (US\$198.4m), Morocco (US\$73.4m), Finland (US\$23m), and Republic of Korea (US\$19.9m) (figure 17).¹⁷⁶

The major trading partners by value of the top 5 importers of cobalt ores and concentrates are the Democratic Republic of the Congo, Zambia, Republic of Korea, Belgium, China, Austria and Congo (see table 4). Most of the ores and concentrates imported to China originated from the Democratic Republic of the Congo and were destined for domestic consumption in the rechargeable battery industry. Nearly all of Zambia's imports of cobalt ores and concentrates are also from the Democratic Republic of the Congo. The imported ores and concentrates are refined to produce metals at the Chambishi at the Chambishi Metals plant and then exported to other markets.¹⁷⁷

Based on available data, the top 5 exporters of cobalt ores and concentrates by value in 2018 were Germany (US\$2.6m), Belgium (US\$1.5m), Zambia (US\$1.3m), Ireland (US\$0.7m) and South Africa (US\$0.6m) (see figure 18). Mirroring import data of cobalt ores and concentrates from China suggests that the Democratic Republic of the Congo is also a major exporter but export data is not available.

¹⁷² <https://www.bloomberg.com/graphics/2018-china-cobalt/>

¹⁷³ <https://www.globenewswire.com/news-release/2019/07/17/1883820/0/en/Roskill-Lithium-prices-to-continue-slide-despite-forecast-supply-disruptions-and-strong-demand-growth.html>

¹⁷⁴ https://batteryuniversity.com/learn/article/bu_309_graphite

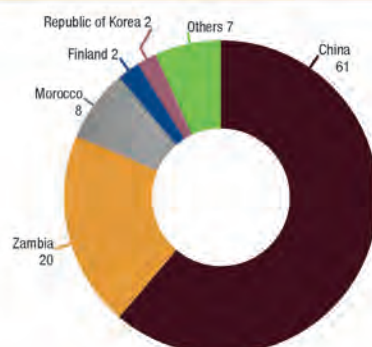
¹⁷⁵ Ibid

¹⁷⁶ The data used in this section is taken from United Nations Comtrade Database, SITC Rev. 4 and HS 17 when it is not reported under SITC.

¹⁷⁷ United Nations Comtrade Database, SITC Rev. 4

¹⁷⁸ The Chambishi plant is the only plant in Zambia producing cobalt metal and is one of the largest cobalt metal producers in the world. It is also unique as it is the only operation in the world which produces both LME registered cobalt and copper metal; <https://www.ergafrica.com/cobalt-copper-division/chambishi-metals/>

Figure 17. Top 5 Importers of cobalt ores and concentrates, 2018
(Percentage)



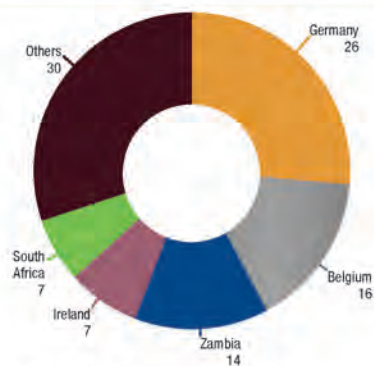
Source: United Nations Comtrade Database SITC Rev. 4, 28793

Table 4. Major trading partners of leading importers of cobalt ores and concentrates, 2018
(Millions of dollars)

Importers	Dem. Rep. of Congo	Zambia	Republic of Korea	Belgium	China	Austria	Congo
China	595.5	3.9	1.3	0.8	0	0	0
Zambia	198.3	0	0	0	0	0	0
Morocco	56.0	0.7	0	0	0	0	14.6
Finland	0	0	0	0	0	22.7	0
Rep of Korea	10.1	0.6	0	0	8.9	0	0

Data Source: United Nations Comtrade Database SITC Rev. 4, 28793

Figure 18. Top 5 exporters of cobalt ores and concentrates, 2018*
(Percentage)



* Data not available for Democratic Republic of the Congo

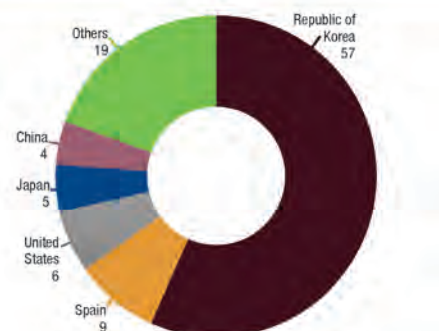
Source: United Nations Comtrade Database SITC Rev. 4 - 28793

Table 5. Major trading partners of leading exporters of cobalt ores and concentrates, 2018
(Millions of dollars)

Exporters	Belgium	Republic of Korea	China	Brazil	United Kingdom	United States
Germany	2.6	0	0	0	0	0
Belgium	0	0	0.9	0.5	0	0
Zambia	0	0.3	0.1	0	0	0.9
Ireland	0	0	0	0	0.7	0
South Africa	0	0	0.6	0	0	0

Source: UN Comtrade Database SITC Rev. 4 - 28793

Figure 19. Top 5 importers of cobalt oxides and hydroxides, 2018
(Percentage)



Source: United Nations Comtrade Database SITC Rev. 4 - 52255

Table 6. Major trading partners of leading importers of cobalt oxides and hydroxides, 2018
(Millions of dollars)

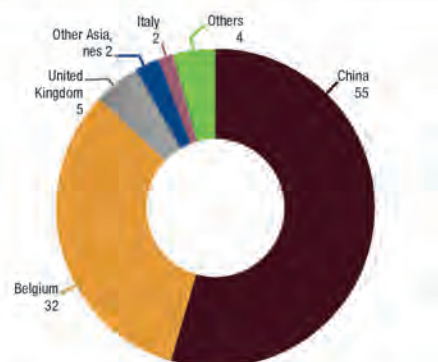
Importers	Finland	Japan	China	United Kingdom	Italy	Belgium	Other Asian countries
Republic of Korea	201.6	0.5	444.7	0	0	180	a
Spain	10.9	0	36.9	9.6	56.1	8.9	0
United States	15.0	0	18.9	20.3	0	35.7	0
Japan	0	0	16.4	0	0	24.4	9.9
China	48.0	2.6	5.8	0	0	0	0

Source: United Nations Comtrade Database SITC Rev. 4, 52255
a: Stands for amounts of less than 0.05 m

The major trading partners of the top 5 cobalt ores and concentrates exporters are Belgium, Republic of Korea, China, Brazil, United Kingdom and the United States (see table 5).

With respect to cobalt oxides and hydroxides, the top 5 importers are the Republic of Korea (US\$837.2 million), Spain (US\$125.4 million), United States (US\$92.5 million), Japan (US\$70 million), and China (US\$64.5 million).

Figure 20. Top 5 exporters of cobalt oxides and hydroxides, 2018
(Percentage)



Source: United Nations Comtrade Database SITC Rev. 4 - 52255

Table 7. Major trading partners of leading exporters of cobalt oxides and hydroxides, 2018
(Millions of dollars)

Exporters	Turkey	Thailand	China	Italy	Japan	Republic of Korea	Spain	United States
China	0.5	0	0	0	14.8	486.7	37	9.7
Belgium	3.6	0	10.7	13.1	26.2	167.6	57.9	35.2
United Kingdom	—	0	0.1	1.6	1.0	0.5	9.2	20.0
Other Asia, nes	0	8.9	7.2	0	9.7	a	0	0
Italy	6.2	0	0	0	0	0	4.7	0

Source: United Nations Comtrade Database SITC Rev. 4, 52255

a: Stands for amounts of less than 0.05 m

Trades in cobalt oxides and hydroxides were also largely driven by rechargeable battery demand. The Republic of Korea alone accounted for 57 per cent of total global imports in 2018 (see figure 19).

The major trading partners by value of the leading importers of cobalt oxides and hydroxides in 2018 are Finland, Japan, China, United Kingdom, Italy, Belgium and Other countries in Asia-not elsewhere specified (nes) (see table 6).

The major exporters of cobalt oxides and hydroxides in 2018 were China, Belgium, United Kingdom, Other Asia, nes (not elsewhere specified), and Italy. China and Belgium supplied 55 per cent and 32 per cent respectively of total global supplies by value (see figure 20).

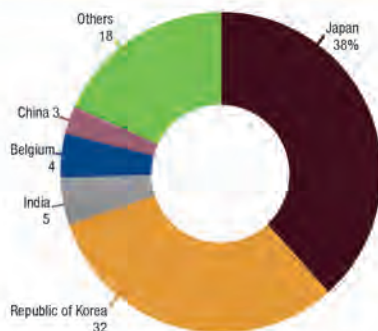
The major trading partners of the top leading exporters of cobalt oxides and hydroxides are Turkey, Thailand, China, Italy, Japan, Republic of Korea, Spain and the United States (see Table 7).

International trade in lithium

Lithium products traded globally are mainly in the form of oxides and hydroxides, lithium carbonates and lithium metal. The principal material used in rechargeable batteries is high purity lithium carbonate, but developments in battery technology is increasing demand for lithium hydroxide.¹⁷⁷ In 2018, the top five importers of Lithium oxide and

¹⁷⁷<https://www.argusmedia.com/en/news/1836977-lithium-hydroxide-demand-to-overtake-carbonate-aabc>

Figure 21. Top 5 importers of lithium oxides and hydroxides, 2018
(Percentage)



Source: UN Comtrade Database Harmonized System of Trade Codes HS(17) - 282520

Table 8. Major trading partners of leading importers of lithium oxides and hydroxides, 2018
(Millions of dollars)

Importers	China	United States	Chile	Russia Federation	Belgium
Japan	214.5	61.3	0.1	3.1	0
Republic of Korea	148.8	1.8	77	0.8	0
India	14.1	0.2	0	11.6	6.3
Belgium	1.5	7.3	7.0	14.8	0
China	5.1	3.8	6.2	3.8	0

Source: UN Comtrade Database; HS(17) - 282520

hydroxide were Japan (US\$280 million), Republic of Korea (US\$ 229 million), India (US\$35 million), Belgium (US\$32 million) and United States (US\$19 million) (figure 19). Japan and the Republic of Korea dominated imports of lithium oxide and hydroxide, accounting for approximately 70 per cent of the value of total global supplies (see figure 21).

The major trading partners by value of the leading importers of lithium oxides and hydroxides in 2018 were China, United States, Chile, Russia Federation and Belgium (see table 8).

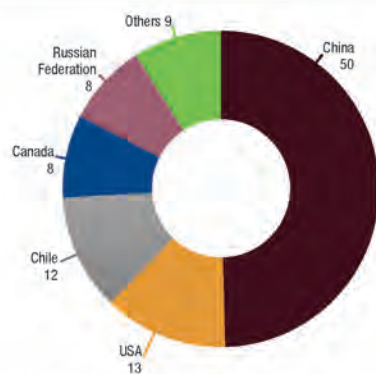
In 2018, the top 5 exporters of lithium oxide and hydroxide were China (US\$398m), United States (US\$102m), Chile (US\$95m), Canada (US\$68m)

and the Russian Federation (US\$67m). Together they accounted for over 90 per cent of the global total of lithium oxide and hydroxide traded (see figure 22).

The major trading partners of the leading exporters of lithium oxides and hydroxides in 2018 were Japan, Republic of Korea, Belgium, India, Germany and China (see table 9).

The top 5 importers of Lithium carbonate in 2018 are Republic of Korea (US\$458m), China (US\$362m), Japan (US\$317m), Belgium (US\$150m) and United States (US\$128m) (figure 23). The Republic of Korea, China and Japan accounted for almost 70 per cent of total global imports of lithium carbonate in 2018 (see figure 23).

Figure 22. Top 5 exporters of lithium oxide and hydroxide, 2018
(Percentage)



Source: UN Comtrade Database; HS(17) - 282520

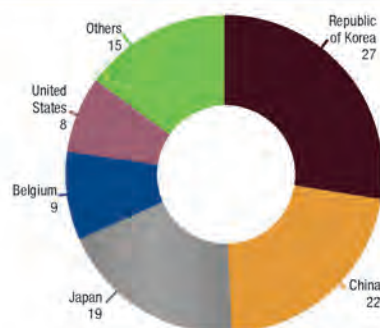
Table 9. Major trading partners of leading exporters of lithium oxides and hydroxides, 2018
(Millions of dollars)

Exporters:	Japan	Republic of Korea	Belgium	India	Germany	China
China	208.4	143.3	1.4	15.5	1.5	0
United States	62.9	1.1	6.5	0.2	10.0	3.8
Chile	0.1	69.8	6.7	0	0	4.6
Canada	0	0	0	0	0	68.1
Russian Federation	0.7	0.1	40	3.5	17.5	a

Source: UN Comtrade Database; HS(17) - 282520

a: Stands for amounts of less than 0.05 m

Figure 23. Top 5 importers of lithium carbonate, 2018
(Percentage)



Source: UN Comtrade Database HS(17) - 282520

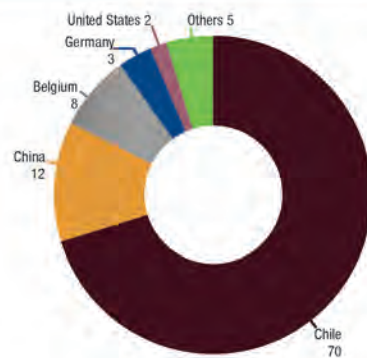
Table 10. Major trading partners of leading importers of lithium carbonate, 2018
(Millions of dollars)

Importers	Chile	China	Argentina	Japan	United States	Rep. of Korea	United Kingdom
Republic of Korea	346	72	38.5	0.8	0.2	0	0.5
China	159.8	0.1	188.8	5.2	0.5	3.4	3.6
Japan	224.5	31.7	55	0	2.4	0	0.7
Belgium	139.3	0.3	7.4	0.2	0.4	0	a
United States	63.3	9.3	52.8	0.3	0	1.7	0.5

Source: UN COMTRADE HS(17) - 283691

a: Stands for amounts of less than 0.05 m

Figure 24. Top 5 exporters of lithium carbonate, 2018
(Percentage)



Source: UN Comtrade Database HS(17) - 283691

Table 11. Major trading partners of leading exporters of lithium carbonate, 2018
(Millions of dollars)

Exporters	Republic of Korea	Japan	Russian Federation	Belgium	China	Germany	France	United States	United Kingdom
Chile	340.0	223.4	0	135.3	136	32.8	0	56.1	0
China	96.8	32.8	15.2	0.3	0	1.8	1.2	9.1	0
Belgium	a	~	31.1	0	~	20.3	21.3	~	15.6
Germany	~	1.7	2.1	3.3	~	0	4.8	0.1	4.0
United States	0.6	1.5	0	0.4	~	12.1	~	0	0

Source: UN Comtrade Database HS(17) - 283691

a: Stands for amounts of less than 0.05 m

The major trading partners of the leading importers of Lithium Carbonate in 2018 are Chile, China, Argentina, Japan, United States, Republic of Korea and United Kingdom (See table 10).

The top 5 exporters of Lithium carbonate in 2018 are Chile (US\$948m), China (US\$165m), Belgium (US\$104m), Germany (US\$46m), and the United States (US\$23m). Approximately 70 per cent of lithium carbonate exports originated from Chile in 2018. (see figure 24).

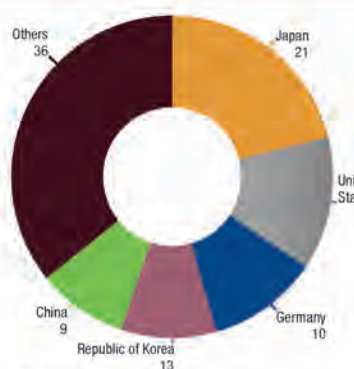
The major trading partners of the leading exporters of Lithium Carbonate in 2018 include the Republic of Korea, Japan, Russian Federation, Belgium, China, Germany, France, United States and the United Kingdom. China is a major importer and exporter of lithium carbonate (see table 11). Local battery makers purify the imports into battery grade lithium carbonate

for domestic use. However, surging supply of good quality lithium carbonate and competitive prices offered by China has contributed to expanding exports between China and its trading partners.

International trade in natural graphite

Natural graphite is used in steel making and metal transformations, but demand is growing for anode materials in LIBs. Natural graphite traded globally is in the form of powder or flakes. The top 5 importers of natural graphite in 2018 are Japan (US\$128m), Republic of Korea (US\$81m), United States (US\$68m), Germany (US\$58m) and China (US\$55m). The largest importer was Japan, accounting for about one fifth of total global imports (see figure 25).

Figure 25: Top 5 importers of Natural Graphite in powder or flakes, 2018
(Percentage)



Source: UN Comtrade Database HS(17) - 250410

Table 12: Major trading partners of leading importers of natural graphite, 2018
(Million of dollars)

Importers	Mozambique	Madagascar	Japan	China	Brazil	United States	Germany	Canada
Japan	0.1	0.2	0	112	0.9	2.6	0.5	0.8
Republic of Korea	0	0	1.0	68	0.1	5.5	5.8	0.2
USA	0.7	3.5	2.0	24	6.8	0	0.8	13.7
Germany	5.2	4.3	0.6	23.6	11.7	0.8	0	0.8
China	12.2	16.1	13.7	0.5	0.4	0.5	1.9	a

Source: UN Comtrade Database HS(17) - 250410
a: Stands for amounts of less than 0.05 m

The major trading partners by value of the leading importers of natural graphite in 2018 are Mozambique, Madagascar, Japan, China, Brazil, United States, Germany and Canada (see Table 12).

The top 5 exporters of natural graphite in the form of powder or flakes in 2018 are China (US\$314.9), Brazil (US\$31.2), Germany (US\$29.5), United States (US\$21.1) and Canada (US\$17). China dominated exports of natural graphite accounting for almost 65 per cent of total global graphite exports (see figure 26).

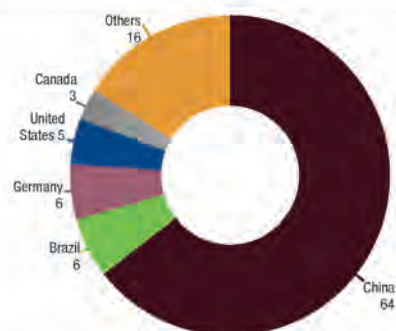
The major trading partners of the leading exporters of natural graphite are Germany, Belgium, Poland,

United States, India, United Kingdom, Canada, Iran (Islamic Republic of), Japan and the Republic of Korea (see table 13).

International trade in manganese

Manganese is widely traded in ores and concentrates as well as in manganese oxides and dioxides. The top 5 importers of manganese ores and concentrates are China (US\$6bn), India (US\$744m), Republic of Korea (US\$417m), Japan (US\$349m), and Norway (US\$330m). China dominated imports of manganese ores and concentrates accounting for 65 per cent of total global imports in 2018 (see figure 27).

Figure 26. Top 5 exporters of Natural Graphite, 2018
(Percentage)



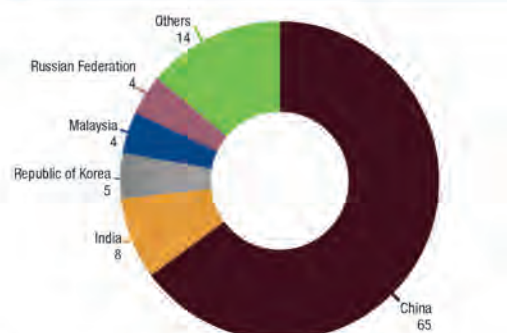
Source: UN Comtrade Database HS(17) - 250410

Table 13. Major trading partners of leading exporters of natural graphite, 2018
(Millions of dollars)

Exporters	Germany	Belgium	Poland	United States	India	Canada	Iran (Islamic Republic of)	Japan	Republic of Korea
China	15.6	2.8	6.7	29.5	19.0	1.5	3.8	111.5	92.9
Brazil	9.7	3.0	3.3	5.5	1.4	0.2	0	0.8	a
Germany	0	1.0	1.1	0.4	0	0	0	0.3	4.8
United States	1.1	0.6	0	0	0.8	3.1	0	2.5	3.7
Canada	1.0	—	0	13.8	—	0	0	0.8	0.2

Source: UN Comtrade Database HS(17) - 250410
a: Stands for amounts of less than 0.05 m

Figure 27. Top 5 Importers of manganese ores and concentrates, 2018
(Percentage)



Source: UN Comtrade – SITC Rev. 4 - 2877

Table 14. Major trading partners of leading importers of manganese ores and concentrates, 2018
(Million of dollars)

Importers	Australia	Brazil	Gabon	Ghana	Malaysia	South Africa	Côte d'Ivoire
China	1576.5	417.8	707.9	377.9	154.6	2312.9	134.8
India	87.0	50.5	57.3	0	0	376.1	44.8
Republic of Korea	222.6	2.7	10.4	0	0	177.9	0
Malaysia	151.4	a	6.3	0	0	204.4	0
Russian Federation	0	0	111.9	0	0	207.5	0

Source: Comtrade – SITC Rev. 4 - 2877

a: Stands for amounts of less than 0.05 m

The major trading partners of the leading importers of manganese ores and concentrates are Australia, Brazil, Gabon, Ghana, Malaysia South Africa and Côte d'Ivoire. (see table 14).

The top 5 exporters by value of manganese ores and concentrates in 2018 (including manganiferous iron ores and concentrates with a manganese content of 20 per cent or more calculated on dry weight) are South Africa (US\$3.5bn), Brazil (US\$406m), Ghana (US\$288m), Côte d'Ivoire (US\$103m) and Kazakhstan (US\$33m).¹⁷⁹ South Africa accounted for approximately three quarters of the total global exports of manganese ores and concentrates in 2018 (see figure 28).

The major trading partners of the leading exporters of manganese ores and concentrates by value in 2018 are

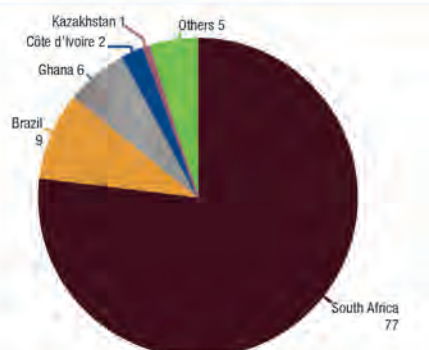
China, India, Japan, Uruguay, Ukraine, Australia and the Republic of Korea (see Table 15).

4.5. PRICE EVOLUTION OF RAW MATERIALS USED IN LITHIUM ION BATTERIES

In 2015, the prices of the raw materials used in LIBs began moving in an upward trajectory as they came under the influence of rising demand due in part to rising sales of EVs (see figure 29). Cobalt prices rose from US\$22,650 per ton in December 2015 to a peak of US\$92,000 per ton in May 2018 on the back of surging demand driven by a rapidly expanding market of electric vehicles and rechargeable batteries, as well as tightening supply. Other factors that contributed to the sharp rise were speculative buying, and low producer stocks. The surge in demand was largely

¹⁷⁹ <https://comtrade.un.org/data>

Figure 28. Top 5 exporters of manganese ores and concentrates, 2018
(Percentage)



Source: Comtrade – SITC Rev. 4 - 2877

Table 15. Major trading partners of leading exporters of manganese ores and concentrates, 2018
(Millions of dollars)

Exporters	China	India	Japan	Uruguay	Ukraine	Australia	Republic of Korea
South Africa	2045.3	285.7	226.9	0	54.6	28.8	134.1
Brazil	266.5	20.6	0	82.7	0	0	2.2
Ghana	237.7	0	0	0	50.4	0	0
Côte d'Ivoire	73.9	15.5	0	0	0	0	0

Data Source: Comtrade – SITC Rev. 4 - 2877

driven by Chinese consumption and EVs, but more broadly by the strength of high-tech industries such as aerospace for which cobalt is a non-substitutable material. The use of cobalt in gas turbines for power generation also played an important role in boosting demand.¹⁷⁹ From May 2018 to July 2019, cobalt prices declined by 71 per cent, largely due to slowing growth rates for the EV sector and abundant supply in the market triggered by increased mining activity as miners sought to capitalize on high prices.¹⁸⁰ Furthermore, slowing down industrial activity in China in 2018 contributed to a buildup of cobalt stocks and added to depressing the price.¹⁸¹ The collapse of cobalt prices was in line with other

Industrial metals such as aluminum, zinc, nickel and copper.¹⁸² The downwards trend in cobalt prices reversed in August 2019 after Glencore announced plans to transition its operation at the world's largest mine in the Democratic Republic of Congo (Mutanda) to temporary care and maintenance by the end of 2019, reflecting its reduced economic viability in the current market environment, primarily in response to low cobalt prices.¹⁸³

Prices of lithium metal also rose sharply from US\$62,498 per tonne in February 2015 to reach US\$145,973 per tonne in June 2018, as demand rose. But prices declined thereafter, reaching US\$90,996 per tonne in September 2019. The fall in lithium metal prices has been largely due to

¹⁷⁹<https://agmetalmine.com/2008/01/16/can-cobalt-maintain-its-meteoritic-rise-in-2008/>

¹⁸⁰<https://internationalbanker.com/brokerage/why-have-cobalt-prices-crashed/>

¹⁸¹<https://www.ft.com/content/98c7d136-ba8f-11dd-aecd-0000779fd18c>

¹⁸²<https://www.ft.com/content/98c7d136-ba8f-11dd-aecd-0000779fd18c>

¹⁸³<https://www.glencore.com/media-and-insights/news/2019-Half-Year-Report-release>

Figure 29. Battery raw materials prices: 2010 to 2019
(Dollars)



Source: Reuters Datastream

oversupply and a slowdown in EV growth.¹⁸⁴ The use of lithium metal in rechargeable batteries is limited because it poses safety risks.¹⁸⁵ Lithium carbonate, which is the most widely produced and consumed lithium compound, came under pressure largely due to slowing demand driven by global trade tensions, slowing growth and the scaling back of Chinese electric vehicle (EV) subsidies, oversupply in the market¹⁸⁶ caused by high levels of production and destocking by Chinese market players due to tightening in credit.¹⁸⁷ Prices fell from US\$14.35 per tonne in June 2018 to US\$9.55 per tonne in September 2019, largely due to oversupply in the market driven by high production growth rates and weak demand due to global trade tensions,

slowing growth and the scaling back of Chinese electric vehicle (EV) subsidies.¹⁸⁸

Manganese prices trended downwards prior to 2016, but growing demand driven by Chinese traders accumulating large volumes of ore,¹⁸⁹ and demand for steel products contributed to tightening the market and reversing the downward trend. Prices rose from US\$2.91 per tonne in January to US\$6.81 per tonne in December 2016, but the rising trend came under downward pressure from excess supply on the market and prices declined by almost 40 per cent in the first quarter of 2017 to US\$4.27. Prices rallied thereafter to US\$6.57 per tonne in September 2018 due in part to production cuts, before returning to a declining path in 2019. The influence of rising demand from rechargeable batteries on prices is not pronounced because most consumption is attributed to iron and steel manufacturing. Nonetheless, the impact of rising

¹⁸⁴<https://www.spglobal.com/en/research-insights/articles/lithium-supply-is-set-to-triple-by-2025-will-it-be-enough>

¹⁸⁵https://batteryuniversity.com/learn/article/experimental_rechargeable_batteries

¹⁸⁶<https://www.reuters.com/article/us-metals-lmeweek-lithium/stung-by-sliding-prices-lithium-industry-pares-back-expansions-idUSKBN1X71DG>

¹⁸⁷<https://www.reuters.com/article/us-lithium-chemicals-prices/solid-demand-to-underpin-lithium-as-price-slides-in-2018-idUSKCN1LX1PF>

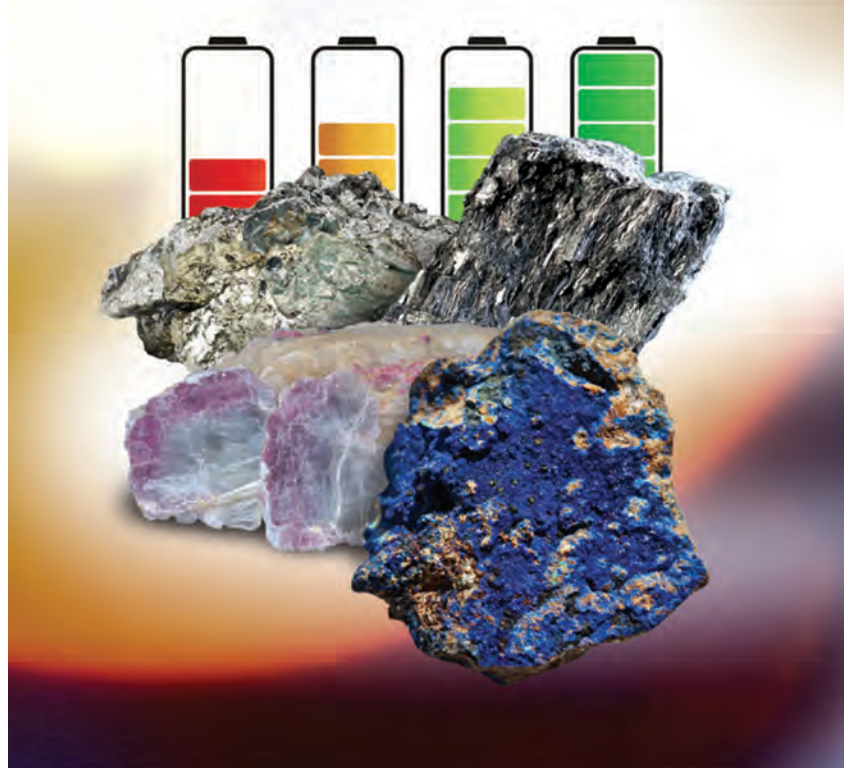
¹⁸⁸<https://www.reuters.com/article/us-metals-lmeweek-lithium/stung-by-sliding-prices-lithium-industry-pares-back-expansions-idUSKBN1X71DG>

¹⁸⁹<https://www.metalbulletin.com/Article/3839025/Year-end-manganese-ore-rally-unlikely-in-2018-sources-say.html>

demand for rechargeable batteries cannot be overlooked and it may well have a stronger impact as projections for EV production continue to be upbeat. Natural graphite prices also reversed a downward and volatile path in 2017, then followed an upward and volatile path in 2018 to reach a peak of US\$36,201 per tonne in January 2019. As it is for manganese, natural graphite's primary consumer remains the steel industry, while batteries only account for only about 13 per cent of total natural graphite demand.¹⁹⁰ Similar to manganese prices, the upward trend in natural graphite prices was largely driven by steel production. LIBs are only beginning to have an impact on demand and consumption. Prices for natural graphite are negotiated bilaterally between buyers and sellers because of the wide range of graphite qualities and purity (figure 29).

¹⁹⁰ <https://www2.argusmedia.com/-/media/Files/white-papers/getting-graphite-prices-right.ashx>

CHAPTER 5

SOCIAL AND ENVIRONMENTAL
CHALLENGES

5.1. CHALLENGES RELATED TO EXPLOITATION OF BATTERY METALS AND MINERALS

The exploitation of raw materials discussed in this report can have social and environmental implications. For example, most of the cobalt supplied to global markets originates from the Democratic Republic of the Congo, of which 20 per cent comes from artisanal mines where child labour and human rights issues have been identified. Up to 40,000 children are estimated to be working in extremely dangerous conditions, with inadequate safety equipment, for very little money in the mines in Southern Katanga.¹⁵¹ The children are exposed to multiple physical risks and psychological violations and abuse, only to earn a meagre income to support their families. The widespread use of child labour in cobalt mining can have global supply implications as supply of minerals extracted using child labour is becoming increasingly unacceptable to manufacturers of products derived from raw materials. The government of the Democratic Republic of the Congo recognizes the issue of child labour in mines and has adopted policies that promote free primary school education and forbids the use of children for dangerous work. It is expected that by 2025 child labour will be eliminated from the mines.

There are also several environmental challenges associated with the exploitation of the battery raw materials. For example, abandoned mine sites and tailings resulting from exploited cobalt-copper mines in DRC may contain sulphur minerals that undergo various reactions to generate sulfuric acid when exposed to air and water, allowing the dissolution of the metal elements. This behaviour known as Acid mine drainage (AMD) causes pollution or contamination of surface water by increasing the toxicity of water.¹⁵² It pollutes rivers and drinking water. Another environmental challenge at cobalt mines is associated with dust released from mechanical excavation, digging or breaking of rocks by hand, as in artisanal mining and pulverized rock. Dust from some of these cobalt mines may contain toxic metals including uranium which is linked to health impacts such as respiration and birth defects. The mines in Southern Congo hold vast deposits of cobalt, copper and uranium. In 2018, excessive traces of uranium found in cobalt caused Glencore exports from the Kamoto mine to stop so that an ion exchange

facility could be built to remove contaminants. Interim operational solutions were introduced in January 2019 so that production could resume at the mine.

The two forms of lithium mining (brine and rock extraction) also present social and environmental risks. For example, indigenous communities that have lived in the Andean region of Chile, Bolivia and Argentina (which holds more than half the world's supply of lithium beneath its salt flats) for centuries must contend with miners for access to communal land and water. The mining industry depends on a large amount of groundwater in one of the driest desert regions in the world to pump out brines from drilled wells. Some estimates show that approximately 1.9 million litres of water is needed to produce a tonne of lithium.¹⁵³ In Chile's Salar de Atacama, lithium and other mining activities consumed 65 per cent of the region's water. That is having a big impact on local farmers – who grow quinoa and herd llamas – in an area where some communities already must get water driven in from elsewhere.¹⁵⁴

As the mining sites overlap with nature conservation areas, mining activities have been responsible for ecosystem degradation and landscape damage. The process of forced migration of populations from villages and the abandonment of ancestral settlements has been precipitated by water scarcity and an increasingly erratic water supply.¹⁵⁵ Lithium rock mining also presents significant environmental risks. Breathing lithium dust or alkaline lithium compounds irritates respiratory tracts and prolonged exposure to lithium can cause fluid to build-up in the lungs, leading to pulmonary oedema. As demand for lithium increases and production is tapped from deeper rock mines and brines, the challenges of mitigating environmental risk will also increase.

The environmental impacts of graphite mining are very similar to those associated with cobalt mining. The use of explosives to open rocks to expose graphite can lead to the release of dust and fine particles into the atmosphere which can result in health issues when inhaled. The dust released in the production of natural graphite also has a significant impact on the communities that are located close to factory sites. In addition, soils may become contaminated as a result of graphite powder spillages and this may have harmful effects on fauna and flora.

¹⁵¹ https://www.unicef.org/childsurvival/drcongo_62627.html

¹⁵² <https://meetingorganizer.copernicus.org/EGU2018/EGU2018-45-1.pdf>

¹⁵³ <https://www.wired.co.uk/article/lithium-batteries-environment-impact>

¹⁵⁴ *Ibid*

¹⁵⁵ <https://iopscience.iop.org/article/10.1088/1748-9326/aae9b1/pdf>

CONCLUSION



Lithium, natural graphite and manganese have been highlighted in this report as critical raw materials for the manufacture of rechargeable batteries such as LIBs. These batteries can play a huge role in the transition to a low carbon energy system and they can also contribute to the implementation of the 2015 Paris Climate Change Agreement if the raw materials are sourced and produced in a sustainable manner. As demand for rechargeable batteries is forecast to grow rapidly due to EVs becoming more integrated into global transportation, the quantity of the raw materials used in manufacturing them is also expected to increase rapidly. This raises concerns about security of supplies, in particular for cobalt, lithium and natural graphite, given that production is concentrated in a few countries, and substitutability is low with the preferred battery chemistries of EV manufacturers. Over 60 per cent of cobalt is mined in the Democratic Republic of the Congo, while over 75 per cent of the global lithium production is mined in Australia and Chile, thus disruption to supply may lead to tighter markets, higher prices and increased costs of LIBs.

There are several options that can be considered to reduce vulnerabilities of consumers to supply shortfalls. For example, one option would be to facilitate research into battery technologies that depend less on critical raw materials and with potential to provide higher energy density. For example, silicon used as anode material instead of graphite Lithium-ion batteries has the potential to absorb more charge, which translates into longer battery life and smaller batteries.¹⁰⁸ Silicon in the form of silicates constitutes more than 25 per cent of the Earth's crust. However, there are challenges that still need to be overcome such as controlling the physical expansion of the silicon when charging.¹⁰⁹

Another option worth considering is employing strategies that allow for dynamic monitoring of the raw material cycles, from mining through processing, refining, and manufacturing to recycling. This would facilitate early detection of supply risks. It also would enable development of mitigation strategies at either company or national level. For example, actions could consist of building strategic stockpiles to alleviate shortages, improving forecasting, and instituting

better-informed decisions regarding investment to expand capacity to meet demand growth. Occasionally, disruption to supply occurs from environmental problems along production lines or the effect of production activities on the surrounding environment. Employing scientific and technologically advanced processes that prevent or control undesired environmental impacts may contribute to mitigating supply disruptions arising from the negative environmental impacts. For example, at Glencore's Katanga cobalt mine in DRC, an ion exchange system is being implemented to treat uranium material found in cobalt ores on a long-term basis.

Recycling of raw materials recovered from spent LIBs can make an important contribution to transforming economies of raw materials host countries into circular economies and alleviate security of supply concerns as demand increases due to a rapidly expanding EVs market. An improved rate of recycling of raw materials can contribute to lower costs of production and less impacts on the environment. It can also contribute to opening the door to new businesses. The task is to design products that allow for better recyclability; ensure better information is provided from manufacturers to recyclers; develop high-efficiency recycling standards linked to a certification scheme; and promote the recovery of critical raw materials from mining waste and landfills.¹¹⁰

Expanding infrastructure at existing mines or establishing new production lines to boost production can also mitigate supply risk.

Policymakers can have a direct influence on the options highlighted to mitigate risks to supplies by facilitating research into new battery chemistries that rely less on critical raw materials, adopting recycling policies and providing a conducive environment to attract investment to establish new mines or expand existing ones. Alleviating the vulnerabilities of consumers to supply disruptions while ensuring sustainable mining practices can contribute to mitigating GHG emissions. By fuelling the transition towards cleaner sources of energy, the production and use of the strategic metals discussed in this report can contribute to efforts to keep global temperature rise well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit temperature increase even further to 1.5 degrees Celsius as enshrined in the Paris Agreement.

¹⁰⁸ <https://www.sciencedaily.com/releases/2019/02/190221130302.htm>

¹⁰⁹ <https://www.sciencedaily.com/releases/2019/02/190221130302.htm>

¹¹⁰ https://ec.europa.eu/growth/content/turning-recycled-raw-materials-business-opportunities-0_fi

ANNEX - STATISTICAL DATA: EXPORTS, IMPORTS, PRODUCTION, RESERVES

Table 16. Leading importers of cobalt ores and concentrates by value.
(Dollars)

Country	2011	2012	2013	2014	2015	2016	2017	2018
China	850'265'891	370'298'756	338'152'198	393'143'105	447'564'240	214'618'918	342'770'008	601'630'320
Zambia	119'262'698	190'458'586	167'388'159	203'429'771	232'492'856	..	180'808'056	198'376'641
Finland	55'161'351	39'927'193	25'204'438	19'714'936	9'083'971	7'223'565	17'537'609	22'655'183
India	28'211'094	12'894'714	612'652	4'217'890	1'809'833	553'573	..	3'323
Morocco	..	..	..	..	378'440	146	10'311'141	73'396'300
Republic of Korea	19'217'981	6'836'847	3'191'913	6'468'403	6'733'090	362'079	1'512	19'915'346
South Africa	1'307'149	732'540	6'763'549	29'453'461	21'924'036	440'018	98'442	41'084
United States	17'467'858	6'291'916	815'051	401'049	1'093'128	519'907	665'180	668'919
Belgium	3'713'515	4'266'529	1'343'173	1'201'492	4'649'713	2'522'008	1'700'073	1'031'068
Spain	50'339	56'359	6'083	31'053	1'572'850	2'693'499	5'902'731	6'048'551
Luxembourg	490'570	273'847	1'621'823	1'983'857	1'234'721	2'251'381	7'969	876'360
China, Hong Kong SAR	1'911'455	4'754'695	..	..	838'630	..	111'742	783'876
Germany	2'490'057	916'551	189'773	714'605	30'154	1'370	1'678	12'732
United Kingdom	606'040	374'022	395'537	443'030	482'141	217'887	137'024	140'474
Australia	..	..	52'652	59'447	..	46'475	1'644'679	2'739
Malaysia	2'039	3'845	1'312'600	4'001	286'399	2'205	..	80'888
France	162'048	84'181	378'787	118'796	180'674	95'342	133'913	101'965
Sweden	..	591	..	..	..	..	196'798	971'095
Brazil	20'852	103'045	68'065	294	49'860	22'458	553'467	8'221
Italy	243'561	107'189	210'393	57'999	65'088	19'923	100'488	..

.. missing data

Source: UN Comtrade (SITC 28793 Rev. 4)

Table 17: Leading exporters of cobalt ores and concentrates by value
(Colliers)

Country	2011	2012	2013	2014	2015	2016	2017	2018
China	..	..	8'300	20	50	..	134'969	..
Zambia	36'557'850	1'925'787	767'051	45	25'443	..	45'251	1'336'407
South Africa	9'658'312	5'147'299	4'292'208	17'586'338	22'682'291	2'766'937	6'690'908	645'771
India	40'021	143'616	814'574	58	112	811	114	..
United States	1'357'210	428'459	1'035'561	1'847'252	98'923	93'857	1'471'044	561'794
Germany	32'149	78'687	..	2'135'406	964'256	913'035	4'827'416	2'571'118
Belgium	3'308'214	638'861	562'631	520'722	1'134'362	1'573'742	1'591'283	1'540'425
China, Hong Kong SAR	1'925'106	4'431'899	26'416	5'030	1'419'226	..	..	..
Ireland	68'876	919'305	972'017	1'101'850	1'130'290	1'009'358	871'749	723'828
Canada	117'428	..	..	5'406'626	188'853	37'654	33'139	..
United Kingdom	91'940	74'340	66'641	203'575	261'110	243'381	889'150	409'197
Italy	455'887	313'906	1'820	678	3'061	1'090	4'928	1'219
Netherlands	48'952	..	2'510	17'515	94	2'025'382	63'164	..
Brazil	..	236	891'893	135'244	..	..	302'179	255'446
Thailand	128'840	160'353	172'444	..	232	723	450'384	364'969

.. missing data

Source: UN Comtrade (SITC 28793 Rev. 4)

Table 18: Leading exporters of lithium oxide and Hydroxide by value (Dollars)

Country	2017	2018
China	237'940'317	398'037'853
United States	112'015'998	101'966'815
Chile	99'171'292	95'454'632
Russian Federation	62'751'826	67'276'467
Belgium	42'483'567	38'001'878
Canada	5'385'377	68'053'619
Netherlands	14'413'289	17'667'344
United Kingdom	3'922'287	4'750'848
India	2'072'645	2'566'532
France	2'117'133	2'467'298
United Arab Emirates	2'134'120	1'606'936
Japan	984'986	805'178
Slovenia	1'357'007	429'579
Switzerland	515'118	846'535
Spain	965'340	319'669
Singapore	..	964'734
Poland	495'393	270'255
Latvia	712'531	..
Turkey	163'303	546'903
China, Hong Kong SAR	683'317	796

.. missing data

Source: UN Comtrade (HS code 17 - 282520)

Table 19: Leading importers of lithium oxide and Hydroxide by value
(bilions)

Country	2017	2018
Japan	218'603'702	279'701'381
Republic of Korea	132'536'916	229'292'522
Belgium	38'689'575	32'246'548
India	35'928'954	34'747'879
United States	28'562'739	18'534'248
China	15'379'272	20'498'745
France	10'880'953	13'555'752
Canada	8'013'530	11'138'739
Thailand	11'035'617	6'807'673
United Kingdom	7'717'008	6'938'174
Other Asia, nes	9'945'444	4'051'262
Spain	5'870'154	7'725'644
United Arab Emirates	4'995'876	7'419'569
Turkey	5'657'267	4'877'051
Singapore	...	9'038'735
Slovenia	5'174'532	3'540'761
Sweden	3'943'114	4'642'451
South Africa	4'476'130	3'935'566
Netherlands	5'163'908	3'072'664
Russian Federation	2'114'239	4'382'582

... missing data

Source: UN Comtrade (HS code 17 - 260500)

Table 20: Leading Importers of Natural Graphite by value
(Dollars)

Country	2015	2016	2017	2018
Japan	82'423'111	81'631'043	89'728'795	127'916'382
USA	61'649'538	49'766'371	61'384'583	67'653'412
Germany	41'971'835	45'920'641	43'533'597	58'048'004
Republic of Korea	29'403'990	30'085'488	43'862'236	81'360'807
China	20'517'203	18'321'647	29'367'408	55'373'535
India	21'318'498	19'282'833	22'086'541	30'417'231
Austria	15'928'249	14'785'814	15'686'076	23'335'993
Poland	7'227'568	8'109'305	12'909'736	15'721'386
Turkey	8'302'168	8'824'929	11'330'838	11'839'649
Belgium	8'445'944	8'990'198	9'175'285	12'462'631
Netherlands	9'895'090	9'083'738	12'015'428	6'648'787
Malaysia	14'375'028	15'303'250	4'472'738	2'795'605
Other Asia, nes	6'510'876	7'967'696	10'197'591	10'021'027
Italy	7'657'256	6'930'810	7'899'748	8'535'326
United Kingdom	5'934'534	5'974'958	7'051'431	7'903'329
France	5'235'469	5'589'575	7'668'518	7'202'765
Spain	6'341'650	4'220'009	5'972'535	6'926'688
Russian Federation	8'995'061	4'702'622	4'854'494	4'814'038
Canada	4'798'044	5'526'762	7'319'020	5'489'831
Czechia	5'525'687	4'903'706	4'578'374	6'239'446

Source: UN Comtrade SITC Rev.4, 27822

Table 21: Leading Exporters of Natural Graphite by value
(Dollars)

Country	2015	2016	2017	2018
China	246'369'345	228'474'530	265'570'428	351'663'809
Brazil	29'406'397	28'270'006	29'590'823	32'926'686
Germany	24'849'271	26'716'892	27'138'619	30'398'611
United States	21'649'862	21'131'438	24'831'072	25'108'685
Canada	13'942'603	13'802'097	18'028'373	17'556'753
Japan	18'340'956	15'165'967	13'624'995	9'541'147
Netherlands	8'733'117	5'855'277	14'887'228	9'013'012
Madagascar	5'980'617	7'367'925	7'093'749	13'003'394
Austria	6'252'042	4'233'485	4'450'271	6'541'660
Ukraine	4'151'802	4'176'666	7'106'896	4'825'386
Mexico	4'952'617	4'005'520	5'615'335	5'645'631
Czechia	5'378'768	4'704'125	4'624'302	4'490'219
United Kingdom	4'604'951	4'690'090	4'374'787	4'206'134
Slovakia	12'204'731	358'271	1'098'054	1'532'133
Belgium	1'136'865	3'168'073	4'272'983	6'549'040
Sri Lanka	3'904'090	4'587'526	4'733'557	...
Zimbabwe	3'720'853	3'444'387	626'139	103'806
Russian Federation	2'292'253	1'105'044	1'431'724	2'530'812
Republic of Korea	1'122'674	1'281'918	1'150'018	1'446'380
Sweden	812'741	1'007'282	1'471'588	1'583'732

... missing data

Source: UN Comtrade SITC Rev.4, 27822

Table 22: Leading importers of manganese ores and concentrates by value (Dollars)

Country	2012	2013	2014	2015	2016	2017	2018
China	2'185'743'661	3'192'360'765	2'718'871'323	1'994'855'380	2'074'642'896	4'005'516'223	5'827'259'479
India	486'729'752	423'690'720	610'768'585	318'159'311	241'533'719	776'563'641	744'386'917
Republic of Korea	292'562'232	364'891'025	301'209'832	220'278'548	168'004'375	324'614'568	416'574'708
Japan	273'180'095	262'983'457	234'248'366	198'179'959	145'255'080	310'953'767	349'308'695
Norway	215'333'985	218'863'299	210'133'784	188'214'854	132'520'301	290'403'939	330'289'993
Ukraine	314'061'261	127'378'850	160'282'026	186'121'196	132'005'788	223'440'049	182'796'197
Russian Federation	137'642'140	172'953'958	141'794'127	103'539'862	107'680'885	212'932'870	364'822'332
United States	115'081'680	138'114'299	91'831'690	98'985'367	45'825'296	78'594'907	131'998'710
Spain	78'242'719	117'083'629	111'505'026	65'585'570	58'904'353	148'275'148	122'713'170
France	90'425'005	88'693'210	49'377'546	52'634'246	51'996'240	86'776'376	106'946'941
Malaysia	775'398	90'890	324'708	14'310'396	44'374'512	242'773'175	377'733'760
Georgia	51'564'749	51'291'453	42'692'621	24'188'617	11'845'549	18'024'373	31'237'966
Mexico	34'912'180	10'853'699	25'806'192	20'374'562	21'695'482	40'223'487	78'866'225
Saudi Arabia	31'676'840	30'415'771	43'717'711	13'173'075	12'105'348	42'370'412	40'463'083
Viet Nam	19'631'465	24'229'040	47'761'595	25'843'911	27'386'366	44'308'712	..
Australia	13'242'966	18'602'156	25'664'882	19'934'290	825'826	43'286'594	30'551'926
Slovakia	37'443'373	21'225'729	7'724'925	3'511'112	1'883'754	8'710'652	4'741'488
Germany	15'393'571	14'763'295	13'577'713	11'742'216	11'020'367	14'282'625	14'676'613
Belgium	13'013'018	13'112'535	12'589'842	11'370'469	11'339'481	14'734'516	18'269'473
Poland	2'260'168	2'717'284	16'783'087	16'945'707	12'046'298	26'799'018	26'921'579

.. missing data

Source: UN Comtrade SITC Rev.4, 2877

Table 23: Leading exporters of manganese ores and concentrates by value
(Dollars)

Country	2012	2013	2014	2015	2016	2017	2018
South Africa	1'199'259'481	1'567'249'267	1'643'561'400	1'128'108'357	1'401'222'018	2'527'612'962	3'507'438'383
Australia	1'245'713'484	1'489'629'154	1'287'859'750	792'386'799	524'321'442	..	..
Brazil	201'122'925	262'463'140	229'453'494	149'146'661	201'815'071	365'636'402	406'305'644
Ghana	104'310'245	134'562'488	..	..	100'662'700	155'381'119	288'074'846
United-Republic of Tanzania	83'526'388	181'082	59'567	..	25	52	5'690
Kazakhstan	79'797'730	103'003'452	80'053'982	20'091'092	20'869'168	49'139'570	33'436'417
Malaysia	45'720'478	55'189'758	40'773'875	28'900'040	34'097'909	23'192'848	23'070'582
Côte d'Ivoire	14'098'584	20'133'257	29'601'048	20'114'717	12'846'083	51'386'230	103'107'842
France	36'182'057	37'691'673	11'238'504	9'041'706	21'756'685	40'227'601	20'385'275
Zambia	15'137'856	27'871'268	13'766'576	907'752	..	31'270'750	26'967'243
Netherlands	18'229'920	22'661'834	21'267'818	11'301'620	3'677'033	15'037'083	14'784'138
China	23'931'584	9'503'096	2'181'729	4'800'537	7'096'775	7'991'302	12'363'905
Turkey	16'255'851	46'755'090	13'704'492	1'449'261	3'217'449	4'812'582	6'616'246
Mexico	3'592'455	11'065'299	15'269'908	12'045'462	21'733'254	16'160'946	9'975'085
Morocco	..	..	..	13'374'246	21'154'986	17'298'239	20'563'654
India	8'695'303	3'290'347	2'047'510	205'187	229'068	249'006	8'275'045
Indonesia	3'054'255	1'006'245	..	..	..	1'953'750	2'325'264
Ukraine	3'036'469	6'356'970	4'163'996	11'362'175	2'804'580	4'729'873	3'828'887
Georgia	3'764'951	2'592'788	2'569'999	3'162'932	19'853'406	3'219'160	9'826'900
Namibia	3'277'567	5'813'883	13'845'625	1'983'810	755'107	1'976'390	1'557'898

.. missing data

Source: UN Comtrade SITC Rev.4, 2877

Table 24. World cobalt reserves
(tons)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
United States	33'000	33'000	33'000	33'000	37'000	23'000	21'000	23'000	38'000
Australia	1'400'000	1'400'000	1'200'000	1'200'000	1'100'000	1'100'000	1'000'000	1'200'000	1'200'000
Brazil	89'000	87'000	89'000	89'000	85'000	78'000	..	..	..
Canada	150'000	130'000	140'000	140'000	250'000	240'000	270'000	250'000	250'000
China	80'000	80'000	80'000	80'000	80'000	80'000	80'000	..	80'000
Democratic Republic of the Congo	3'400'000	3'400'000	3'400'000	3'400'000	3'400'000	3'400'000	3'400'000	3'500'000	3'400'000
Cuba	500'000	500'000	500'000	500'000	500'000	500'000	500'000	500'000	500'000
Morocco	20'000	20'000	20'000	20'000	..	..	..	..	..
New Caledonia	370'000	370'000	370'000	370'000	200'000	200'000	130'000	..	..
Papua New Guinea	..	..	..	..	..	..	..	51'000	56'000
Philippines	..	..	..	..	270'000	250'000	290'000	280'000	280'000
Russia	250'000	250'000	250'000	250'000	250'000	250'000	250'000	250'000	250'000
South Africa	..	..	..	..	32'000	31'000	29'000	29'000	24'000
Zambia	270'000	270'000	270'000	270'000	270'000	270'000	270'000	270'000	..
Other Countries	740'000	990'000	1'100'000	1'100'000	750'000	610'000	690'000	560'000	640'000

.. missing data

Source: USGS

Table 25. Lithium reserves
(Tons of Lithium content)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
United States	38'000	38'000	38'000	38'000	38'000	38'000	38'000	35'000	35'000
Argentina	850'000	850'000	850'000	850'000	850'000	2'000'000	2'000'000	2'000'000	2'000'000
Australia	580'000	970'000	1'000'000	1'000'000	1'500'000	1'500'000	1'800'000	2'700'000	2'700'000
Brazil	64'000	64'000	46'000	46'000	48'000	48'000	48'000	48'000	54'000
Chile	7'500'000	7'500'000	7'500'000	7'500'000	7'500'000	7'500'000	7'500'000	7'500'000	8'000'000
China	3'500'000	3'500'000	3'500'000	3'500'000	3'500'000	3'200'000	3'200'000	3'200'000	1'000'000
Portugal	10'000	10'000	10'000	60'000	60'000	60'000	60'000	60'000	60'000
Zimbabwe	23'000	23'000	23'000	23'000	23'000	23'000	23'000	23'000	70'000

Source: USGS

Table 26: Graphite reserves
(Tons)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Brazil	360'000	360'000	360'000	58'000'000	40'000'000	72'000'000	72'000'000	70'000'000	72'000'000
China	55'000'000	55'000'000	55'000'000	55'000'000	55'000'000	55'000'000	55'000'000	55'000'000	73'000'000
India	5'200'000	11'000'000	11'000'000	11'000'000	11'000'000	8'000'000	8'000'000	8'000'000	8'000'000
Madagascar	940'000	940'000	940'000	940'000	940'000	940'000	1'600'000	1'600'000	1'600'000
Mexico	3'100'000	3'100'000	3'100'000	3'100'000	3'100'000	3'100'000	3'100'000	3'100'000	3'100'000
Mozambique	..	..	..	..	..	..	13'000'000	17'000'000	17'000'000
Tanzania	..	..	..	..	..	..	..	17'000'000	17'000'000
Turkey	..	..	..	..	..	90'000'000	90'000'000	90'000'000	90'000'000
Vietnam	..	..	..	..	..	..	..	..	7'600'000

.. missing data

Source: USGS

Table 27: Manganese reserves
(Thousands of tons)

	2010	2011	2012	2013	2014	2015	2016	2017	2018
Australia	93'000	93'000	97'000	97'000	97'000	91'000	91'000	94'000	99'000
Brazil	110'000	110'000	110'000	54'000	54'000	50'000	116'000	120'000	110'000
China	44'000	44'000	44'000	44'000	44'000	44'000	43'000	48'000	54'000
Gabon	52'000	21'000	27'000	24'000	24'000	22'000	22'000	20'000	65'000
Ghana	..	..	..	..	..	13'000	12'000	13'000	13'000
India	56'000	56'000	49'000	49'000	52'000	52'000	52'000	34'000	33'000
Kazakhstan, concentrate	..	..	5'000	5'000	5'000	5'000	5'000	5'000	5'000
Mexico	4'000	4'000	5'000	5'000	5'000	5'000	5'000	5'000	5'000
South Africa	120'000	150'000	150'000	150'000	150'000	200'000	200'000	200'000	230'000
Ukraine, concentrate	140'000	140'000	140'000	140'000	140'000	140'000	140'000	140'000	140'000

.. missing data

Source: USGS

Table 28. World Lithium mine production
(tons of Lithium content)

	2010	2011	2012	2013	2014	2015	2016	2017	2018*
Argentina	2'950	2'950	2'700	2'500	3'200	3'600	5'800	5'700	6'200
Australia	9'260	12'500	12'800	12'700	13'300	14'100	14'000	40'000	51'000
Brazil	160	320	150	400	160	200	200	200	600
Chile	10'510	12'900	13'200	11'200	11'500	10'500	14'300	14'200	16'000
China	3'950	4'140	4'500	4'700	2'300	2'000	2'300	6'800	8'000
Portugal	800	820	560	570	300	200	400	800	800
Zimbabwe	470	470	1'060	1'000	900	900	1'000	800	1'600

* Estimates for 2018

Source: USGS

Table 29. World Manganese mine production
(Thousands of tons)

	2010	2011	2012	2013	2014	2015	2016	2017	2018*
Australia	3'100	3'200	3'080	2'980	3'050	2'450	2'240	2'820	3'100
Brazil	780	1'210	1'330	1'120	1'040	1'090	1'080	1'160	1'200
China	2'600	2'800	2'900	3'000	3'000	3'000	2'330	1'700	1'800
Gabon	1'420	1'860	1'650	1'970	1'860	2'020	1'620	2'190	2'300
Ghana	..	..	..	533	418	416	553	810	850
India	1'000	895	800	920	945	900	745	734	770
Kazakhstan, concentrate	..	390	380	390	385	222	212	168	170
Malaysia	..	225	429	430	378	201	266	478	510
Mexico	175	171	188	212	236	220	206	212	220
South Africa	2'900	3'400	3'600	4'300	5'200	5'900	5'300	5'400	5'500
Ukraine, concentrate	540	330	416	300	422	410	425	735	740
Other countries	1'340	1'740	920	597	740	678	681	898	940

.. missing data

* Estimates for 2018

Source: USGS

Table 30: World Cobalt mine production
(Tons)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018*
United States	..	..	..	..	..	120	760	690	640	500
Australia	4'600	3'850	3'900	5'880	6'400	5'980	6'000	5'500	5'030	4'700
Brazil	1'200	1'600	3'500	3'900	3'000	2'600	..	..	..	..
Canada	4'100	4'600	7'100	6'630	6'920	6'570	6'900	4'250	3'800	3'800
China	6'000	6'500	6'800	7'000	7'200	7'200	7'700	..	3'100	3'100
Democratic Republic of the Congo	35'500	47'400	60'000	51'000	54'000	63'000	6'3000	64'000	73'000	90'000
Cuba	3'500	3'600	4'000	4'900	4'200	3'700	4'300	4'200	5'000	4'900
Madagascar	..	..	..	..	..	3'100	3'700	3'800	3'500	3'500
New Caledonia	1'000	1'000	3'200	2'620	3'190	4'040	3'680	3'300	..	..
Morocco	1'600	2'200	2'200	1'800	..	..	..	..	2'200	2'300
Papua New Guinea	..	..	..	..	..	..	..	..	3'310	3'200
Philippines	..	..	..	..	3'000	4'600	4'300	3'500	4'600	4'600
Russia	6'100	6'200	6'300	6'300	6'300	6'300	6'200	6'200	5'900	5'900
South Africa	..	..	..	..	3000	3000	3'000	3'000	2'300	2'200
Zambia	5'000	5'700	5'400	4'200	5'200	5'500	4'600	4'600	..	..
Other countries	3'700	6'800	6'700	8'820	8'000	7'080	11'600	8'300	7'650	7'000

.. missing data

Source: USGS

Table 31. World Graphite mine production
(Tons)

	2010	2011	2012	2013	2014	2015	2016	2017	2018*
Brazil	76'000	73'000	110'000	95'000	80'000	80'000	95'000	90'000	95'000
Canada	25'000	25'000	25'000	20'000	30'000	30'000	30'000	40'000	40'000
China	600'000	800'000	800'000	750'000	780'000	780'000	780'000	625'000	630'000
India	140'000	150'000	160'000	170'000	170'000	170'000	149'000	35'000	35'000
Korea, North	30'000	30'000	30'000	30'000	30'000	30'000	6'000	5'500	6'000
Madagascar	5'000	4'000	4'000	4'000	5'000	5'000	8'000	9'000	9'000
Mexico	7'000	7'000	8'000	7'000	22'000	22'000	4'000	9'000	9'000
Mozambique	..	..	..	..	..	..	..	300	20'000
Norway	2'000	2'000	2'000	2'000	8'000	8'000	8'000	15'500	16'000
Pakistan	..	..	..	..	..	..	14'000	14'000	14'000
Russia	..	14'000	14'000	14'000	15'000	15'000	19'000	17'000	17'000
Sri Lanka	8'000	4'000	4'000	4'000	4'000	4'000	4'000	3'500	4'000
Turkey	..	10'000	5'000	5'000	29'000	32'000	4'000	2'300	2'000
Ukraine	6'000	6'000	6'000	6'000	5'000	5'000	15'000	20'000	20'000
Vietnam	..	..	..	..	..	..	5'000	5'000	5'000
Zimbabwe	..	..	6'000	4'000	7'000	7'000	6'000	1'580	2'000
Other countries	6'000	7'000	2'000	1'000	1'000	..	2'000	4'120	6'200

.. missing data

*Estimates for 2018

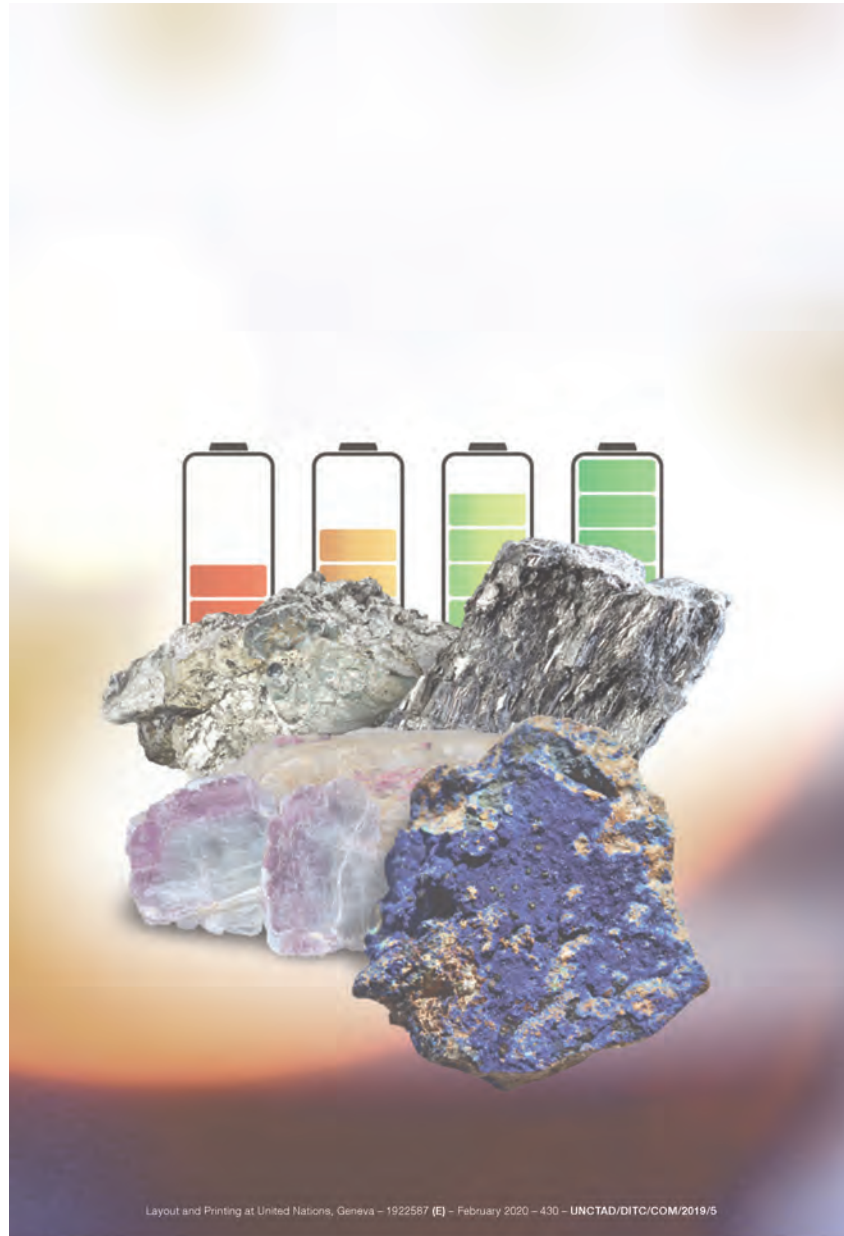
Source: USGS

COMMODITIES AT A GLANCE

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- N° 2: Special issue on cotton in Africa
- N° 3: Special issue on energy
- N° 4: Special issue on food security
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- N° 6: Special issue on gold
- N° 7: Édition spéciale sur l'or (in French)
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- N° 9: Special issue on shale gas
- N° 10: Special issue on coffee in East Africa
- N° 11: Édition spéciale sur le café en Afrique de l'Ouest et du Centre (in French)
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The CHAIRMAN. Thank you, sir.
And now we have Mr. Satterthwaite.

**STATEMENT OF TONY SATTERTHWAITE,
VICE CHAIRMAN, CUMMINS INC.**

Mr. SATTERTHWAITE. Chairman Manchin, Ranking Member Barasso, thank you for inviting me to participate in today's hearing. My name is Tony Satterthwaite and I am Vice Chairman of Cummins. Since our founding, more than 100 years ago in Columbus, Indiana, technological innovation has been at the core of what we do. Increasingly, customers require not just dependable power at a fair price, but power that results in fewer greenhouse gases and fewer criteria pollutants that contribute to climate change and poor air quality. Cummins embraces environmental standards and uses our innovation to grow our business, create American jobs, and improve communities, taking a leadership role in our industry with our positions on emissions and sustainability. Today, I will discuss three things: our path to zero emissions, the importance of government support for innovation in infrastructure, and the technologies where innovation is crucial.

Our customers need the right vehicles and equipment to do their work today and in the future. The solutions must be reliable, efficient, operationally flexible, and sustainable to meet evolving demands. They also need these solutions to be affordable so they can do the work that helps power the economy, make their payroll, and continue to create jobs. Cummins has embarked on a strategy for reducing the greenhouse gas impact of our products. Our path to zero emissions will get us the biggest reduction in emissions in the fastest way for the lowest cost. Innovation is key to the path and the path is almost as important as the destination.

We must capture all the benefits we can from all technologies, including internal combustion, natural gas and alternate fuels, hybrid, range-extended electric vehicle, battery electric vehicle, and hydrogen fuel cell, as we work toward the goal of zero emissions. Switching to renewable diesel and other low-carbon fuels can further build upon these benefits and provide real carbon reductions. Innovation in internal combustion engines with mild hybridization and low-carbon fuels can reduce emissions to improve air quality today. Natural gas engines also offer performance and reliability while delivering near-zero emissions. And as these technologies improve, range-extended electric vehicles can make further improvement in well-to-wheels CO₂ emissions while offering customers flexibility and resilience. For zero-tailpipe emissions, battery-electric and hydrogen fuel cell powered vehicles will work in tandem, with batteries well-suited for light-duty, last-mile delivery and urban applications, and hydrogen fuel cells as a power-dense option for applications such as long-haul trucking, rail, mining, and marine.

The path to zero emissions for commercial vehicles should also promote innovation for infrastructure through robust funding for research, development, demonstration, and deployment of decarbonized hydrogen production and distribution; development and distribution of low and net zero carbon fuels to maximize the use of existing infrastructure; and decarbonizing the grid and creating

a fast-charging network for trucks. If U.S. transportation is to get to zero emissions in a way that is cost-effective, timely, and promotes U.S. jobs and manufacturing, significant support is needed from DOE, national labs, and other research institutions to innovate an infrastructure development and deployment. Continued innovation in internal combustion including natural gas and other alternate fuels, hybridization, batteries, fuel cells, and hydrogen technology are critical for the U.S. to meet our climate, air quality, and jobs goals. Hydrogen technologies are particularly right for government and industry investment in innovation. It is one of the most effective enabling technologies for broad and deep decarbonization of hard-to-abate sectors like rail. The DOE has many programs in this space and the programs we have participated in have had a real impact on reducing criteria pollutants and greenhouse gases in the U.S.

I would like to close by saying that Cummins is leading the way by investing and innovating in a broad portfolio of power so our customers can have the right solution to get their jobs done today and tomorrow. Government-supported innovation is needed to meet our global energy and environmental challenges and to maintain American competitiveness and jobs. Enacting policies that ensure that this country and every community in it has the proven technology necessary to serve the economy while meeting air quality and climate goals on the path to net zero emissions is critical.

Thank you for this opportunity to share this with you today. I look forward to your questions.

[The prepared statement of Mr. Satterthwaite follows:]

Tony Satterthwaite
Vice Chairman
Cummins Inc.

Chairman Manchin, Ranking Member Barrasso, thank you for inviting me here today and for your interest in transportation technology innovation. My name is Tony Satterthwaite, and I am Vice Chairman of Cummins Inc. Since our founding more than 100 years ago, technological innovation has been at the core of what we do. I believe that innovating to sustain a vibrant economy while preserving the planet for generations to come is the challenge of our time. Increasingly, customers are demanding not just dependable power at a fair price, but power that emits fewer greenhouse gases and fewer criteria pollutants that contribute to climate change and adversely impact air quality. My role at Cummins is to guide our business to help us meet this growing demand. The challenges before us require investment and collaboration among public and private entities to ensure the solutions are developed and implemented quickly, effectively and affordably. Today, I'd like to tell you how we got here, and how we're innovating to power a more prosperous world including putting forth our own plan for a path to a zero emissions future.

Cummins Inc.

Cummins Inc. was founded and is headquartered in Columbus, Indiana. We are 102 years old and have grown from a small diesel engine company to the largest independent producer of power solutions in the world, with a legacy of constant technological innovation.

Cummins advanced diesel and natural gas engines, hybrid, range extended electric vehicles (REEV), battery electric and hydrogen fuel cell platforms are in a wide range of applications including small pickup trucks, delivery trucks and tractor-trailers that move goods across the country, as well as transit and school buses. You will also find our products in refuse trucks, mining equipment, oil-and gas operations, passenger trains and tugboats. We produce power generation equipment in a wide range of applications from mobile power systems that support our military to critical backup power systems that keep data centers and hospitals up and running 24 hours a day, seven days a week. Our products are critical to keeping the nation's supplies moving and hospitals running. National landmarks that many Americans see every day, like Wrigley Field and the Statue of Liberty, also rely on Cummins for their backup power needs. We also manufacture electrolyzers that produce hydrogen, including at the largest green hydrogen facility in the country in Douglas County, WA.

Globally, we have nearly 60,000 employees and operate in over 190 countries throughout the world. In the United States, we employ over 20,000 people and have manufacturing facilities in Indiana, Minnesota, New York, North Carolina, South Carolina, Tennessee, Wisconsin, California and Oregon. In addition to our manufacturing operations in the United States, we also own all our distributor branches with over 11,000 employees and locations in almost every state.

The technological innovations of our product line and greening of the grid are enabling our products to be an integral part of addressing climate change. Because we serve many markets and applications that are critical to a functioning global economy, we have a keen understanding

of the power they need to get the job done. These relationships with our customers are one of the reasons we believe our path to zero emissions is so credible.

Cummins has long acknowledged that our company is only as strong as the health of our communities. Cummins embraces tough environmental standards and uses our technological expertise and innovation to grow our business, create American jobs and improve communities, taking a leadership role in our industry for our positions on emissions and sustainability.

Cummins always has championed innovation. In 2019, for example, Cummins' technical staff received more than 250 global patents for a fourth straight year. These patents represent our commitment to continual innovation and collaboration with stakeholders in government, academia and industry. They also allow us to export our groundbreaking technology globally, increasing U.S. competitiveness, technical leadership and American jobs.

Powering our customers today and in the future

The future of power requires multi-faceted innovation. Our customers need the right vehicles and equipment to do their work today and in the future. The integrated power solutions must be reliable, efficient, flexible and sustainable to meet the evolving demands for powering our communities and the infrastructure and equipment that shape our world. They also must comply with stringent emission regulations; help address climate change and be part of the solution for the energy and environmental challenges facing the planet. And just as importantly, they need these solutions to be affordable, so our customers in trucking, construction, delivery, rail and inland waterway transportation, can do the work that helps power the economy, make their payroll and continue to create jobs in our communities.

To deliver on our promise of powering a more prosperous world, both economic growth and environmental sustainability must be achieved. Our strategy for reducing the greenhouse gas impact of our products is to continue an intense focus on research and development to provide substitute technologies in applications where they work well, and to reduce greenhouse gases by improving the fuel efficiency of products and fuels in applications without substitute technologies. Switching to renewable diesel and other low carbon fuels can further build upon those benefits.

We commend the Committee's commitment to facilitate the energy transition of the U.S. economy through innovation and engaging our feedback as a stakeholder. Cummins has committed, through our PLANET 2050 initiative, to emitting net-zero carbon in all our facilities, operations and products in use globally by 2050. Doing our part to address climate change and air emissions is part of our company's mission.

The path to zero emissions

To achieve this ambitious goal, Cummins supports an innovation-focused path to zero emissions for commercial vehicles. These include innovations in high efficiency internal combustion engine (ICE) technologies, utilizing low carbon fuels, hybridization, REEV, and ultimately hydrogen fuel cell (FCEV) and battery electric vehicles (BEV) with zero tank-to-wheel emissions. Complementary measures to decarbonize the grid and build out charging and fueling infrastructure are also critical to this path.

In the next 10 years, innovation in high efficiency ICE with mild hybridization and low carbon fuels can immediately reduce both CO₂ and criteria emissions to improve air quality for disproportionately impacted communities today. Natural gas engines offer performance and reliability while offering near-zero emissions. Our natural gas spark-ignited combustion engines provide emissions lower than current EPA standards – 90% below on particulate matter and nitrogen oxides and 16% below on GHGs. They can achieve sub-zero emissions when using renewable natural gas (RNG). Natural gas engines are also the most mature, proven, and least disruptive alternative power technology available today.

Natural gas engines fit current transportation, people and goods movement models; are powered with abundant, low-priced domestic fuel; don't require radical changes in vehicle technology, transportation or support infrastructure; contribute to energy independence initiatives and deliver a reduction in carbon intensity. Continued innovation in spark-ignited natural gas engines can further improve on these benefits. As these technologies improve and renewable electricity and alternative fuel infrastructure come online at scale, REEVs can make a dramatic improvement in well-to-wheels carbon intensity while offering customers flexibility and resilience to improve on these benefits. Further research on ICE range extended solutions can take full advantage of low carbon fuels and significantly leverage the available infrastructure that supports the market today.

Advanced internal combustion with low carbon fuels, hybrids and REEVs can and should be deployed in the interim to significantly reduce emissions. For zero- tailpipe emissions, battery-electric and hydrogen fuel cell powered vehicles will work in tandem, with batteries well-suited for light-duty, last-mile delivery and urban applications, and hydrogen fuel cells as a power-dense option for applications like long-haul trucking, rail and mining. We should also consider the impact of upgrading large installed fleets of old technologies to current state of the art power options. The fast upgrade of America's extensive freight locomotive, fracking and drilling equipment to the latest technology can make a significant impact to reduce emissions today.

Robust funding for innovation

The path to zero emissions for commercial vehicles should promote innovation for infrastructure through robust funding for research, development, demonstration and deployment of decarbonized hydrogen production and distribution; development and distribution low and net zero carbon liquid and gaseous fuels to maximize the utilization of existing fuel infrastructure; and deployment of a decarbonized electrical grid and implementation of fast charging networks. This is critical to success on our path to zero emissions. If the U.S. is to achieve this path to zero in a way that is cost effective, timely and promotes U.S. jobs and manufacturing, significant public support is needed from DOE, our national labs and other research institutions to innovate in infrastructure, development and deployment.

We were encouraged by the Department of Energy's (DOE) recent Notice of Intent announcement on a variety of research, development, demonstration and deployment (RDD&D) programs focused on trucks, and the scope of the RDD&D will not be exclusive to one fuel source or vehicle type. By improving energy efficiency and reducing emissions across the entire transportation sector, DOE can help ensure that the benefits of this work are equitably distributed to all Americans.

Hydrogen should be an important area of investment

Hydrogen technologies are also ripe for government and industry investment in innovation. Cummins has invested significantly in the entire hydrogen value chain because it has shown to be one of the most effective enabling technologies for broad and deep decarbonization of hard-to-abate sectors where Cummins' products operate. Europe and East Asia have an early lead in this space, having committed hundreds of billions of dollars respectively to promote decarbonized hydrogen production and fuel cell equipment deployment. The recently published [U.S. Hydrogen Roadmap](#) provides a robust analysis of areas of needed investment for the U.S. to be a technology leader. Congress can increase the U.S.' international competitiveness by calling for a U.S. national hydrogen strategy to coordinate needed innovation, investment and activities throughout the government and private sector.

Initial pilot programs to achieve scale and bring down cost for hydrogen and fuel cells should be launched by DOE in regions like the Gulf Coast with low-cost hydrogen already deployed for refining purposes, or in closed ecosystems with pressing air quality concerns like the Port of L.A. These are also locations where road, rail and marine transportation intersect – offering a great chance to advance hydrogen adoption into multiple complementary applications with a single fuel infrastructure. By developing these regional hydrogen hubs, the U.S. can demonstrate the capability and leverage scale to achieve a cost parity with traditional technologies. Further public investment is also needed in the areas of larger scale electrolyzer plants for decarbonized hydrogen production, and hydrogen fuel cell fleet management. Research is needed in reduction of precious metals and expensive materials in electrolyzer stacks and fuel cell systems for heavy duty trucks. All of this should be supplemented with purchase incentives and work force development for a robust domestic energy, manufacturing and job market. The U.S. should also support the innovation in the domestic membrane manufacturers who supply an integral part of the Proton Exchange Membrane (PEM) technology for both the electrolyzers which produce the hydrogen from electricity and the fuel cells which convert the hydrogen to power for vehicles, in the same way the government is promoting domestic battery cell manufacturing.

Hydrogen fuel cells are also recognized as one of the innovative solutions necessary for rail, generating enough energy to power passenger trains. Rather than using the overhead wiring, hydrogen fuel cell technology is an alternative approach to electrifying passenger trains using existing rail infrastructure. In this case, hydrogen fuel cell power modules on the top of the train car are at the heart of the system and provide enough energy by combining hydrogen and oxygen. The fuel cells work by extracting oxygen from the ambient air, while the storage tanks supply the hydrogen demand. The fuel cells and the hydrogen tanks are mounted on the roof of the train. When in motion, the fuel cell powered passenger train emits only water vapor, which is the only by-product of the hydrogen and oxygen reaction in the fuel cell, a truly clean energy conversion. Today, Cummins is the largest provider of hydrogen fuel cells for passenger trains in the world, with trains already in operation in Europe.

Research, development and demonstration programs from the Department of Energy are needed to optimize cost and performance for all the technologies listed. Investment in this space will ensure continued American leadership in technologies and exports needed for decarbonization.

Investing in these technologies will promote U.S. economic competitiveness by strengthening domestic manufacturing and technical capability.

Overall, with the right investment in innovation, the U.S. will continue to lead the way globally in technology, jobs, domestic manufacturing and energy supply. Hydrogen and fuel cells are a critical piece of the puzzle in the hard-to-abate sectors.

An exemplar of public-private partnership: SuperTruck

Strategic public-private research partnerships with industry like SuperTruck, led by the Department of Energy (DOE), leverage technical expertise and prevent duplication of efforts. They also ensure public funding remains focused on the most critical barriers to technology commercialization and accelerate progress.

SuperTruck promotes the research, development, and demonstration of a suite of technologies, improving the freight hauling efficiency of heavy-duty Class 8 long-haul vehicles and the demonstration of applicability of these technologies to heavy-duty regional-haul vehicles as well – with an emphasis on cost-competitiveness.

The commercialization of the technologies developed under the SuperTruck I initiative will save 7.9 million gallons of diesel fuel per day with the associated economic, energy security, and greenhouse gas emissions benefits. The project initially reduced CO2 emissions by 33% from the 2009 baseline. SuperTruck II was recently able to demonstrate a further 50% reduction in CO2 emissions, doubling the efficiency from the 2009 baseline and included additional performance and cost effectiveness requirements to foster a more rapid market adoption of new energy efficient technologies.

A new SuperTruck III program will build upon these improvements with the focus on CO2 reducing technologies such as efficiency improvements, low carbon fuels, hybridization, battery electrification and fuel cell optimization for entire fleets. Examining the full commercial vehicle ecosystem and efficiencies will make a substantive reduction in the energy it takes to deliver the nation's goods.

Conclusion

The heavy-duty and non-road vehicle industry is undergoing significant change, and Cummins is leading the way by investing and innovating in a broad portfolio of power including advanced diesel, natural gas, hybridization, electrified power, fuel cell technology and alternative fuels – so our customers can have the right solution to get the job done. However, industry working alone will not get us where we need to be in a time frame that is feasible. Government supported innovation is needed to meet our global energy and environmental challenges.

Enacting policies that promote the power of choice for every market will help ensure that this country and every community within it has the proven technology necessary to serve the economy while meeting air quality and climate goals on the path to net-zero emissions. We appreciate the opportunity to have a further dialogue on the most important technologies for innovation to improve the U.S. competitiveness and create high quality jobs.

The CHAIRMAN. Thank you, sir.
 And finally, we have Mr. Wimmer.
 Mr. Wimmer, for your opening statement, please.

STATEMENT OF ROBERT WIMMER, DIRECTOR, ENERGY AND ENVIRONMENTAL RESEARCH, TOYOTA MOTOR NORTH AMERICA, INC.

Mr. WIMMER. Chairman Manchin, Ranking Member Barrasso, and members of the Committee, thank you for this opportunity.

Toyota has been investing in America and employing Americans for over 60 years. Today, we have ten plants in the U.S., nearly 1,500 dealerships, and 180,000 people working across the country. In West Virginia, approximately 2,000 team members built some of Toyota's most efficient engines, transmissions, and hybrid drive trains. This year marks the plant's 25th anniversary, and we have recently signed a 15-year agreement to purchase West Virginia wind power.

Every auto company is committed to developing electric vehicle technology. Many have made aspirational statements about when they will phase out internal combustion engines, but we also have to acknowledge the current reality. Last year, less than two percent of the vehicles sold in the U.S. were battery electric. If we are to make dramatic progress in electrification, it will require overcoming tremendous challenges, including refueling infrastructure, battery availability, consumer acceptance and affordability, and reliability of the electric grid. Too often, electrification has been defined as exclusively battery electric vehicles, or BEVs for short. BEVs are an important part of the answer, but not the only answer. Hybrids are also electrified, as are plug-in hybrids and hydrogen fuel cell electric vehicles. All these alternatives will help lower carbon.

The narrow focus on BEVs as the only solution is likely because they burn no gasoline. It is true that if you compare an average hybrid, plug-in hybrid, BEV, and fuel cell electric, you'll find that BEVs and fuel cells emit less, followed by plug-in hybrids and hybrids. While true in many cases, it's not true across the board. Recent data shows that plug-in hybrids can achieve nearly the same or better GHG reductions than BEVs, depending on your daily driving patterns, carbon in the electric grid, the carbon resulting from battery production, and other factors. Don't misunderstand me, we're not saying plug-in hybrids are better. We're saying maximum GHG reductions can be achieved with consumers having more access to technology, not less.

Electrification isn't new for Toyota. We introduced a fully electric RAV4 in the U.S. in 1997 and a second generation in 2012. Since the Prius launch in 1997, we sold 17 million hybrids globally and over four million in the U.S. We currently sell 16 hybrid models, including two plug-in hybrids in the U.S. and we recently announced a third plug-in hybrid and two new battery electric vehicles coming next year. We're also a leader in fuel cell electric vehicles, which offer the longer driving range and quick refueling consumers have come to expect from gasoline vehicles. We have sold over 6,500 Mirai fuel cell electric vehicles in the U.S. and over

10,000 globally. We are also commercializing fuel cells in buses, trucks, and power generation.

Our 25 years of electrified vehicle history has taught us two important lessons. First, consumer needs vary greatly. Some live in urban areas with short commutes and some need room for families and some live where weather or terrain mandate four-wheel drive. Some need towing capability and some have garages where they can charge their vehicle while others don't. This diversity in requirements is exactly why OEMs offer a wide range of vehicle types, styles and power trains. It's also precisely why multiple electrification pathways are needed to reduce carbon emissions. If we tie our horse to a single approach, many consumers will simply opt for an internal combustion vehicle.

Second, transitioning to new technology takes time. Selling those four million hybrids in the U.S. took us 20 years. Significant BEV penetration may pose an even greater challenge given the cost of batteries, the need for national infrastructure, long recharging times, limited driving range and the need for consumer behavioral change. Without a doubt, technology-inclusive policies will provide more Americans with electrified options and will likely achieve greater GHG benefits as a result. The most effective, near-term policy is consumer purchase incentives. These should be structured to promote all electrified vehicles, allow consumer choice, and provide greater opportunity for GHG reductions than a single pathway can provide. And these incentives can't sunset too quickly or they won't provide the investment certainty manufacturers need. Similarly, robust incentives for infrastructure and fuel production are needed. The former will speed deployment of electric chargers and hydrogen stations and increase consumer willingness to purchase. The latter will reduce fuel costs and accelerate the use of low-carbon feedstocks.

Our collective destination is a carbon-free transportation system and I believe we can get there. But our experience tells us it won't happen overnight, and it won't be a single technology. We believe that this country, and the world, is moving inevitably to electrified transportation, but we need to overcome many obstacles along the way and remain supportive of all electrification technologies.

Thank you for your time today.

[The prepared statement of Mr. Wimmer follows:]

TESTIMONY OF:

Robert Wimmer, Director
Energy & Environmental Research
Toyota Motor North America, Inc.

Senate Committee on Energy and Natural Resources
“Driving Innovation in the Transportation Sector Forward”
Tuesday, March 16, 2021

Chairman Manchin, Ranking Member Barrasso and members of the committee, thank you for inviting me here today.

Toyota has been investing in America and employing Americans for more than 60 years. Today, we have 10 manufacturing facilities in the US, nearly 1,500 Toyota and Lexus dealerships, and 180,000 people working across the country.

In West Virginia, approximately 2,000 team members build some of Toyota’s most efficient engines, transmissions and hybrid drivetrains. This year we will commemorate the plant’s 25th anniversary. And as part of our on-going commitment to reduce CO2 emissions, Toyota has signed a 15-year agreement to purchase West Virginia wind power - roughly equivalent to all the electricity we use in the state.

Every auto company is committed to developing electric vehicle technology. Many have made aspirational statements about when they will phase out the internal combustion engine. But we also have to acknowledge the current reality. Last year, less than 2% of the vehicles sold in America were battery electric. If we are to make dramatic progress in electrification, it will require overcoming tremendous challenges, including refueling infrastructure, battery availability, consumer acceptance and affordability, and the reliability of the electric grid.

Too often, electrification has been defined as exclusively battery electric vehicles – or BEVs for short. We agree that BEVs are an important part of the answer – but they’re not the only answer. Hybrid vehicles are also electrified, as are plug-in hybrids and hydrogen fuel cell electric vehicles. All these alternatives will help in the pursuit of lower carbon.

The narrow focus on BEVs as the only solution stems from the view that they must be the most carbon friendly since they burn no gasoline. It’s true that if you compare an average hybrid, plug-in hybrid, BEV and fuel cell electric, you’ll generally find that BEVs and fuel cells are the lowest emitting, followed by plug-in hybrids and hybrids. While true in many cases, it’s not true across the board.

In fact, recent data shows that plug-in hybrids can achieve nearly the same or better GHG reductions than BEVs depending on your daily driving patterns, the carbon in the electric grid, the carbon resulting from battery production, and other factors.

Don't misunderstand - we're not saying plug-in hybrids are preferred over BEVs – we're saying maximum GHG reductions can be achieved with consumers having more access to technology – not less.

Toyota has been in the electrified vehicle business for a long time. We introduced a fully electric RAV4 in the US in 1997 and a second-generation version in 2012. And starting with the Prius launch in 1997, we've sold 17 million hybrids globally and over 4 million in the US – more than the rest of the industry combined. We currently sell 16 hybrid models including two plug-in hybrid models in the US. And we recently announced a third plug-in hybrid and two new BEVs coming next year.

We're also a leader in fuel cell electric vehicles, which offer the long driving range and quick refueling consumers have come to expect from their gasoline vehicles. We've sold over 6,500 Mirai fuel cell electric vehicles in the US and over 10,000 globally. And we're commercializing fuel cell powertrains in transit buses, trucks, industrial equipment and stationary power generation.

Our 25-years of electrified vehicle history has taught us two important lessons.

First, consumer needs vary greatly. What works for one doesn't work for all. Some live in urban areas with short commutes, some need room for families, some live in areas where weather or terrain mandate 4WD, some need towing capability, and some have garages where they can charge their vehicles while many others do not.

This diversity in requirements is exactly why OEMs offer a wide variety of vehicle types, styles and powertrains. It's also precisely why multiple electrification pathways are needed to reduce carbon emissions. If we tie our horse to a single approach, many consumers will simply opt for an internal combustion vehicle.

Second, transitioning to new technology takes time. We're proud of having sold more than 4 million hybrids in the US, but it took us 20 years to get there. Achieving significant BEV penetration may pose an even greater challenge given the cost of batteries, the need for national infrastructure, long recharging times, limited driving range and the need for consumer behavioral change.

Without doubt, technology-inclusive policies will provide more Americans with more electrified options and will likely achieve greater GHG benefits as a result.

The policy with the greatest immediate impact on sales is consumer purchase incentives. These incentives should be structured to promote all electrified vehicles, allow consumer choice, and provide greater opportunity for GHG reductions than a single pathway can provide. And these incentives can't sunset too quickly or they won't provide investment certainty manufacturers need.

Similarly, robust incentives for infrastructure development and fuel production are needed. The former will speed deployment of electric chargers and hydrogen stations and increase consumer willingness to purchase. The latter will reduce fuel costs and accelerate the use of low-carbon feedstocks.

Senators, our collective destination is a carbon free transportation system and I believe we can get there. But our experience tells us it won't happen overnight, and it won't be a single technology. We believe that this country, and the world, is moving inexorably to electrified transportation. But we need to overcome many obstacles along the way and remain supportive of all the many electric technologies on the road to that future.

Thank you for your time today and I will be happy to answer any questions you may have.

The CHAIRMAN. Thank you, Mr. Wimmer.

We are going to start our questions and my first question will be to Ms. Speakes-Backman and Mr. Muellerweiss.

With the growing adoption of electric vehicles, I see the lack of domestic EV battery recycling as problematic. With that being said, sourcing and manufacturing are also problematic. We're moving toward a carbonless EV, if you will, and I want to make sure the cart is not in front of the horse—the cart is not in front of the horse and the horse cannot push very well. So what do you see as the biggest challenges we need to address in this situation of recycling and manufacturing of EV batteries?

Ms. Speakes-Backman.

Ms. SPEAKES-BACKMAN. Thank you, Mr. Chairman, for the question. And I would like to take a quick opportunity to thank you so much for your leadership in providing the provisions that could very well relate to this in the Energy Act of 2020.

The CHAIRMAN. Right.

Ms. SPEAKES-BACKMAN. There is so much more that we can do, however. I believe Secretary Granholm appeared in front of you during her confirmation and she spoke to the need of really a three-prong approach and that's what we're working on at DOE and within EERE. And that is, number one, to diversify the supply that we have. Number two, to find substitutes for non-critical materials—of critical materials to the non. And the third is reuse and recycling so that we are minimizing the need for raw materials.

The CHAIRMAN. Allow me to interrupt.

Are we along the research as far as finding substitutes for raw materials to make these types of batteries?

Ms. SPEAKES-BACKMAN. We are making progress but there's a lot more work to be done.

The CHAIRMAN. Okay.

Ms. SPEAKES-BACKMAN. And we need to accelerate that.

The CHAIRMAN. Mr. Muellerweiss.

Mr. MUELLERWEISS. Yes, the number one constraint, it really is a mindset where traditionally we've focused on developing new solutions, bringing them into the marketplace, and dealing with the end of life later in the process when large quantities of batteries or other products reach the end of life. We really need to start that process right up front. And I need to commend the work of Argonne National Lab and not only the other national labs that are looking at the end of life of vehicle batteries, particularly EV batteries, current chemistries and future chemistries and identifying opportunities for reuse, recycling, recovery, and ideally, even a circular economy of batteries where we can take those same materials in that battery and make new ones.

But I want to build on that point about hybrid vehicles. We are already seeing in today's economy the remanufacturing of some of the early hybrid vehicle batteries, so they're being reused in the ideal second life or second use which is the application that those batteries were originally designed for. So more of that is what's needed, more focused efforts and really a fundamental change in mindset from a linear approach to a circular one that looks at ways to use those materials to supply new battery manufacturing, not just end-of-life waste.

The CHAIRMAN. Thank you.

This is going to be for Mr. Wimmer and Mr. Satterthwaite. Both of your companies have been putting a heavier emphasis on hydrogen and hydrogen fuel cell technologies. I am intrigued by fuel cell technology because fuel cell vehicles, like the EVs, produce electricity without combustion or emissions and do not rely on lithium batteries. This is old technology. In the 1990s, Bob Wise, who was our Congressperson at that time in West Virginia, pushed it very aggressively and we had a fueling station in West Virginia. It never took off. We had a couple of our buses, transit buses, and it seemed like a novel idea, and for some reason, it never caught on with the public. We had no more expansion even as much as we promoted it.

So I am asking, in what application do you see the most potential for hydrogen because I think it has an unlimited amount of potential in our commercial energy fields also. So whoever wants to go first, Mr. Wimmer, then Mr. Satterthwaite.

Mr. WIMMER. Very good question, Chairman. I was actually involved, prior to Toyota, with that bus program——

The CHAIRMAN. You remember that? Yes.

Mr. WIMMER [continuing]. That ended up in West Virginia and I can speak from personal experience, that was a little bit before prime time for the technology.

The CHAIRMAN. Okay.

Mr. WIMMER. It was a little bit early, but we've come a long way in the last——

The CHAIRMAN. I am glad to hear that West Virginia was ahead of its time.

Mr. WIMMER. Yes, yes, they were.

So over the last 20 years, we have been developing the technology. We are now on our second-generation stack technology, which is allowing us to produce stacks in much larger quantities. We can produce upwards of 30,000 stacks a year, and it's a very scalable technology, so it can be applied to a standard four-door sedan like I mentioned, the Mirai, but if you put two of those stacks into a Class A tractor trailer, as we're doing for a program at the Ports of Long Beach and L.A., those tractor trailers are being used to haul drayage from the port to different locations around the L.A. basin through some very disadvantaged communities that are very impacted by emissions from the streets and the highways nearby. So replacing a diesel vehicle with a zero-emission vehicle, particularly a fuel cell, is beneficial for reducing carbon emissions of course, but also for pollution.

The CHAIRMAN. Do we rely on any other foreign countries for the technology or for the raw materials for us to do that?

Mr. WIMMER. The raw materials primarily are carbon in the stacks. We do purchase some of the precious metals in fuel cells from outside of the country, but we also purchase about the same amount for catalytic converters in cars.

The CHAIRMAN. Got it.

Mr. WIMMER. So what we are really looking at is taking that resource——

The CHAIRMAN. Transferring.

Mr. WIMMER [continuing]. And transferring it from cars.

The CHAIRMAN. Mr. Satterthwaite, really quickly. I'm sorry, we're running out of time, if I may.

Mr. SATTERTHWAITE. Yes, Chairman, thank you.

The energy and density emissions weight and fueling properties of hydrogen make it an ideal energy carrier for the equipment that Cummins powers. But let me also talk about the production of hydrogen because in order to use hydrogen we need to make hydrogen fuel and that could be produced domestically from renewable energy or in a carbon-neutral way with natural gas and carbon capture and sequestration, which means, we think hydrogen is an ideal fuel for energy-dense applications like long-haul trucking, marine, mining, and rail.

The CHAIRMAN. Thank you, sir.

Senator BARRASSO.

Senator BARRASSO. Thanks so much, Mr. Chair.

Mr. Satterthwaite, I want to continue with you. You said your company is working toward an energy-diverse future where your customers have a broad portfolio of options so that they can choose what works best for them. So in your experience, if we had mandates that forced the technology, is that going to help or hurt the innovation that you are working on in the transportation sector?

Mr. SATTERTHWAITE. Thank you for the question, Senator.

In our experience, performance-driven standards allow us to reduce emissions today and continue to innovate and improve as infrastructure challenges are addressed. And we do not believe a technology mandate will be helpful. Other things we have experienced in our past is when technology is pushed into the market before it's ready, there are three effects that we see. The first is that the cost of the technology is typically higher and so customers get frustrated with that. As the reliability of the technology is not great, manufacturers have to spend more money on warranty and support. And then finally, as customers don't have great confidence in the technology, then they keep their older vehicles longer which, I think, does not meet the goal of greening our economy as quickly as possible.

So we do not believe technology-forcing mandates actually help. We believe performance-based standards make the biggest difference.

Senator BARRASSO. Thanks so much.

Mr. Nkurunziza, I have a couple questions for you.

In your report, you explain that the production of minerals necessary for electric vehicles has contributed to child labor problems, to human rights abuses, and to environmental damage around the world from Asia to Africa to South America. To the extent that the United States has reserves of minerals necessary for electric vehicles, would increasing our mineral production right here at home in the United States help electric vehicle manufacturers responsibly obtain the minerals that they need?

Mr. NKURUNZIZA. So two ways really to handle that. Yes, of course, if there are domestic resources—cobalt, lithium—you can produce them economically because also the economic side comes in. If they are competitive—can be produced competitively—yes, the U.S. can very much benefit from that. But the second aspect is that you can also get them from where they are and that's what

most countries are doing now because not every country will have all the resources it has to advance its development. So what I think is the U.S. can be a champion actually. Of all these problems we've seen, they can go in with a better model, better standards, invest in what I said—what I call the impact investment, which tries actually to correct the wrongs that we observe in those countries while, you know, ensuring that the value chain is internalized there within the United States, just procuring the raw material from where it is.

So I would see the problem in, really, in two ways. That's why I mentioned this issue of international trade, because whether we like it or not, we will probably still need to get some of the material from abroad, whether it's rare earths or cobalt, for example. So that's how I would approach this question.

Senator BARRASSO. Your report notes that the advantages and disadvantages are there for recycling metals used in batteries.

Mr. NKURUNZIZA. Yes.

Senator BARRASSO. For example, it says that although there is a high potential to recover metals from a lithium-ion battery, these metals, you say, are often combined with several different elements in a complex mix, making recycling extremely difficult. So what are the specific challenges that limit the amount of material that we can recover when recycling lithium-ion batteries?

Mr. NKURUNZIZA. Thank you very much.

Yes, again, I think this is where technology comes in. What we say is we use the current technologies, but we know that technologies are really evolving in this area, they are growing at a very high speed. So I'm sure in a few years there will be new technologies that allow us to recycle more than we do today. Going back, probably to something else I said earlier, in Bolivia, for example, we know Bolivia has the highest concentration of lithium, but it is not extractable because of technology. The current technologies cannot allow that lithium to be extracted.

So technology, again, with the development of new methods, that will be possible and I'm sure, maybe in a few years.

Senator BARRASSO. Thank you.

Mr. Chairman, I have one other question for Mr. Satterthwaite. I just want to say, you know, Wyoming has some of the largest reserves—is among the biggest producers of natural gas in the country. Can you discuss the opportunities that liquefied natural gas, LNG, provide for reducing our dependence on foreign oil and air emissions for, say, heavy-duty vehicles?

Mr. SATTERTHWAITE. Yes, Senator. Thank you for the question.

Switching any application from diesel to natural gas is a tremendous opportunity to reduce emissions. Natural gas engines can provide performance and reliability. They are a mature and proven technology and they offer both criteria pollutant emissions 90 percent below current EPA diesel standards and greenhouse gas emissions 16 percent below current EPA standards. And so natural gas engines are mature, proven, and one of the least disruptive alternatives available to start on the path of decarbonizing our transportation sector.

Senator BARRASSO. Thanks, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

Senator Cantwell.

Senator CANTWELL. Thank you, Chairman Manchin and Ranking Member Barrasso, for this important hearing. Clearly, we have to keep manufacturing more efficient cars, drive down costs for consumers, and deal with pollution. So I very much appreciate this panel and very much appreciate the past efforts by Congress in passing a CAFE standard that helped us save two trillion gallons of gasoline. That really is about the same as it takes to fill up all the light duty trucks in the United States for 15 years. So it was really quite an achievement and the R&D efforts of the Advanced Technology Vehicles program and the DOE's SuperTruck program. All of these have been very positive developments, including the EV tax credit that we were able to establish in 2008 to help spur more investment in electric vehicles.

So my question now is do you think we need to focus on more of the other aspects of the transportation sector—freight, transit, maritime, and aviation and do we need to look at, you know, like a technology-neutral tax credit or other ways to make the U.S. sector more competitive in this area? And if you could be as succinct as possible because I have two other questions I want to get through.

Ms. SPEAKES-BACKMAN. Thank you for your question, Senator Cantwell, and thank you for your authorship and leadership of the \$7,500 tax credit years ago, and it really did spur an industry on the EV and now it's time to do more. Now it's time to reach beyond the light-duty vehicles and the electric vehicles and into the rest of the space of the sustainable transportation world that we want to see. That is rail, it is heavy-duty vehicles, it is air, and it is sea. And that is why we focus in our Sustainable Transportation Office on more than just electric vehicles and battery electric vehicles. We focus on hydrogen and we focus on biofuels to go across the entire transportation sector.

Senator CANTWELL. Great.

So maybe joining in with the rest of the witnesses, do you think that this competition between us and, you know, the rest of the world—communities also trying to catch up on this. In 2005, the capital investment in clean energy technologies was about \$60 billion and in 2020 it was \$501 billion. So there are a lot of people that are making these investments. Do we need to do more in the area of battery technology and transition and grid storage, and the truck issue? Do we need to do more?

Ms. SPEAKES-BACKMAN. Absolutely, and I appreciate your question.

You know, something that I heard across all five testimonies today was that this is not just about battery electric vehicles, this is that consumers need more choices and that these choices need to be accessible to all Americans. We need to explore and use the natural resources that we have here at home in order to make sure that we have a secure supply, and I think we need to accelerate that process. We have the expertise of the Department of Energy and our 11 laboratories, really standing at the ready, to be able to work toward that common future.

Senator CANTWELL. And what do we do about this issue of the supply chain and making our supply chain more resilient or redun-

dant or resolving conflict. The U.S. International Trade Commission is looking at this SK Innovation and LG Chem dispute and clearly, we do not want people stealing patents or unfair competition. But this will hurt us in our supply chain in the United States, correct? And we need to have it resolved or do something about it to make sure that we have more resiliency.

Ms. SPEAKES-BACKMAN. It's certainly a challenge facing us today in terms of accelerating the sustainable transportation and the domestic battery electric vehicle—domestic production, in contrast with making sure that we have a fair playing field. And so while Department of Energy is not at the center of that discussion, we look forward to helping to support wherever we can—the ITC in its decision-making and the rest of the Administration.

Senator CANTWELL. Okay.

What else do we need to do to, on the materials side, to help with the supply chain? What do you think we should do there on the materials side?

Ms. SPEAKES-BACKMAN. Well, reducing the reliance on critical materials, critical minerals, is really important and it's a big focus of us at Department of Energy and across our labs, really focusing on diversifying the supply of these critical materials. Secondly, really, is finding substitutes for them through our research and development. And thirdly is reuse and recycling of those critical materials that are already in the space so that we don't have to dig up more.

Senator CANTWELL. Thank you.

That last point is so important because we have had several hearings before this Committee before and I feel like we just gloss over that point. And yet I think it is the most critical point for us in the United States because there is something we could do about that right now if we just would focus on the recycling aspect.

Ms. SPEAKES-BACKMAN. I appreciate that. And we do have, actually, a few prizes and programs within DOE that are pretty exciting. The Lithium-Ion Recycling Prize and the ReCell battery research and development center, for which Clarios is a participant. So we will continue that work and we look to expand it.

Senator CANTWELL. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

I don't think Mr. Lankford is able to get on the call right now. Senator Cassidy. Will he be available?

If he is not available, we are going to go to Senator Heinrich.

Senator HEINRICH. Thank you, Chairman.

Ms. Speakes-Backman, I wanted to ask you a little bit about electrolyzers. We heard a lot of different testimony today about hydrogen and one of the things that, I think, it is clear, whether you are Cummins or anybody who is starting to invest in that space, that we need to bring down the cost of electrolyzers. So that is one of the key goals here. Can you talk a little bit about how we move electrolyzer costs down the deployment cost curve more quickly and, from your DOE perspective, what we should be doing as a policymaking body to support that?

Ms. SPEAKES-BACKMAN. Thank you for your question and thank you for your leadership on so many aspects of energy storage, ei-

ther stationary or vehicle, and on addressing the climate crisis. I really appreciate the time and the question.

We at DOE, while we are looking to demonstrate and deploy the technologies that are already at hand, we don't stop or we don't slow down the work that we have to do on the research and development of lowering the costs of electrolyzers and the entirety of the process of production for hydrogen, whether that be green hydrogen, whether it be other forms of hydrogen through carbon capture or whether that be through natural gas. We are working on all three of those fronts with our labs and we appreciate the support that you all give us to do that.

Senator HEINRICH. Mr. Satterthwaite, I appreciate the investment that Cummins is making in hydrogen technology. I am curious if you have thought about potential policies that might help with some of those, bringing down costs with deployment and certainly, you know, one of the things we have learned and seen in recent years is how tax incentives like the Investment Tax Credit have been incredibly efficient at moving solar from the most expensive source of power to the cheapest source of power in a relatively short period of time. I am curious if you have looked at whether a vehicle like the Investment Tax Credit would be helpful in driving down the cost of electrolyzers, in particular?

Mr. SATTERTHWAITE. Thank you for the question, Senator.

We believe tax credits are an effective way to spur demand and investment. The current challenge that we see with electrolyzer cost is essentially the further technology development and increased volume. I think this Committee is aware that Europe has moved forward quite quickly with the European Green Deal and is offering some pretty significant incentives for investments in green hydrogen. And we think that some of those similar incentives here in the U.S. could spur the development of electrolyzers. I think demand for electrolyzers will also go hand-in-hand with demand for hydrogen. And so I think the other way to get electrolyzer costs down is to spur demand for hydrogen as a fuel, and I think there have been many, many of my fellow panelists who have talked about how we can do that, but that would be the other demand pull that we could use to increase the volume of electrolyzers.

Senator HEINRICH. That is a great point. And you talked a little bit about what sort of CO₂ standards you would be comfortable with and you said that you support performance standards. And I am curious if you mean that you would, for example, support a standard that moved from today's emissions of diesel motors and setting that as, sort of, 2021 and then sliding that scale to zero for CO₂ emissions at a date certain in the future. Is that the kind of performance standard that you were referring to?

Mr. SATTERTHWAITE. Thank you, Senator. That is correct. We support that kind of a standard that meets the objectives of our country and our air quality goals and allows industry to compete and consumers to have choice about which tech they choose.

Senator HEINRICH. And obviously, that's technology neutral.

Mr. Wimmer, I wanted to ask you a little bit about infrastructure because I was able to pull up from September 2018 the data that happened to pop in a story about the different cars that sold in the U.S. Congratulations, Toyota Camry was number one in September

2018. The best-selling American car in September 2018 was the Tesla Model 3—it was about 3,000 vehicles behind it at 24,000. You were at 27,640 for the Camry. The Mirai is not on that list. I do not raise that to pick on the Mirai. I raise it to bring up the issue of infrastructure because I can pull up a gas station or a charging station, hundreds of them, anywhere, on my phone, pretty much anytime, with the exception of rural areas where we still have a lot to do on electrification infrastructure, and we're getting ready to talk about a potential big infrastructure package. And I think addressing both the current issues with rural electrification and hydrogen potential infrastructure is a huge opportunity within that infrastructure focus.

Do you want to share some thoughts on that, the importance that if we are talking about hydrogen we have to be talking about infrastructure?

Mr. WIMMER. Thank you, Senator, that's a very good question.

The approach that has been taken in California, where there's nearly 50 hydrogen stations open today, is to scale the infrastructure along with the vehicles. So you basically would want to grow infrastructure so they balance the number of vehicles and the number of stations. There is also a difference with the hydrogen infrastructure. It's very similar to a gasoline pump dispenser and it can service hundreds, if not a thousand vehicles a week from one station, very different than battery chargers. So you don't need to build as many stations as you would individual chargers.

The other key is that there is cooperation between the auto makers, the infrastructure providers, and the government to grow all that together because it's a long-term commitment. We're talking a decade or more long commitment to invest in the stations or the vehicles. So it's key that there's this cooperative aspect to doing that and that's occurred in California. We're doing the same thing in the Northeast U.S. to grow that as well. But again, with the modest infrastructure, as that grows, we will increase vehicle production to meet the demand for the vehicles.

The CHAIRMAN. Thank you, Senator.

Senator Murkowski.

Senator MURKOWSKI. Thank you, Mr. Chairman, and good morning. I appreciate this hearing on innovative transportation technologies. And I know that most of my colleagues, when you think about transportation, you are thinking about what is driving on our roads and I appreciate that we have someone from automobile manufacturing. But in way too many of my communities we do not have that, those roads. And so, for us, transportation looks just a little bit different and we talked about how we move on the water, which I think, for us, for the United States, really for the world, this is a space and an area where we need to be spending some time and attention.

We have had an opportunity, Mr. Chairman, to go to Norway. We have seen a country like Norway that, again, has a lot of areas that you cannot access readily by road. And so what they have done with their ferry system and their marine highway system to allow that to be powered through renewable opportunities, electricity—I think about our Alaska marine highway system. It has actually been designated as a National Scenic Byway and an All-American

Road. This is our road out there. We have incredible opportunities for hydro resource, again, a renewable resource there that can generate this electricity. But when we think about what we have in Kodiak—another series of ferries that go around that island. That island community is—the City of Kodiak, anyway—is about 99 to 100 percent renewable, between the hydro and the wind opportunities and the storage that they have there.

So talk to me a little bit in terms of what is being done in terms of the R&D to lower the cost of hybrid electric ferry conversion. What more is being done in this space to help not only ferry systems, but I also think about our fishing fleet in Alaska and the desire that so many have to convert their fleets to get them off of diesel and to get them to a different way of operation within their own systems.

So I think that goes to you, Ms. Speakes-Backman, in terms of what we are seeing in the innovation in this space as it applies to transportation on our water, whether it is a fishing fleet or whether it is a marine highway system like we have in Alaska?

Ms. SPEAKES-BACKMAN. Well, thank you very much for the question, Senator Murkowski, and thank you for your leadership in all these energy issues that are so important to us. Our Water Power Technologies Office has undertaken the Powering the Blue Economy initiative, which is very exciting, centered on unlocking the opportunities for waterway energy systems, also working with the Department of Transportation, working with the Department of the Interior, working across the entire government, really, to find ways to electrify ferry systems as well as demonstrating projects for communities. We have also partnered across DOE offices to launch the Energy Transitions Initiative Partnership Project, as you're well aware. We have the Waves to Water Prize, for which we just announced a recent winner, which is about desalination systems for disaster relief. We have the Ocean Observing Prize, which is working on development of wave energy powered ocean systems.

That, plus working on the ferry electrification systems are really where we're working to decarbonize across the entire economy. And whether we do this through electrification or zero carbon fuels for the ferry systems, we're working on both of those aspects. We are looking to integrate the transportation sector to involve much more than just the road systems, but really water, rail, and air as well.

Senator MURKOWSKI. Well, I would like to work with the folks at DOE on this. As I mentioned, we have an awful lot of—not only remote and islanded communities, but they are just not connected to anybody else. Again, we talk about the microgrids and how we are kind of doing it on our own, but the opportunities, I think, for us to be doing more when it comes to creating these highways on the water, how we are able to access one another through that—I will just note that some of our communities are already really pushing out. Juneau, our capital, is. They have, on a per capita basis, one electric vehicle for every 76 residents. For that community, their big problem was getting dealers from Seattle to ship EVs up to the state because everybody thought they did not want them there. In the community of Cordova, there were no EVs, and so the mayor decided he was going to deal with the chicken and

egg thing and put in two charging stations and now we have several EVs. So you build it and they will come.

In my remaining minutes, I want to bring up the issue of critical minerals and the elements that are so necessary. The discussion that has been had about recycling, and as much as recycling holds promise, I will just remind that you cannot recycle until you have put it into the cycle in the first place. So we recognize that we have work to do when it comes to ensuring that these resources are there.

I was part of a discussion yesterday, getting a little bit of an update about a project in the Salton Sea where they are taking the geothermal brine and basically extracting from that, lithium and it—apparently, it holds some incredible promise. But I mentioned the geothermal brine that you have in Iceland and how they are using it for skin and facial products. Maybe we can be doing that as well as figuring out a way—

The CHAIRMAN. I know we all tried it. It did not help us much either—

Senator MURKOWSKI. Come on, some of us—

The CHAIRMAN. —benefited by it.

[Laughter.]

Senator MURKOWSKI. Mr. Chairman, I am well over my time, but this is an area that, I think, has great promise and great interest. But we clearly do not want to get too far behind when it comes to being able to develop and process our own critical minerals and those important elements here in this country as well.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

Is Senator King on? I am not sure if he has joined us. If he has, if he would please come on. If he has not, we will go to Senator Cortez Masto.

Senator CORTEZ MASTO. Thank you. Thank you, Mr. Chairman, Ranking Member and thank you for the panel. This is great conversation today.

You know, right now we are in the middle of a legislative session in the State of Nevada and the Governor and some of our legislators have introduced a substantial energy bill during this legislative session that would mark one of the state's largest investments in electric vehicle infrastructure. And so I am so pleased with the conversation today. But let me ask you, Ms. Speakes-Backman, I have introduced legislation because I think we need to have a national strategy and a clear strategy on electric vehicle framework to include the DOE and our local and state governments in this national strategy. And generally speaking, is that something that DOE is supportive of or is that something you are looking at and developing and working with the states and local governments around a national strategy?

Ms. SPEAKES-BACKMAN. Senator, thank you so much for the question. In fact, yes, as we are looking to focus more on the demonstration and deployment of these technologies that we have worked so hard over the years to be ready to have deployed, we are absolutely thinking about how we coordinate, not only across the Federal Government, but across state governments as well through programs such as "Clean Cities" and "Connected Communities,"

that we work with, as well as looking at what that national strategy might be. Just last week, or maybe it was the week before last, I sat down with the Board of Directors of the National Association for State Energy Offices, really, to talk about what we can do to be helping and supporting the states to do the work that they need to make sure that they can support the legislation that has gone through. So thank you for the question.

Senator CORTEZ MASTO. That is wonderful. Thank you.

Let me touch on something that we really have not focused on, which is workforce. In addition to the opportunities and challenges presented today, we also have to prepare our workforce for many of these technologies and the expansion of jobs that come with them. This could provide ample opportunities to work with our partners in organized labor as well. So let me just open this up to the panelists. Can you talk to the potential benefits that electric vehicles and the deployment of charging infrastructure could have for domestic job creation and production? And let me open that up to the panelists and see if anybody has any thoughts on that.

Ms. SPEAKES-BACKMAN. Well, I'll jump in, if you don't mind.

Senator CORTEZ MASTO. Okay.

Ms. SPEAKES-BACKMAN. Thank you for the question.

Absolutely. Everything that we do at the Department of Energy is focused on, of course, reducing carbon in our energy infrastructure, but also to be able to enable all Americans to have—to benefit from—the work that we do and that includes not just the environmental benefits, but the workforce development side of this and training as well. And so in the deployment of infrastructure, it certainly can help us to get to that goal of creating of millions of good-paying, middle class jobs with the opportunity to join a union, as well as helping, not just in the deployment of this, but in the operations and maintenance of the transportation sector.

Senator CORTEZ MASTO. Thank you. I am glad you said that because I know I have worked with our regional transportation commissions in Nevada. We have electric buses already, but I know, particularly in northern Nevada, working with our Washoe RTC, that they highlighted for me the shortage of workers that had the know-how to service electric vehicle buses. And so I think this is an area where we can grow our workforce and train them, create jobs—create new jobs—transition the skills to these jobs, which will benefit our workforce as well. Thank you for that.

Let me touch on battery recycling, while I have just a few minutes left. Mr. Muellerweiss and Mr. Nkurunziza, is that right? I do not want to butcher your name.

Mr. NKURUNZIZA. Yes, that's right.

Senator CORTEZ MASTO. Great, thank you.

Both of your testimonies speak to the many benefits of developing better battery recycling programs and keeping the recycled materials in the United States in an effort to gain control of the feedstock for future battery production.

Mr. Muellerweiss, in your written testimony, you mentioned the “2 Million Battery Challenge.” Can you further elaborate on this initiative and speak to its applicability for the recycling of other critical minerals and rare earths?

Mr. MUELLERWEISS. Sure, thank you for that question.

The 2 Million Battery Challenge is something the Responsible Battery Coalition put together to go after the estimated number of batteries that are currently not being pulled back into the recycling system for their conventional lead-acid battery recycling. Through that effort, we've worked with a number of organizations, including Backhaul Alaska, that are looking at remote villages and that have stranded batteries so there may be a higher cost to access—to capture—very similar to maybe some of the current chemistries that are coming online and maybe reaching end of life. So we're learning by going after some of the more difficult-to-reach batteries from around the country—from around the world, frankly—but that effort is really focused in trying to identify how to make it economically viable, how to sort transportation needs to get it from some of the most remote locations to responsible recycling centers.

And as I mentioned in my testimony, there's a lot that can be learned from these traditional recycling systems that have been established in creating pull-through value that allows the materials to be processed and then, ideally, turned back into new batteries.

Senator CORTEZ MASTO. Thank you.

The CHAIRMAN. Thank you, Senator.

And now we have, let's see who we have. Senator Lankford, is he available yet? If not, we are going to go to Senator Cassidy.

Senator CASSIDY. Okay, thank you, all.

Mr. Satterthwaite, I have been down at some of the Louisiana boat building places and they are using your engines. Is there a hydrogen powered engine that works in a marine vessel?

Mr. SATTERTHWAITE. Senator, thank you for the question.

We are running demonstration projects. We currently have a hydrogen fuel cell in an e-ferry in San Francisco, an 84-passenger ferry, but these are still technology demonstration projects. I would not say that the fuel cell technology is ready for prime-time, off-shore operation just yet.

Senator CASSIDY. But is it ready for an 18-wheeler?

Mr. SATTERTHWAITE. Neither. It is not ready for an 18-wheeler just yet. We are developing. We have a number of demonstration projects. My fellow panelist from Toyota talked about the trucks that are at the ports. Cummins has a number of those as well. We are working with customers on demonstration projects, but we are not production—or, you know, efficient-use ready with those technologies as of yet.

Senator CASSIDY. This is purely curiosity, for either you or Mr. Wimmer. It is my understanding that when you make hydrogen from methane you extract about 55 percent of the energy potential of the methane. That would, obviously, increase your cost of fuel roughly by 50 percent. So can we anticipate that this technology will improve, or is it going to be somewhat limited because you are always going to have some decrease in energy potential as you transition from one fuel to the other, aside from the energy it takes to strip the hydrogen from the methane to begin with?

Mr. MUELLERWEISS. Senator, you bring up a very good question. The real key is what is the price of that fuel when it's delivered to the customer? Efficiency will be part of that, but the efficiency of the whole system is really, ultimately, up to the price of that fuel at the pump. So when you look at electricity, depending on how you

produce the electricity, that could be a very inefficient process as well. And we don't really think about that when we buy electricity. So I think we really have to think about if we can bring the cost down through whatever process is used to make the hydrogen so that it's affordable for the consumer at the pump.

Senator CASSIDY. Okay.

Ms. Speakes-Backman, Louisiana has a lot of pipeline infrastructure. We produce a lot of methane. We have great geology by which to store carbon if we wish, to strip the hydrogen atoms off to make a fuel cell, but then to make it zero carbon hydrogen. How do we capitalize on this infrastructure if I want my state to be part of this hydrogen future that may be out there?

Ms. SPEAKES-BACKMAN. Thank you for the question, Senator. And we want every state to become a part of the hydrogen future as well as the electric transportation future and the biofuel future, as it's appropriate.

We would love to work with you to talk about local programs that we can put in place in order to move this forward. And so we would love to be in touch following up.

Senator CASSIDY. So is blue hydrogen part of the plan as opposed to the so-called green hydrogen? Blue hydrogen being made from methane?

Ms. SPEAKES-BACKMAN. Absolutely. We have done work on blue hydrogen. My Office of Energy Efficiency and Renewable Energy has not been the lead on that, that's been our Office of Fossil, but they are also looking at carbon reduction ways from the fossil fuels to be able to create hydrogen. In fact, there's a funding opportunity on the street right now regarding that. So yes, sir.

Senator CASSIDY. Mr. Satterthwaite, do you have a sense of how long it will take for the technology to get to the point where we could have an 18-wheeler or a marine vessel that's run on hydrogen?

Mr. SATTERTHWAITE. Cummins' projection that we shared with investors in November of last year is that we think that penetration of hydrogen fuel cells in, for instance, our heavy-duty trucking market in the U.S. will be in the single digit percent by 2030.

Senator CASSIDY. And what about LNG as a transportation fuel in a marine vessel? What would be that penetration?

Mr. SATTERTHWAITE. LNG has been discussed many times. It has some opportunities, but natural gas in smaller-sized marine vessels is a challenging technology that still needs some work. There are some very large ships which use LNG, but the size that Cummins' are today—really, it's hard to get enough fuel density on board to match the density of diesel. And so customers suffer reduced range if they move to compressed natural gas or LNG opportunities.

But in terms of emissions reductions, LNG offers a good opportunity to reduce emissions in products and they think technology is essentially available and reliable and durable today.

Senator CASSIDY. Thank you. I yield back.

Senator BARRASSO [presiding]. Thanks so very much.

Senator King.

Senator KING. Well, thank you, Mr. Chairman. I apologize for being late to this hearing. I was at an Armed Services Committee hearing and interestingly, there is a connection between the two.

The Armed Services Committee witnesses included the NORTHCOM Commander who deals with issues in North America and the Arctic and the SOUTHCOM Commander who deals with everything below Mexico. And the common thread is climate change. Seventy-five percent of the Arctic ice has melted in the last 40 years and that's in terms of volume and the Arctic is changing fundamentally as a national security issue in terms of both Russia and China. In Central America, the testimony was that part of what's driving the crisis at our border is the COVID impact in those countries, trans-national criminal activity which is gangs, which is just out of control and finally, two major hurricanes that hit the region this fall and people just want to get out for a safer life and they are headed for our borders.

So here we are talking about electric vehicles and alternative fuel vehicles and it is all part of the same issue. I think it is important that we realize that all these things are connected. I have to say—and I am not going to mention the brand—I just bought a brand-new car, which I rarely do, which is one of the most amazing vehicles that I have ever encountered. It is a plug-in hybrid and it can be plugged in and you have 25 miles of all electric transportation for getting around town, but it also has a hybrid engine for longer distance. And coming in yesterday from Dulles Airport, it averaged 61 miles per gallon on the hybrid engine. So this is, I think, the future of transportation—a very efficient utilization of resources.

I think, and I do not know if this has come up, but one of the benefits of alternative-fueled vehicles, particularly electric vehicles, is a more efficient utilization of the grid. Our grid is like a church designed for Christmas and Easter—it has extra pews the rest of the year. Our grid is designed for the hottest day in August, and there is a lot of additional capacity on the grid in the middle of the night in February or March or December or whenever, and this is when most people would be charging their vehicles. So there is an opportunity here for a much more efficient utilization of the grid and, of course, transportation, as I am sure has been noted in this hearing, is about a third of our greenhouse gas emissions.

I am interested in the alternatives, other than electricity. We have had a lot of discussion about that. If one of the witnesses could sort of give me 30 seconds on the status of hydrogen, for example, as a feasible transportation alternative and where that stands and what the obstacles are at this point.

Mr. WIMMER. I can speak for Toyota.

I think it's showing that it is feasible. As I mentioned, we have deployed over 6,500 Mirai, our fuel cell, four-door sedan in the State of California. There are 50 stations. We have had an immense amount of learning on doing this over the last five years, both from the infrastructure side—hydrogen production—as well as from the vehicle side. We're now on to our second-generation fuel cell vehicle that improves performance and fuel efficiency range at a lower cost. So from our perspective it is a technology that will grow. We are selling it around the world, in Japan, as well as Europe. We are also working on heavy-duty Class A tractor trailers to deliver cargo in the L.A. area. I think, from our view, we see it

as a fundamental technology that will grow going forward and help us achieve our climate goals.

Senator KING. And the hydrogen can be produced by excess electrical capacity, can it not?

Mr. WIMMER. Yes, that is one way to produce hydrogen. Hydrogen can be produced many different ways, so excess capacity, electrolyzers, renewable energy, as was mentioned earlier from natural gas with carbon sequestration. So there's just a variety of ways to produce the hydrogen. It really can vary by region. So whatever each region of the country has, they can use it to produce hydrogen.

Senator KING. And the emission from the burning of hydrogen is H_2O , is that correct?

Mr. WIMMER. Correct. We're not burning hydrogen. We're actually just recombining it with oxygen to form water and that's what comes out of the tailpipe.

[Laughter.]

Senator KING. Well, I think water is a lot better than CO_2 . So I appreciate that technology.

And how many vehicles did you say you have deployed in California at this point?

Mr. WIMMER. We've deployed over 6,500, and then if you add in our competitors' vehicles, it's between 7,500 and 8,000 vehicles, I think.

Senator KING. Is this a cost-competitive technology now, or when will it be so?

Mr. WIMMER. Well, we can't really talk about costs. I think we can look at the price of the vehicle and see that it's—I think the new generation is approximately \$57,000 with three years of free hydrogen. So I think from the consumer standpoint, it's a very attractive price, but I can't speak to cost at this time.

Senator KING. Okay, thank you.

Thank you, Mr. Chairman.

Senator BARRASSO. Thanks, Senator King.

Senator Lankford.

Senator LANKFORD. Senator Barrasso, thank you. To the witnesses, thank you very much for what you are doing and for bringing the conversation in today. Let me go through several things.

Mr. Muellerweiss, let me ask you about the battery recycling that has come up several times and obviously, the challenge that we have with some of the minerals coming from conflict areas and child labor and from multiple areas where we have nations like China and Cuba that seem to dominate the market in certain, different minerals. So the battery recycling becomes a big issue for us.

My understanding is we are around five percent at this point for some of these batteries. Not dealing with existing car batteries now, we are at near 100 percent of recycling. But for some of the lithium-ion and some of those, where are we on recycling and what can we do better for that?

Mr. MUELLERWEISS. First and foremost, Senator, no child should ever be harmed with materials that are used in batteries, full stop. That's why it's so important to understand the full life cycle of these materials, as I mentioned in my testimony, from mining to manufacturing, to end of life and recycling. As you noted, a very

small percentage of lithium-ion chemistries are currently being recycled today. There's a significant amount of diversity. There isn't a one-size-fits-all when you say lithium-ion. That can be a variety of different configurations, chemistries, creating a little bit more additional complexity for recovery and recycling.

But one of the key things that is evident and why we are excited to be a participant in the DOE's Lithium-Ion Recycling Prize is there's an opportunity to collect those used batteries which have some of those rare earth and critical minerals and ensure that they can be recovered in a cost-effective, responsible way right here in the United States, to be able to turn those materials back into batteries.

Senator LANKFORD. So why aren't we getting more of those rare earths and critical minerals from here in the United States? We do have things like lithium here. North Carolina has that. But what has been the challenge that we have had of actually doing more of that production here? Cobalt—we are still very, very dependent on the Congo and a tremendous amount of child labor that is happening to be able to do that mining there. So what can we do to develop more of that here in the United States?

Mr. MUELLERWEISS. Well, others on the panel may be able to speak more on the mining, but what I can tell you, certainly related to cobalt, is that that is a significant concern, not only for us, but the entire battery industry. We're a part of the World Economic Forum's Global Battery Alliance that has a cobalt initiative that is specifically focused on responsible sources, but I would defer to others on the panel on the mining capabilities here in the United States.

Senator LANKFORD. Would someone else want to make a comment on that?

Ms. SPEAKES-BACKMAN. Senator, I would appreciate the opportunity to comment on this. This is Kelly Speakes-Backman.

Secretary Granholm has spoken to this very Committee and has made a commitment to really look and work with you all on how we can better source safely and responsibly the critical materials that are here. But in addition to that, she also has supported a three-pronged approach really of number one being able to lessen the need for these critical materials by diversifying our supply, getting away from some of these areas that are just not acceptable to be taking these critical materials. Second is in being more sustainable in the way that we do that work, and third is reuse and recycling. I understand that this is some new work that's being done, but I can tell you that at the Department of Energy we have the ReCell Center, which conducts research and development specifically focused on economically direct recycling from batteries. Our Critical Materials Institute at the Ames National Lab focuses on materials recovery, and we're working with the Departments of Commerce and Defense, and we recently launched a federal consortium on advanced batteries to address just these issues.

Senator LANKFORD. Okay. Let me do a follow-up question for you as well. It has been a challenge for us just in the Federal Government, period. If I go back to the 1970s, it was federal policy at that point to say we are running out of natural gas, and so we need to shift all of our power generation to coal because we have plenty of

coal and we are running out of natural gas, and so all of our incentives turned that way. We have watched this occur, even in wind power. When wind power was nascent, we did a tremendous number of incentives to be able to help pick it off the ground. It is profitable. It is definitely off the ground at this point. It has been a great energy source for us for power generation. But we still seem to struggle with all of these different incentives that are built-in for wind, even though it is certainly not a nascent technology anymore.

So my question for you is, how do we learn the lessons of the past to be able to make sure that whatever we are incentivizing for the future of clean energy, that we are not actually picking winners and losers here and actually driving some out in the process of actually trying to help others?

Ms. SPEAKES-BACKMAN. I appreciate that question. I think there are a number of ways that we can work toward incentives that allow for innovation. I think that's a lot of the important work that we're doing, but it's not just on the incentives, it's also on the early research and development, and the Department of Energy certainly is a world leader in that aspect. When it comes to incentives such as tax incentives and such, there is discussion on technology-neutral tax incentives. That's certainly worth a conversation. And I'd really love to have that conversation with you to talk through what the best path forward might be.

Senator LANKFORD. Okay. Glad to be able to have that dialogue.

You had mentioned by 2050 trying to be at a carbon-neutral environment. Is that for transportation or is that for power generation as a whole?

Ms. SPEAKES-BACKMAN. Yes, sir. We are looking to follow the President's directive to have a carbon-neutral grid by 2035 and be carbon-neutral economy-wide not later than 2050. So that includes transportation. It includes more energy efficiency. It includes more grid-interactive buildings. It includes a sustainable industrial sector and it includes transportation, sir.

Senator LANKFORD. Is there any particular fuel that is in that, that you look to say by this point, by 2035, we will need to have that completely eliminated because as you mentioned before with hydrogen, you are still talking about using blue hydrogen from natural gas. Is that gone by 2035? Is that gone by 2050? What is your model there for certain fuels that would disappear by then?

Ms. SPEAKES-BACKMAN. I really appreciate that question. Really, it's more of a focus on what fuels do we need to deploy in order to get to that carbon-neutral space. So that is including bio energies. It's including hydrogen and it's including electrification of our transportation sector. And not one-size-fits-all. This is about finding what applications fit best with what fuels, rather than figuring out what we're going to be carving out and shutting down. It's really about what can help us get to that goal of 2050.

Senator LANKFORD. Yes, I get that. It was interesting, though. We had a hearing just last week. We talked about trying to be able to move power that was done by renewable sources from one state to another. We have states in the West that they actually started working on transmission lines in 2007 and they do not have a single one of the lines up yet because we are still going through the

permit and the study process. They hope to actually break ground on the first of their transmission lines within the next two years.

So when we talk about trying to be able to eliminate certain items by 2035, and then we realize just moving electricity over a couple of states, in some of our states, already has taken 13 years and it is not actually put in a tower yet. We realize 2035 is really not very far away and one of the challenges we are going to have is to try to say “What are we doing with vehicles? What has to happen to the permitting? What has to happen in the process?” And what actually needs to occur for those that are in poverty to not be driven to a very expensive vehicle of \$50,000, \$60,000, \$70,000 that they cannot afford. And so that suddenly, vehicles are on the top shelf, only for a select few because you are not in the mix. So trying to be able to strike that balance—that we are not actually pushing people in poverty into more isolation, or to be able to set a goal that we already cannot achieve based on what we have seen in the past, unless we clean up some of our permitting process.

The CHAIRMAN [presiding]. Senator Lankford, we want to thank you for that great analogy. We are going to have to move on, if you do not mind?

Senator LANKFORD. Thank you.

The CHAIRMAN. Senator Kelly.

Senator KELLY. Thank you, Mr. Chairman.

So in addition to EV use, efforts to develop and extend the life of advanced high-capacity batteries are an important part of ensuring grid reliability as our nation transitions to renewable energy production. We also need a secure supply chain for these materials, but the transition to advanced batteries will not happen overnight, which is why I am a proponent of federal and private R&D into alternative energy technologies. And I believe we may be only scratching the surface of advanced battery technology.

So this question is for Mr. Muellerweiss. Clarios manufactures and recycles batteries and one of your distribution plants is located in the State of Arizona in Yuma. So my questions for you: have manufacturers of advanced batteries settled on the chemical make-up, whether it be for the use in EVs or for renewable energy storage and how does that affect your efforts to perfect battery recycling?

Mr. MUELLERWEISS. So there is a current generation of chemistries that is being used in electric vehicles today, but as we heard from some of the other panelists, and I noted in my testimony, there is incredible work being done in the national labs, you know, particularly at NETL, at Argonne and NREL, really looking at other chemistries besides what has been traditionally used or is predominantly in the market today. And I think, as has been highlighted by others today, there are some unique opportunities and benefits from chemistries that may not require the kind of rare earth or the availability of materials that are in limited supply here in the United States. And I would say that that's the really exciting point about where we're at in this new battery economy. We're just getting started, Senator. And it's the work at the national labs. It's unleashing the private sector and it's really focusing on the opportunities ahead that, I think, are really going to create new opportunities, new fast forward.

I also mentioned in my testimony that there's no one silver bullet, no one single solution that's going to solve these problems. There are unique chemistries with unique attributes that are perfectly suited for stationary energy storage to help buffer EV charging stations, to extend the grid, others that may be more applicable for EVs and mode of power. And so we're just scratching the surface, as you mentioned, and I think the great work at DOE is just a great starting point and a jumping off point for that work to continue.

Senator KELLY. Could you give me an example of one of these new chemistry makeups, the new technology?

Mr. MUELLERWEISS. So Senator, my role isn't as a technologist. I'm not an engineer. I focus on looking at the life cycle and the responsible management of those batteries. But I can tell you we're looking at and working with Argonne and several of the national labs on other chemistries than they use—magnesium, sodium, other forms of lithium, other combinations of lithium that may make it easier to recycle. So there's a myriad of different solutions. And that's why the work and the modeling work, particularly of Argonne, the ReCell facility that was mentioned and the EverBatt modeling capabilities are so critical because they are building an inventory of this variety of different chemistries, variety of different combinations and what the impacts would be upstream in terms of raw materials and downstream in terms of end of life and in terms of greenhouse gas emissions.

Senator KELLY. Well, with the understanding that the development of these technologies often takes some time, will we be able to achieve a capacity for recycling batteries any time soon that will supplant the development of our domestic reserves of lithium and our need to import cobalt and additional lithium from other nations?

Mr. MUELLERWEISS. Well certainly, I think it was mentioned earlier that, you know, the initial supply source is going to come from somewhere. The ability to recover and reuse that material at the end of life of batteries is critical to complement the supply of raw materials from mines and other locations around the world. But what is really promising is the ability to take the increasing volume—I mentioned there's over 200 million pounds of used lithium-ion batteries from EVs that are expected in the very near future. To be able to look at those as a critical resource to complement what was originally mined is really something that we think is within reach.

And I also want to point to the Lithium-Ion Recycling Prize as one of the key paths forward. It's really challenging the private sector. We're working with a number of private-sector companies in our team to really find a way to accelerate and have that step change to achieve the kind of lithium-ion recycling that I mentioned in my testimony.

Senator KELLY. Thank you. Thank you for your testimony.

Mr. MUELLERWEISS. Thank you for your question.

The CHAIRMAN. Thank you, Senator.

Now we are going to have Senator Marshall.

Senator MARSHALL. Thank you, Chairman, it is good to be back.

My first question is for Mr. Satterthwaite from Cummins. Mr. Satterthwaite, let me start by saying thank you for your footprint in Kansas. I actually used your services in Wichita for a generator a couple years ago. I want to talk about energy, just for a second and power, and really I'm going to focus in on power. In the world I live in, we need power. We need power for the tractors to pull a big implement or a large combine. Or I think about the trains that haul our wheat and products to Mexico and across the country. I think about our big semi-trucks full of cattle. We need power.

And what seems counterintuitive to me with electric motors—

The CHAIRMAN. Senator, excuse me one second. Would someone mute their mic, if they would. Maybe it is on—there we go. Whoever that was, thank you.

Go ahead, Senator. I am sorry.

Senator MARSHALL. That is all right. Hopefully, Mr. Satterthwaite is hearing my question.

It seems counterintuitive to me when you are trying to get power from electric motors that they weigh so much you would have to—disproportionately, you have to add more and more electric generators, electric motors and you lose so much of that power just to support the weight of it versus your traditional combustion engines—we just, you know, we keep adding cylinders. So it seems to be more efficient when you are looking for power. What does Cummins think about the power situation from electric motors?

Mr. SATTERTHWAITE. Thank you for your question, Senator. Cummins is investing in all technologies right now, internal combustion, diesel, natural gas, and as I mentioned, also battery electric. We see real tradeoffs between the power density, the amount of power you can generate for the amount of weight that you're putting on a vehicle and we still see that tradeoff as being very challenging for batteries. The more power you need, the more the batteries weigh and you lose, to your point exactly, you lose payload.

And so, we believe that the right technology for power-dense applications is hydrogen fuel and a hydrogen fuel cell which can operate and deliver power much more equal to the current diesel engines for the same or lower weight and that's the entire weight of the system. So that would include the fuel cell, the tank, and the hydrogen and our comparisons are always against the diesel engine today with the tank and a tank full of diesel. So we do see challenges for electric batteries in these power-dense applications, as you mentioned, and we are investigating hydrogen to try to resolve—try to provide zero emissions and still get the same power and—

Senator MARSHALL. But, if I could interrupt just to kind of move on here. If, in the meantime, while we are waiting on that technology, what has been the impact to biodiesel and renewable diesel on the carbon footprint of your diesel engines? Do you see that as a great opportunity to keep decreasing our carbon footprint?

Mr. SATTERTHWAITE. Cummins does. All of our engines are certified to B20 so they can run on 20 percent biofuel mixed with regular diesel. Current amounts of biofuel that I recall are available in the U.S. only allow really what we call B5. So there is an oppor-

tunity to use more biodiesel and reduce emissions that way, but renewable diesel is quite exciting.

Senator MARSHALL. Yes.

Mr. SATTERTHWAITE. And the most exciting part about renewable diesel is it can reduce emissions in our existing fleet of trucks and other diesel-powered equipment that are on the road today. So we're not just changing the future, we're actually improving the current fleet significantly.

Senator MARSHALL. So the renewable diesel looks just like traditional diesel to your engines?

Mr. SATTERTHWAITE. Yes, based on what we know so far, Senator. The details, of course, are important and I'm not aware of every renewable detail, but in general, that is the perspective we're taking and the benefits are real.

Senator MARSHALL. Great, thank you.

I am going to move to Ms. Speakes-Backman. Welcome. Are you familiar, is there any data out there that show the carbon footprint to build an electric car versus to build a traditional combustible engine car?

Ms. SPEAKES-BACKMAN. Thank you for your question, first of all, and I really appreciate your thoughtfulness in thinking through the life-cycle carbon impact of the vehicles. I will have to get back to you on the specific data points, but I am absolutely sure that we have that, but I will certainly get back to you on that response.

But again, I appreciate the way you're thinking through the life cycle of the—

Senator MARSHALL. Right, yes. I've got to continue through the life cycle, from an electrical generation standpoint to produce the energy for an electric car versus using renewable diesel or biodiesel, are you—are there metrics out there for that as well?

Ms. SPEAKES-BACKMAN. Thank you again for the question. We examine, at the Department of Energy and across our Sustainable Transportation Office, we examine different types of fuels that are carbon neutral or carbon zero fuels that can impact each of the different applications. So we're looking at electric vehicles for the light duty vehicle type and passenger cars. We look at bio—

Senator MARSHALL. But when you say carbon zero, are you referring, I mean, certainly to generate electricity for any type of electric car uses carbon. You use carbon to generate the electricity. And that is what I am trying to figure out—how much carbon do we use to make renewable diesel versus the electricity for a car, and that is certainly a metric we should be able to get, I would think.

Ms. SPEAKES-BACKMAN. Certainly, and we'll be certain to follow up with you.

Senator MARSHALL. Okay. One more—my last question for you. How do we measure the environmental impact of disposing of the batteries?

Ms. SPEAKES-BACKMAN. Thank you for that question as well. We are working on a number of initiatives on recycling and reuse and their carbon impact. We've mentioned a few of those programs earlier today with the ReCell and the prizes that we have going. We're working on that aspect.

Senator MARSHALL. Well, I know there is a future, that we are hoping we are able to recycle, but right now, certainly, there is an

environmental impact—to do something—as we dispose of the electric batteries. How are we measuring that impact?

Ms. SPEAKES-BACKMAN. Certainly, we are measuring that impact with respect to the electric vehicles as well as all types of vehicles, whether they be internal combustion or electric vehicles.

Senator MARSHALL. Okay. Thank you and I yield back.

The CHAIRMAN. Thank you, Senator.

We will go back to Senator Hoeven at this time.

Senator HOEVEN. Thank you, Mr. Chairman.

The CHAIRMAN. Oh, I am sorry. Senator Hoeven? I am so sorry, I have to go to Senator Hickenlooper first, then I will come to you.

Senator HOEVEN. That is what I thought. Absolutely.

The CHAIRMAN. Senator Hickenlooper, I am sorry.

John, you are on mute, buddy. There we go.

I am sorry, brother. I did not mean to knock you off.

Senator HICKENLOOPER. Am I off mute?

The CHAIRMAN. You are on now. You are on, sir.

Senator HICKENLOOPER. Okay.

Small businesses are at the forefront of the clean energy economy and I think promoting these new technologies in renewable energy and energy efficiency takes on increasing importance. As we discussed today, the transportation sector is responsible for the largest share of U.S. greenhouse gases and, given the urgency of climate change, it is critical that we use every tool to address this head-on.

So Ms. Speakes-Backman, how can DOE better partner with small businesses and universities and the federal labs to accelerate the innovation that is going to ultimately lead to a more successful addressing of the climate challenge?

Ms. SPEAKES-BACKMAN. I so appreciate that question, Senator, and thank you for your leadership in the work that you do.

There are a number of ways that the Department of Energy, through its funding opportunities, encourages small business investment. One of those—we actually just had a roundtable of small businesses through our Advanced Manufacturing Office, where we work on, actually, workforce training. They are college students learning how to do energy efficiency upgrades as well as making sure that those upgrades are applied to small businesses. We also have a small business investment research program and a number of different ways that we are looking to expand our involvement with small businesses at the community level and at the state level. So thank you very much for that question.

And if you have more ideas, we are thinking through our big ideas across Department of Energy and within EERE and especially within the Vehicle Technologies Offices.

Senator HICKENLOOPER. Great, thank you.

The Advanced Technology Vehicle Manufacturing Loan Program, which has supported the manufacturing of light duty vehicles and the qualifying components, how can that direct loan program better support the small manufacturers, the guys who are just getting off the ground, but are beginning to get some momentum and help make this an emerging industry?

Ms. SPEAKES-BACKMAN. Yes, thank you for the very direct question. The Loan Program Office program really focuses on the light

duty vehicles only, but not all small businesses are working just on the light duty vehicles, some are looking at medium duty vehicles and some are doing a longer haul. And so being able to use that funding source to apply to a larger spectrum of what we know can help reduce carbon across our transportation sector would certainly be helpful across the hydrogen work that we do and across the biofuels that we work with.

Senator HICKENLOOPER. That is great. I am so enthusiastic about this. As we get more resources to these smaller manufacturers and to smaller partners with DOE the rate of innovation is going to continue to increase.

Ms. SPEAKES-BACKMAN. Absolutely.

Senator HICKENLOOPER. I yield the rest of my time.

The CHAIRMAN. Thank you, Senator.

Before I go to Senator Hoeven, Senator Barrasso.

Senator BARRASSO. Thanks, Mr. Chair.

Just to put into the record a few things. I have a letter from the National Association of Convenience Stores, the National Association of Truck Stop Operators, and the Society of Independent Gasoline Marketers of America. The letter outlines the groups' recommendations to improve the environmental characteristics of transportation fuels. I ask unanimous consent to introduce that, Mr. Chairman.

The CHAIRMAN. Without objection.

[Letter for the record follows:]



March 15, 2021

The Honorable Joseph Manchin
Chairman
Committee on Energy and Natural Resources
U.S. Senate
Washington, D.C. 20515

The Honorable John Barrasso
Ranking Member
Committee on Energy and Natural Resources
U.S. Senate
Washington, D.C. 20515

Dear Chairman Manchin and Ranking Member Barrasso:

Our trade associations represent America's retail fuel community. More than ninety percent of retail sales of motor fuel in the United States occur at our members' outlets. On behalf of this diverse and forward-thinking industry, we are eager to work with you and your respective teams to help improve the environmental characteristics of transportation energy in the United States. We would like to work with you to collaborate on policies that will spur improvement and change to the transportation sector.

The most expeditious and economical way to achieve environmental advancements in transportation energy technology is through market-oriented, consumer-focused policies that encourage our membership to offer more alternatives. Fuel retailers have demonstrated in recent years that they are prepared to invest in any transportation energy technology that their customers desire. With the right alignment of policy incentives, the private sector is best equipped to facilitate a faster, more widespread, and cost-effective transition to alternatives – including electricity – in the coming years.

As discussed further below, policies that adhere to the following principles will create new jobs, accelerate the deployment of advanced alternative fuel infrastructure and vehicles, benefit consumers through a competitive and robust marketplace and drive massive economic investment and improvements in air quality:

- Science should be the foundation for transportation climate policies.
- Establish performance goals without mandating specific technologies to allow for the benefits of innovation and technology development.
- Develop competitive market incentives to ensure a level playing field and provide long-term consumer benefits.
- Harness existing infrastructure to help commercialize new technology, maximize diverse investments, and achieve near-term and long-term emission reduction goals.
- Set consistent, uniform national policy so that (i) the market has certainty to help it invest, and (ii) state policies do not create inconsistent or counterproductive measures.

- Ensure fair treatment so that all households are not forced to subsidize alternative energy users.

Science should be the foundation for transportation climate policies

Any effort to improve transportation energy's emissions characteristics requires an accurate accounting of the lifecycle carbon intensity associated with particular fuels and technologies. This analysis should include everything from acquisition of natural resources, engine and battery manufacturing, tailpipe emissions, and vehicle end-of-life consequences. It should also be regularly updated so that policy is nimble enough to adjust to efforts to innovate and improve the environmental characteristics of different alternatives. Additionally, every sector of the economy should assume a burden of reducing carbon emissions that is proportionate to its share of nationwide emissions.

Policy should set performance goals without mandating specific technologies to allow for the benefits of innovation and technology development

While it may be tempting to prematurely pick winners and losers from an energy technology standpoint, sound policy must be grounded in science and recognize that the state of technology can change rapidly. Incentives to invest in alternative fuel technologies should be tied to those technologies' lifecycle environmental attributes rather than the underlying technology itself.

No one solution will decarbonize transportation energy. Policies should incentivize multiple technologies. What policymakers think is the best solution today may be surpassed by subsequent ingenuity and innovation. Sound policy should not stifle innovation by mandating specific fuel solutions. Instead, policy should set performance goals and let the market – guided by consumers – innovate to find the best way to meet those goals.

Retailers' experience is valuable in this respect because they bring a technology-agnostic perspective with an underlying attention and loyalty to consumer preferences and low prices.

Develop competitive market incentives to ensure a level playing field and provide long-term consumer benefits

Fuel retailers today are best positioned to provide alternative sources of transportation energy because they have a keen understanding of consumer preferences and tendencies. Refueling stations are strategically located throughout the country where refueling demand is greatest, competing with one another on price, speed, and quality of service. Those sites include disability accessible restrooms and parking lots, food and beverage options, vehicle service and repair centers, and even showers and other amenities for professional drivers. Consumers demand all of this, regardless of the type of fuel their vehicle consumes.

Existing alternative fuel incentives – such as the Renewable Fuel Standard and biofuel blending and alternative fuel infrastructure tax credits – have allowed retailers to offer less expensive, lower carbon fuels to their customers, while also supporting investments in renewable fuel production. Regardless of how one may feel about ethanol and biodiesel, the *incentives* Congress established have been successful given the amount of petroleum-based fuel that has been displaced by these renewable fuels since 2005.

These benefits can be replicated for new technologies if policymakers adopt the same market-oriented and consumer-focused perspective. Policy mechanisms worth considering include:

- Ensuring credit regimes and/or tax incentives make alternative fuel less expensive for the end user, thereby providing a stable economic case for upstream investment.
- Permitting all EV charging station owners to generate a profit by selling electricity to EV owners without being subject to regulation as a utility. This allowance is essential if fuel retailers are to have any incentive to invest in EV charging technology.
- Adopting uniform retail pricing measurements (e.g., dollars per kilowatt-hour) and requirements for consumer-friendly price disclosures.

Conversely, policies that at first blush appear to be quick and easy solutions tend to have the unintended consequence of undermining retailers' incentives to invest capital in alternative fuels. This inevitably hinders the growth and expansion of alternative transportation energy. Examples of these counterproductive policies include:

- *Allowing EV charging infrastructure at Interstate rest areas* – Not only would this discourage off-highway fuel retailers from investing in charging infrastructure, but it will signal to prospective EV drivers that they will need to refuel at often desolate, poorly maintained state-run rest areas rather than the off-highway travel centers, convenience and fuel retailers with all of the amenities that drivers have come to expect.
- *Forcing ratepayers to underwrite electric utilities' investment in EV chargers or to subsidize the cost of electricity that charges electric vehicles* – Where this occurs, the utilities are operating in a guaranteed rate of return environment without putting a single dollar at risk. Retailers cannot compete with electric utilities in this environment. While there is good reason for ratepayers underwriting the cost of the grid and other upgrades, there is no public policy rationale why utilities should be given a leg up over private actors who wish to enter the market for chargers that consumers use to power their vehicles. Utilities' ongoing pursuit of this uncompetitive arrangement is the single greatest deterrent to fuel retailers investing in EV charging infrastructure.
- *Prohibiting fuel retailers from selling electricity to individual consumers* – Certain states prohibit the sale of electricity (i.e., fuel) to individual consumers except by price-regulated utilities. This discourages additional deployment of such infrastructure. EV charging station owners must be permitted to generate a profit by selling electricity to EV drivers if they are to have any incentive to invest in the technology.
- *Permitting utilities that own EV charging stations to charge other EV station owners higher rates for power than the internal transfer price they charge their own operations* – A prohibition on such practices is the only way to provide a level playing field and ensure competitive pricing for individual consumers.

Harness existing infrastructure to help commercialize new technology, maximize diverse investments, and achieve near-term and long-term emission reduction goals.

It is exponentially less expensive to leverage existing infrastructure than create entirely new supply chains and infrastructure. To the extent environmental objectives can be achieved by harnessing existing infrastructure – including removing hurdles to bringing alternative fuels to market – customers will more seamlessly gravitate to new types of fuels and vehicles. American companies have spent more than sixty years building out a refueling infrastructure system that optimizes logistics and maximizes customer

benefits. Deployment of new technology that complements this infrastructure will (all else being equal) be less expensive and thus more likely to generate consumer loyalty.

In just the past decade, there has been extraordinary growth in consumption of biofuels such as ethanol and biodiesel, as well as other low carbon fuels such as renewable natural gas, compressed natural gas, renewable diesel, and biobutanol. These are all liquid fuels that are mostly compatible with existing infrastructure that was originally developed for hydrocarbons. With all of these fuels, industry has responded to policy signals by allocating capital toward bringing the fuels to market. Retailers then sell the fuels to consumers for less money than the fuels that were being displaced. This has created enormous environmental benefits in a relatively short period of time. We can build upon current policies to leverage existing infrastructure and achieve meaningful environmental benefits as we work toward reaching our longer-term aspirations.

Set consistent, uniform national policy so that (i) the market has certainty to help it invest and (ii) state policies do not create inconsistent or counterproductive incentives

Federal policy should be designed to lower the cost of alternatives fuels to make those sources of transportation energy more competitive with petroleum-based fuels. This is the only way to ensure that consumers will gravitate toward low carbon technologies. Although some state incentive programs adopt this approach, others have vacillated between different approaches in a way that does not allow private market participants to plan long-term investments in alternatives. Such inconsistent policies are ultimately self-defeating, and that approach should be avoided.

Ensure fair treatment so that all households are not forced to subsidize alternative energy users.

Fundamental tenets of fairness dictate that users of transportation energy, including alternative energy sources, pay for that energy and related infrastructure. Unfortunately, this is not occurring today in two ways:

First, when utilities rate-base their EV infrastructure investments, it raises the monthly utility bills for all of a particular rate class, even though the benefits are confined to a small group of users. It is patently unfair and inequitable for policymakers to force most households to subsidize the refueling costs for EV drivers. Vehicle owners should pay the costs of powering their own vehicles in order to create a market system that will keep energy prices down and avoid regressive charges.

Second, it is imperative that highway infrastructure funding comes from all highway users, and not just those that rely on a particular technology. Our country's infrastructure has been woefully underfunded for decades. Our associations strongly support the Biden Administration's desire to remediate that and bring our roads, bridges, and broader transportation system into the 21st Century. Any user fee to generate increased revenue, however, must capture all vehicles that use the roads.

* * * *

In the current policymaking landscape, it is tempting to paint a picture of how we want the world to look in ten, twenty, or thirty years without focusing on the steps needed to get from here to there in a way that establishes a sustainable market that will benefit consumers and the environment. Fuel retailers want to assist in this endeavor and urge you not to allow long-term aspirations to distract you from building on existing policies and infrastructure to achieve tangible, real-world progress.

All of our associations believe that national, consumer-focused, and market-oriented climate policy is achievable. We appreciate President Joe Biden's goal of pursuing pragmatic policies so that we can come

out of the COVID-19 pandemic ready to hit the ground running toward a sustainable future for our nation. On behalf of the approximately 125,000 retail fuel locations in the United States, we are eager to work with you to achieve what we fundamentally believe are mutually compatible objectives.

Sincerely,

National Association of Convenience Stores (NACS)
National Association of Truckstop Operators (NATSO)
Society of Independent Gasoline Marketers of America (SIGMA)

cc: Members of the Committee on Energy and Natural Resources

Senator BARRASSO. And I have a March 13th article published by Bloomberg, entitled, “Electric Cars Will Cost More Using Ethically Sourced Batteries.” The article discusses a report from a panel of scientists to the European Union outlining the child labor and human rights abuses associated with cobalt production in Congo—some of the things we have discussed here, and it goes on with the risks associated with lithium, natural graphite, manganese, and nickel. And unanimous consent, also, to admit that.

The CHAIRMAN. Without objection.

[Bloomberg article follows:]

Electric Cars Will Cost More Using Ethically Sourced Batteries

Bloomberg Green

By Jonathan Tirone

March 13, 2021

The European Union's efforts to ethically source a key battery metal face headwinds that could make it more expensive for automakers to go electric.

Cobalt is the battery metal at the highest risk of being exploited in ways that damage the health of people and the environment. Most of the world's supply comes from the Democratic Republic of Congo, with as much as a third of that supplied by small-scale miners who often work in dangerous conditions. Regulators have begun developing rules designed to help industry avoid damaging its reputation.

But those "ambitious requirements might currently be too difficult," according to an assessment prepared by researchers advising the European Commission. The report, which will be published by Elsevier Ltd.'s *Resources Policy* journal in June, suggests a tightening market for responsibly-sourced cobalt.

"If, as proposed by the European Commission, due diligence on cobalt supply chain will be mandatory for batteries sold in the EU markets in the near future, the demand for responsibly sourced cobalt will increase rapidly," the study prepared by the EU's Joint Research Centre said.

Many downstream companies have been reluctant to purchase hand-dug cobalt because of concerns about child labor. Glencore Plc, which operates two of the world's biggest industrial cobalt mines in Congo, assures its buyers like Tesla Inc. that only responsibly-sourced cobalt feeds into its products.

But some Chinese companies that sell processed cobalt to Europe mix certified streams of the metal with material sourced from unregulated mines, according to the report. Congo produces some three fifths of the world's cobalt and as much of a third of that is extracted by hundreds of thousands of freelancers. Miners told the researchers that wages and mineral prices continued to be subjects of dispute.

By 2030, EU economies need to secure more than 64,000 tons of ethically-sourced cobalt beyond existing supply-chain constraints, a volume of metal worth around \$3.2 billion at current prices, to fuel the transition to electric vehicles. The run on the metal's price is prompting mining companies to seek new reserves from Australia to the deep sea.

Senator BARRASSO. Thank you, Mr. Chairman.

The CHAIRMAN. Senator Hoeven.

Senator HOEVEN. Thank you, Mr. Chairman, and I appreciate the witnesses being here.

I would like to start with Ms. Speakes-Backman. In North Dakota, we are working very hard to do what we call, "crack the code" on carbon capture and storage. Obviously, it is technologically feasible. But we have got to make it commercially viable or commercially feasible to do it from our coal-fired electric plants. We are also doing it with the CO₂ from ethanol plants. And we have put the regiment in place in our state to do it, and we are EPA-approved. Now we need DOE's help to put the equipment on these plants to separate and capture CO₂, and like I say, do it in a commercially viable way.

So A, we would ask for your help in that endeavor and link it to one of the things we are talking about today, which is hydrogen as a fuel source. So please tell me if you are committed to helping us get that done and how we are going to do it together.

Ms. SPEAKES-BACKMAN. Thank you so much for the question. I keep flipping on and off my volume there.

Certainly, carbon capture and storage, as part of the Department of Energy's Fossil Energy Office, has been working very hard and I have had the joy to work with Jen Wilcox, who is leading that effort to see where we can collaborate, especially on issues of carbon capture and how it may be involved in the development of hydrogen for a cleaner energy support. And I really look forward to working with you to see how we can leverage across all the energy offices. We have Fossil Energy, EERE, of course, the Office of Electricity, to make sure that we can work toward less carbon-intense fuel sources across the energy sector.

Senator HOEVEN. Well, that is it exactly—and we already have partnership arrangements with you at DOE and so are you committed to work across the different entities within DOE, help coordinate their efforts in support of this objective?

Ms. SPEAKES-BACKMAN. Yes, sir. I am happy to coordinate and collaborate across the other offices within DOE.

Senator HOEVEN. Thank you and we very much look forward to working with you to do just that. So thank you so much for your response.

Mr. Satterthwaite, in Dickinson, we have a facility that we are working now. It was actually originally constructed as a diesel facility to produce diesel from oil, but now we are actually converting that to a renewable diesel facility that would produce about 12,000 barrels per day of renewable diesel from corn and soybean oil. Talk to me a little bit about what you see for—first, that it is usable in any current diesel engine. Is that correct? And then talk about some of the benefits and what you see as the marketplace for the renewable diesel.

Mr. SATTERTHWAITE. Thank you, Senator.

I'll first start by saying I'm not a fuels expert so I can't speak specifically to the fuel, but it is my understanding that the renewable diesel fuels that are being developed are interchangeable and usable, definitely, in Cummins' diesel engines, but I think across the industry and with our competitors as well. And so the huge

benefit and opportunity I see for renewable diesel is not just the opportunity to put new product into the market that is low emissions, but to actually reduce the emissions of every single engine that's in the market and working today. That is the big opportunity, both from a market and a carbon reduction perspective.

And so we are excited by the opportunities of low-carbon fuels and what that can mean to reducing the carbon impact of not only tomorrow's products, but yesterday's and today's products as well.

Senator HOEVEN. Thank you.

And I am probably not going to get this name just right, but I am going to try, Nkurunziza? Sir, if I didn't get your name correct, I apologize, but talk to me about getting some of these rare earth elements out of coal, instead of from China. That is something that we are working on. Do you think that is something that should have strong support from the DOE and something that we can do?

Mr. NKURUNZIZA. Thank you for the question.

I think now, even America is producing rare earths again. It has the Mountain Pass Mine in California that had been closed for several years. It was closed, I think, in 2002. So now it's back in operation. It was closed because of environmental concerns. Now again, coming back with new technologies, I think they are now able to mine rare earth again. And America now is becoming again, a leader, really, in the production of rare earth.

Now, the other point I made earlier is that there are other countries other than China, where you can find these rare earths—Australia, a few countries in Africa, and some of them are actually underexplored. So I think exploration is also something that maybe presents a number of opportunities for American firms. I think America is back, really, in the rare earth sector and I think that is very good for the American economy.

Senator HOEVEN. Thank you, sir. Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator.

Are there any other Senators that we have or on video here that wish to speak?

[No response.]

The CHAIRMAN. If not, I want to thank all of the witnesses for joining us this morning for your discussion. Your input was extremely, extremely helpful for all of us and I am sure we will be calling on you further as we move legislation.

Members will have until close of business tomorrow to submit additional questions for the record.

The CHAIRMAN. The Committee stands adjourned.

[Whereupon, at 11:43 a.m., the Committee was adjourned.]

APPENDIX MATERIAL SUBMITTED

U.S. Senate Committee on Energy and Natural Resources
March 16, 2021 Hearing: *Ways to Strengthen Research and Development*
in Innovative Transportation Technologies with a Focus on Solutions that Decrease
Emissions,
Reduce our Reliance on Foreign Supply Chains, and Increase Manufacturing in the United
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Questions for the Record Submitted to Ms. Kelly Speakes-Backman

QUESTIONS FROM CHAIRMAN JOE MANCHIN III

Q1. West Virginia was the first state in the nation to provide EV chargers at every single one of their state park lodges. This effort was made possible by the West Virginia Office of Energy which is a part of Department of Energy's Clean Cities program and received funding for the project through DOE's State Energy Program. These charges reduce "range anxiety," and, given the time it takes to fully charge an EV, allow people to take advantage of surrounding restaurants and stores which helps our local economies. It seems like innovative thinking at the local level can also help to encourage cleaner forms of transportation that will work in our towns and cities. These technologies are not necessarily one size fits all, and I think there is a lot we can learn from our local partners about finding the right solutions to reduce emissions that work for them, particularly in rural areas.

Q1a. What are your plans to work with rural communities to make sure the innovative transportation solutions coming from DOE work for them?

A1a. EVs mustn't be a luxury, but an affordable and accessible choice for all Americans. EERE's Vehicle Technologies Office's Technology Integration Program supports a broad technology portfolio that can reduce transportation energy costs for businesses and consumers. This includes projects aimed at ensuring access to mobility options for rural communities, potential beneficiaries of our electrification efforts.

Ensuring equitable access to charging for rural communities will require coordination with utilities on electric service capacity and demand charges as well as investments in distributed energy resources. EERE's Vehicle Technologies Office supports light-duty EVs for carsharing, electric transit shuttles, and information sharing for transportation service providers. Through these methods, we aim to connect rural communities to towns and cities and do so using electric vehicles that provide both environmental and health benefits. Current efforts are taking place in San Joaquin Valley, California, Hood River, Oregon, Athens, Ohio, and Bastrop, Texas.

Q1b. How will you work to foster innovation at the local level?

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A1b. Public-private partnerships are key to fostering innovation at the local level. For example, the DOE Vehicle Technologies Office engages local communities through its national network of Clean Cities Coalitions.¹ DOE has more than 75 coalitions currently designated under the program, representing nearly every state and covering 80% of the U.S. population. Clean Cities Coalitions implement innovative transportation projects in communities to address local/regional energy and air quality challenges. These partnerships are comprised of local businesses, utilities and fuel providers, vehicle fleets, state and local government agencies, and community organizations.

¹ <https://cleancities.energy.gov/coalitions/>

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QUESTIONS FROM SENATOR JAMES E. RISCH

- Q1. At the Idaho National Lab, we are also leading a project with three utilities to develop integrated energy systems – particularly coupling nuclear with hydrogen production. Integrated energy systems can be used to improve the long-term competitiveness of our nuclear fleet and support a hydrogen transportation fuel market, among many other uses. Can you share your thoughts on the opportunity for integrated energy systems and hydrogen to deploy to the transportation sector?
- A1. Integrated energy systems leveraging low-cost renewable electricity in conjunction with baseload power, such as nuclear, are of growing interest to the transportation sector, particularly in areas that complement battery electrification. The Department of Energy (DOE)'s Hydrogen and Fuel Cell Technologies Office and the Office of Nuclear Energy are co-funding Idaho National Laboratory, as well as other National Labs and industry, to demonstrate proof-of-concept integration of electrolyzers with both electricity and thermal sources to optimize the production of hydrogen. This hydrogen could be used in various applications, particularly for heavy-duty, long-haul trucks where hydrogen fuel cells can help achieve the driving range and short fueling times required to meet market demands. Electrolyzers using variable sources like solar and wind are used only intermittently, whereas an *integrated system*, using nuclear power, for instance, allows the electrolyzer to be used continuously, which increases the amount of hydrogen produced. Such optimization is key to reducing cost and enabling hydrogen to be competitive for the transportation sector and other industries like steel manufacturing and chemical production, including ammonia. An additional opportunity for clean, low-cost hydrogen is in the production of biofuels, where the production of sustainable aviation fuels will require hydrogen.
- Q2. As our country moves to adopt more electric vehicles, how do we ensure there is equitable access to charging for rural communities and for residents who do not have access to charging at home?

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- A2. EV's mustn't be a luxury, but an affordable and accessible choice for all Americans. EERE's Vehicle Technologies Office's (VTO) Technology Integration Program supports a broad technology portfolio that can reduce transportation energy costs for businesses and consumers. Among these projects are those aimed at ensuring access to mobility options for rural communities, making sure they are beneficiaries of electrification efforts. For example, our ROADMAP project is developing a set of potential technology solutions for electrification in rural areas, including the implementation of electric shuttle buses for a circulator route through Athens (OH). The project also incorporates outreach to local transportation service providers like taxi and shuttle fleets to encourage the adoption of electric vehicles in these fleets, supplemented by the deployment of a EV charging locations in the city of Athens to support more widespread electrification. Ensuring equitable access to charging for rural communities will require coordination with utilities on electric service capacity and demand charges, as well as investments in distributed energy resources. For VTO's Rural Mobility Projects, applicants were encouraged to focus project activities on US counties that are at least 50% rural as defined in the United States Census Bureau County Classification Lookup.²

Our country can ensure equitable access to EV charging for residents who do not currently have access to charging at home by investing in workplace charging, curbside charging, and public-access locations such as transportation hubs, commercial destinations, libraries, and government buildings. We can also address existing barriers to installing EV charging for residents of multi-family housing through innovative charging and management technology, outreach and education efforts targeting developers and property managers, and finance models.

- Q3. Stress on the Grid - Widespread electric vehicle adoption has the potential to dramatically reduce carbon emissions and stimulate U.S. auto manufacturing. However, there is concern that EV charging will stress the electric grid that is already over-burdened in

² <https://www.census.gov/geo/reference/urban-rural.html>

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some areas of the country. What additional research and development is needed to accurately forecast load on the grid from EV charging? How could modeling and simulation establish the means to seamlessly integrate EV charging with the grid?

- A3. DOE is currently conducting a scenario analysis to better understand the national impact of electrifying the transportation sector and the potential impacts this will have on generation. We are also investigating how EVs can provide more system flexibility (through managed charging and vehicle-to-grid). Finally, we are investigating the implications of necessary grid upgrades at the distribution level where fleet electrification will be taking place soon.

In 2019, the U.S. DRIVE partnership published a comprehensive report on how the grid is impacted by large numbers of EVs.³ The report found that based on historical growth rates, sufficient energy generation and generation capacity are expected to be available to support a growing EV fleet as it evolves, even with high EV market growth. DOE is continuing R&D by collecting charging profiles for EVs and determining how these loads impact the electric grid. These data feed DOE R&D on Smart Charge Management technologies and systems that will enable EVs to be a grid asset when integrated with the grid.

Long-term modeling and analytics will show the most efficient way to support grid reliability while also supporting a carbon-free environment through the broad integration of EVs into the grid.

³

<https://www.energy.gov/sites/default/files/2019/12/f69/GITT%20ISATT%20EVs%20at%20Scale%20Grid%20Summary%20Report%20FINAL%20Nov2019.pdf>

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QUESTIONS FROM SENATOR STEVE DAINES

- Q1. Historically the United States has relied on the private sector to provide fuel for vehicles and motorists. I believe the private sector is the most efficient and best fit to provide the same services to the next generation of motor vehicles.
- Q1a. Do you believe that the private sector or the federal government should lead in deploying charging stations for EVs?
- A1a. The private sector will need to maintain a sustainable market for EV charging stations with a long-term business case. However, the federal government has a role to play in supporting the initial deployment of charging stations in areas where this infrastructure is needed but a supporting business case is difficult to make (for example, stations in rural or underserved areas to encourage initial market development of EVs in these areas). DOE has several current projects to deploy community-appropriate advanced technologies in rural and underserved areas that include electrification as a component of a larger transportation system view, including a project for deploying electric charging stations and electric vehicles for a car share program in a rural tourist area of Oregon. Federal and state governments have a role to ensure that national coverage is provided similar to how the U.S. highway system was developed to provide national coverage.
- Q1b. If the federal government is to get involved in providing charging stations, do you believe that there should be a level playing field between government owned and subsidized charging stations and private owned charging stations?
- A1b. A level playing field will be necessary to empower stakeholder engagement and encourage private-sector investment in EV charging infrastructure.
- Q1c. What federal and state obstacles do you see as hindering private deployment of charging stations?
- A1c. The obstacles that can hinder the deployment of EV charging stations occur primarily at the state level. Securing the required permitting to install EV charging equipment and

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seeking final approvals to commission an EV charging station can adversely impact construction/installation schedules. The Codes and Standards for EV Charging are covered under the National Electric Code (NEC). States and localities can adopt all or part of the NEC codes as they see fit. At the national level, DOE can provide technical assistance and dispense objective information, and other resources, to inform Codes Officials, Electrical Contractors, Utilities, and Charging Station providers about best practices and lessons learned to help expedite the permitting. At the local level, DOE's nationwide network of Clean Cities coalitions can collect and share best practices, data, and lessons learned to inform local decision-makers resulting in the successful implementation of advanced transportation infrastructure development. resulting in the successful implementation of advanced transportation infrastructure development.

- Q2. Last week this committee held a hearing on the reliability of the electric grid and the need to ensure a balanced grid that can provide electricity at all hours and during any weather event. The addition of more and more electric vehicles will have an effect on the grid due to increased electricity needs, especially at night when most people charge their cars. What are your thoughts on ensuring grid reliability in a time when electricity demand will rise due to electric vehicles while baseload power is shrinking?
- A2. The transportation sector already relies on electricity for fuel delivery, such as for pumping, metering, operations, and communications. As the transportation sector increasingly relies on electricity, electric grid reliability and resilience will need to be reconsidered. The process of interconnecting sectors (sector coupling), in this case for Transportation and Electricity, should proceed with forethought and design, such that each sector is strengthened by this connection, and not merely accommodated. EVs should complement and strengthen the grid, just as the grid should advance an EV's primary service as efficient transportation. To support this, DOE is working with utilities and vehicle manufacturers on smart-charge management technology that will enable a higher level of vehicle-to-grid integration (VGI).

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- Q3. According to President Obama's State Department Environmental Impact Statement, transportation related CO2 emissions would be 28% to 42% higher if oil that would flow through the Keystone XL Pipeline was sent instead by rail or tanker (2012 Final Supplemental Environmental Impact Statement ES.5.4.2).
- Q3a. Is it the goal of President Biden to reduce transportation emissions?
- A3a. Yes
- Q3b. Are you aware that the Obama EIS demonstrated a rise in transportation emissions through the no action scenarios as stated in ES.5.4.2?
- A3b. Comparing emissions across different scenarios is complex and includes considerations such as the price of oil and market conditions, among others. Depending on those variables and how they change, different conclusions can be drawn.
- Q3c. Are you aware that the company operating the Keystone XL pipeline has promised that the pipeline will be operated at net-zero emissions?
- A3c. Emissions resulting from transport are only one source of emissions. Other sources of emissions include extraction and power generation. Other public interest determinations also play a role, such as water quality, species or habitat impacts.
- Q3d. With the pipeline operating at a net-zero emissions standard and the findings of the Environmental Impact Statement that the use of the pipeline reduces transportation emissions, would it not follow that by killing the Keystone XL Pipeline it would result in higher emissions than allowing it to operate?
- A3d. When it comes to looking at emissions it is important to look at the entire cycle. As I've noted above, that includes extraction, transportation, as well as power generation.
- Q3e. If the goal of President Biden is to reduce overall emissions and the Keystone XL Pipeline would result in lower transportation emissions, wouldn't it be in the interest of President Biden to support the Keystone XL Pipeline?

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- A3e. The administration's decision is in part based on the fact that the multitude of factors that include extraction, transportation, and the utilization of oil from tar sands is particularly polluting, among other considerations.
- Q4. In order to increase electric vehicle production, you have to also increase the domestic development or the importation of critical minerals to build the batteries and components needed to deploy more EVs. If responsible production does not happen in the U.S. it will happen in countries with worse environmental and labor standards. For example, the Democratic Republic of the Congo produces the vast majority of the cobalt that is used in EV batteries.
- Q4a. How can the U.S. reverse this and bring back domestic production and manufacturing of critical minerals?
- A4a. As laid out in the February 24 Executive Order on America's Supply Chains, the Biden Administration is prioritizing resilient American supply chains to revitalize and rebuild domestic manufacturing capacity, maintain America's competitive edge in research and development, and create good-paying jobs. Under this Executive Order, DOE has been tasked with submitting a report within 100 days identifying risks in the supply chain for high-capacity batteries, including electric-vehicle batteries. The Department of Commerce has been tasked with submitting a report identifying risks in the semiconductor manufacturing and advanced packaging supply chains.
- The U.S. can also address critical materials through mitigation strategies, including diversifying supply; developing alternatives/substitutes; and the reuse, recycling, and more efficient use of critical materials. This approach is included in DOE and the Federal Critical Materials Strategies.⁴
- Q4b. Does it concern you that the U.S. is reliant on foreign countries for critical minerals used in the transportation industry?

⁴https://www.energy.gov/sites/prod/files/2021/01/182/DOE%20Critical%20Minerals%20and%20Materials%20Strategy_0.pdf

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- A4b. The Department is a leader in addressing critical material supply chain challenges through investments in its three-pronged strategy: Diversifying Supply Chains, Developing Substitutes, and Improving Reuse and Recycling. The critical material provisions in the Energy Act of 2020 will allow DOE to continue to build on its expertise. Through the Office of Energy Efficiency and Renewable Energy, and the Office of Fossil Energy and Carbon Management's new Division of Minerals Sustainability, the Department will leverage essential R&D on recycling, alternatives, and diversifying supply across critical material supply chains.
- Q4c. How is the supply chain affected when we rely on China and foreign countries for critical minerals?
- A4c. Relying on other countries inherently increases the risk of supply chain disruptions for intermediate or end products used in the U.S. As Secretary Granholm has previously stated, it's important to promote responsible mineral development, processing and recycling that will protect the environment and provide the United States with a competitive advantage in producing batteries and other technologies, enabling the U.S. to advance renewable energy and other industries supported by critical mineral development. The Secretary is committed to working with you and others to make sure that the United States has its own critical mineral supply.
- Q4d. We have seen recent moves by China to restrict Rare Earth Elements exports. Has this or will this affect EV production?
- A4d. We have not seen these moves affect EV production yet, and our research projects continue to find ways to reduce or eliminate rare earth element dependency for electric vehicles, including alternative magnet materials and electric motor designs that do not rely on rare earth elements.

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- Q4e. What are the key critical minerals needed to reduce emissions in the transportation industry?
- A4e. Critical materials are used in both catalytic converters to reduce engine emissions and in electric drive system motors and batteries in electrified vehicles. DOE's Critical Materials Strategy lists the following as critical materials: Cerium and Platinum Group Metals (Platinum, Palladium, and/or Rhodium) for catalytic conversion; Dysprosium, Praseodymium, and Neodymium for magnets used in electric motors; and Praseodymium, Neodymium, Lanthanum, Cobalt, Manganese, Nickel, Lithium, and Cerium in batteries.
- Q5. During the COVID-19 pandemic we saw a dramatic decrease in gasoline and diesel consumption as more people were staying at home. Experts, including the Energy Information Administration under DOE, expect demand to rise in 2021 and 2022 as travel increases. As we look towards innovation within the liquid fuels world, one product has already shown tremendous promise to bridge the gap between conventional fuel and renewable fuels. Refined Renewable Diesel is a 'drop in' fuel that can help lead to lower emissions while at the same time keeping and growing traditional refinery jobs. Montana is home to a number of small refineries that are an important part of our local communities and renewable diesel can play an increased role in Montana and throughout the U.S.
- Q5a. Does the Biden Administration believe that renewable diesel can be used to reduce transportation emissions?
- A5a. DOE has been developing three main technology paths to decarbonize transportation: electrification; hydrogen fuel cells; and biofuels. All three technology paths will be required to support economic growth and quality of life while decarbonizing the transportation sector. Renewable diesel is a drop-in biofuel that can reduce transportation emissions and DOE RDD&D plays a key role in making these fuels more affordable. Several commercial entities are producing renewable diesel in the United States and internationally. These processes typically use fats, oils, and greases as a feedstock and result in 60% to 80% lower greenhouse gas emissions than a petroleum baseline. However, there is a limited supply of fats, oils, and greases that can be used for fuel

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production. Renewable diesel can also be produced from other feedstocks including municipal solid waste, cellulosic biomass, and algae, which have similar emissions reductions and are being actively pursued through RDD&D funded by the DOE Bioenergy Technologies Office.

Q5b. What regulatory barriers are there that may stop the growth of renewable diesel?

A5b. A major driver in the growth of the renewable diesel market has been the Biodiesel Mixture Excise Tax Credit, commonly known as the biodiesel tax credit or BTC. Uncertainty of the BTC beyond 2022 could impact the growth of the renewable diesel market.

Q5c. Can you commit to working with me and this committee to promote this new fuel and identify areas where the administration can be supportive?

A5c. Yes, I can commit to working with you to promote new fuels that have low carbon intensities such as renewable diesel and renewable jet fuel (commonly called Sustainable Aviation Fuels or SAF), and identify areas where the Administration can be supportive. The creation of new fuels that reduce greenhouse gas emissions and creates new good-paying jobs and economic development, including rural America, is an Administration priority.

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QUESTIONS FROM SENATOR MARTIN HEINRICH

DOE's Battery RD&D/Collins-Heinrich BEST Act (Sec. 3201, Energy Act of 2020)

- Q1. The EU has recently approved more than \$3 billion for lithium-ion EV battery R&D in Europe. We are in real danger of falling behind, which is why I was pleased to partner with Sen. Collins in introducing the Better Energy Storage Technology or "BEST" Act, which was enacted in December in the bipartisan Energy Act of 2020. The BEST Act authorizes a comprehensive program of research, development and demonstration to help drive down the cost of energy storage technologies that will be essential to decarbonizing the economy and electrifying America's future.

What are DOE's plans, status and timeline to implement the BEST Act?

- A1. Through the Department of Energy (DOE)'s Energy Storage Grand Challenge (ESGC) initiative, we are implementing a crosscutting strategy to advance energy storage technology, including lithium-ion batteries, that supports some of the Nation's most significant energy needs. DOE has been a global leader in the development of lithium-ion battery technology and has several partnerships with leading European research groups in battery technology. Near-term efforts include funding opportunities across multiple offices to identify innovative research, development, and demonstration (RD&D) projects that address multiple storage technologies for different use cases. These projects will address critical areas such as advanced manufacturing, large scale demonstrations, development of testbed facilities, and improvement of system cost and performance. In order to further align on the storage strategy laid out in the BEST Act, an ESGC lab coordination effort is underway to increase visibility and communication of DOE storage activities, encourage stakeholder engagement and collaboration, and collect insight on challenges that will be necessary to inform a comprehensive RD&D strategy.

- Q2. Hydrogen and Fuel Cell RDD&D

I am pleased to see the wide range of RDD&D activities at the Department of Energy around hydrogen energy and fuel cell technologies across various departmental offices. I believe reducing the cost of hydrogen production is a priority and understand there is

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ongoing work at DOE on technologies using steam methane reforming, gasification, pyrolysis and water-splitting electrolysis. How is the department ensuring there is good coordination of effort among the various offices and programs so that we are maximizing our investments and preventing any duplication of effort?

- A2. As described in the DOE-wide Hydrogen Program Plan,⁵ our efforts on hydrogen span multiple offices, including the Office of Energy Efficiency and Renewable Energy, Fossil Energy, Nuclear Energy, Science, Office of Electricity, and ARPA-E. Coordination is ensured through several mechanisms including joint solicitation development and workshops, as well as proposal and project reviews to avoid duplication and leverage resources. As one example, the Hydrogen and Fuel Cell Technologies Office (HFTO) has held monthly meetings for over a decade, with members from DOE offices as well as other federal agencies involved in hydrogen, to share key activities and opportunities for strengthening collaboration. The Hydrogen Program Annual Merit Review is another important example of collaboration, where funding recipients present their work, and projects are merit reviewed. This event draws over a thousand participants and provides valuable feedback that allows the Department to continuously improve its portfolio. Also, the Office of Science, in collaboration with the applied offices, is planning a roundtable workshop to bring together the scientific community and identify any remaining gaps that need to be addressed. Recently, the Under Secretary of Science and Energy launched Science and Energy Technology Teams (SETTs) in key cross-cutting areas, including Hydrogen. The Hydrogen SETT is another formal mechanism through which collaboration occurs to optimize taxpayer investment, develop appropriate strategies, and prevent duplication.

- Q3. Expansion of Advanced Technology Vehicle Manufacturing, (ATVM, Title XVII Loan Program)

Back in 2007 our former colleague on the committee, Sen. Stabenow, authored the Title XVII loan program for manufacturing of advanced technology passenger vehicles. There

⁵ <https://www.hydrogen.energy.gov/pdfs/hydrogen-program-plan-2020.pdf>

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are now proposals to expand the loan program to include medium and heavy-duty vehicles.

What are your views on expanding the existing ATVM loan program for medium and heavy-duty vehicles to help drive production and deployment of advanced technologies, such as hybrid or emission-free trucks powered by hydrogen or batteries?

A3. Under current law, the Loan Programs Office is limited to financing manufacturing of eligible light-duty or ultra-efficient vehicles, eligible component manufacturing and eligible engineering integration services. Stakeholders are interested in using our loan authority to support the growing demand for medium- and heavy-duty vehicles that use advanced or alternative technologies. We believe, based on the Advanced Technology Vehicles Manufacturing program's current accomplishments, that we can catalyze the deployment of zero-emission technologies such as hydrogen, to fuel medium- and heavy-duty vehicles, and the next generation of passenger vehicles, if statutory changes are enacted.

Q4. Model Building Codes for EV Charging Infrastructure

I'm very interested in model building codes for installing electric vehicle charging systems, especially for multi-unit housing and urban parking structures as a way to reduce the cost. Is there work at DOE to establish Model Building Codes for EV charging infrastructure? What assistance does the Department of Energy currently provide to states, localities, and tribes seeking to pursue EV charging deployment initiatives?

A4. The Building Technologies Office (BTO) is an active participant in industry processes to develop model building energy codes, including the International Energy Conservation Code (IECC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1, which are administered by the International Code Council (ICC) and ASHRAE, respectively. DOE is directed to seek adoption of energy efficiency measures that are technologically feasible and economically justified (42 USC 6836) and provide technical assistance to states implementing energy codes (42 USC

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6833). While BTO participates in these processes, it is important to note that DOE does not directly promulgate or enforce building codes.

Through this role, BTO supports advanced technology integration through building energy codes, including infrastructure for EV charging (and EV-“readiness”). BTO coordinates with other technology offices at DOE and across the Office of Energy Efficiency & Renewable Energy (EERE), such as the Vehicle Technologies Office (VTO), on issues related to building codes and EV charging. As a national example, ASHRAE Standard 189.1, the Standard for the Design of High-Performance Green Buildings, includes provisions for EV charging. Provisions related to EV charging were also considered for the IECC, the national model energy code. While these proposals did not prevail for the most recent edition, the 2021 IECC, they are expected to be considered by the ICC again for future editions.

DOE also manages the Alternative Fuel Data Center (AFDC) which provides technical information and tools that states, localities, and tribes can utilize when pursuing EV charging deployment initiatives. The AFDC contains information on EV charging infrastructure deployment best practices, laws and incentives, case studies, and publications.⁶ The AFDC station locator provides locations of electric vehicle charging stations nationwide. DOE manages a network of Clean Cities coalitions in communities across the country that engage in discussions to help states, localities, and tribes develop and implement EV charging deployment initiatives. The Clean Cities coalitions provide a local connection to DOE National Laboratory technical assistance, participate in EV charging planning activities to identify priority locations for charging infrastructure, make connections with local EV charging manufacturers, identify funding opportunities, and assist applicants with funding applications. Clean Cities coalitions also partner with state DOTs and metropolitan planning organizations to develop and nominate electric

⁶ https://afdc.energy.gov/fuels/electricity_infrastructure.html

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charging corridors in partnership with the FHWA alternative fuel corridor designation initiative. Through the competitive FOA process, DOE is funding multiple projects that will deploy EV charging infrastructure in partnership with states and localities such as the EV Community Partner projects.

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QUESTIONS FROM SENATOR LISA MURKOWSKI

- Q1. Commercial fishing is a key industry for Alaska, and fishing vessels are the backbone of the majority of our coastal economies. Communities like Sitka want to convert their fishing fleets to hybrid electric propulsion to reduce their reliance on costly diesel fuel and maintain a healthy ocean ecosystem. The challenges that non-interconnected communities in Alaska face in improving their existing fishing vessels and infrastructure is compounded by last year's dismal fishing season and the COVID-19 pandemic. Initiatives like National Renewable Energy Lab's Energy Transitions Initiative Partnership Project will help communities transform their energy systems by leveraging the expertise and experience of local stakeholders and the federal government. What else can the Department of Energy do to promote rural and islanded infrastructure improvements?
- A1. Vs mustn't be a luxury, but an affordable and accessible choice for all Americans. EERE's Vehicle Technologies Office's Technology Integration Program supports a broad technology portfolio that can reduce transportation energy costs for businesses and consumers, including in rural areas, but does not currently have any deployments on electrifying marine transportation.

On April 20, the Department of Energy's (DOE's) Energy Transitions Initiative Partnership Project (ETIPP) announced it will work with 11 remote and island communities around the United States to provide Federal assistance to bolster their energy infrastructure, reduce the risk of outages, and improve their future energy and economic outlook. New communities will be able to apply under the second round of ETIPP federal assistance in Fall, 2021. While ETIPP helps communities, like Sitka, plan and implement community-driven energy transitions, ETIPP is part of a larger ecosystem under the broader Energy Transitions Initiative (ETI), which has worked with island and remote communities for over a decade to support community-driven clean energy transitions through technical assistance on integrated planning and deployment, and local capacity building.⁷ Based on lessons learned and needs revealed through ETI's

⁷ <https://www.energy.gov/eere/energy-transitions-initiative>

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partnership engagements with island and remote communities in Alaska, Hawaii, Puerto Rico, the U.S. Virgin Islands, the Commonwealth of the Northern Mariana Islands, Guam, Maine, New Hampshire, North Carolina, and the Caribbean, ETI has developed:

- Tools, data sets, and training for energy modeling and decision support, such as Engage.⁸
- Discussion papers, disaster recovery resources, and design briefs to support community and stakeholder discussions.
- The Energy Resilience Playbook, a recently updated proven and phased framework to guide community-driven transitions to clean, resilient energy.⁹

DOE is currently exploring opportunities to leverage ETI's community-driven approach and expand federal assistance for rural and islanded infrastructure improvements as well as other community types.

The Office of Electricity (OE) Microgrid program develops technologies to interconnect electricity infrastructure in isolated communities to share loads and generation resources to enhance the resilience of connected communities beyond the level that each individual community would achieve on its own. The interconnecting technologies have recently been evaluated for the upcoming tie-line between Alaska's St. Mary's and Mountain Village microgrids to operate as an integrated infrastructure network.

Also, DOE's Loan Program Office has a Tribal Energy Loan Guarantee Program (TELGP) that can provide up to \$2 billion in partial loan guarantees to support economic opportunities to tribes through energy development projects and activities. Under TELGP the Department can guarantee up to 90% of the unpaid principal and interest due on any loan made to a federally recognized Indian tribe or tribal energy development organization for energy development.¹⁰

Ensuring equitable access to EV charging for rural and remote communities will require coordination with utilities on electric service capacity and demand charges as well as investments in distributed energy resources.

⁸ <https://www.energy.gov/eere/engage-energy-modeling-tool>

⁹ <https://www.eere.energy.gov/islandsplaybook/>

¹⁰ For more information about TELGP is available at <https://www.energy.gov/LPO/TELGP>.

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- Q2. I am concerned that the U.S. is becoming more vulnerable to cyber-attacks as an increasing number of critical infrastructure and modes of transportation are connected to and supported by the grid. Diversity in the transportation fuel mix and electrification of the transportation industry has several benefits. However, we need to balance the electrification of the transportation sector while maintaining our cybersecurity posture. Are cybersecurity standards and norms keeping pace with the electrification and digitization of the transportation sector?
- A2. Building-in cybersecurity during the technology development phase is the best approach for cost effective cybersecurity investments. As we electrify our transportation system, we are executing a cybersecurity “defense in depth” approach in all aspects of the system from the vehicle, the charging stations, and the electric system. This comprises conducting penetration testing to identify and mitigate potential vulnerabilities in system design, monitoring of networks and systems, and supply chain testing of firmware and software (including identification of software bill of materials). Standards will play an important role in establishing a baseline for cybersecurity, but cybersecurity standards may struggle to keep pace with the evolving threats.
- Q3. How would a lack of electricity - like the recent power outages in Texas or California - affect the transportation sector, and was the transportation industry impacted by recent blackouts?
- A3. With any black/brown out, fuel delivery to the transportation sector is at risk because in most cases electricity is required to distribute the fuel, including for fuel pumps at filling stations and to keep operations and communications functions running.
- Q4. I believe there is great promise for the deployment of electric vehicles in Alaska, and some of our coastal communities are already embracing it. Communities such as Juneau have on a per capita basis one electric vehicle for every 76 residents, and the interest in purchasing electric vehicles isn’t limited to just Juneau. Cordova, a small fishing town and one of the 165 Alaskan communities that can only be reached by plane or boat, installed four electric charging stations to support just two electric vehicles. Communities across Alaska want to reduce their emissions and reliance on conventional fuel by purchasing electric vehicles but lack the necessary infrastructure to support electric

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vehicle deployment. Are there private-public sector partnerships that can support the installation of electric vehicle charging stations in Alaska?

- A4. Public-private sector partnerships are key for deploying electric vehicle charging in Alaska and across the U.S. and will be a focus of this Administration. DOE has a current proof-of-concept project with Anchorage's municipal Solid Waste Authority to explore how electric drive technology can work in the city's refuse truck and support truck fleets for example. This includes a grid-connected DC fast charging station with battery energy storage developed by a private-sector partner to address utility demand charges. This demonstration will be a visible encouragement for further development of public-private partnerships to expand electric vehicle use in Alaska. Also, communities across Alaska are encouraged to connect with the Vehicle Technologies Office's regular newsletters to be aware of any funding opportunities in this space for which they may be eligible. The DOE Vehicle Technologies Office engages local communities through its national network of Clean Cities Coalitions.¹¹ Over 75 coalitions are currently designated under the program representing nearly every state and covering 80% of the US population. Clean Cities Coalitions implement innovative transportation projects in communities across the country that help to address local/regional energy and air quality challenges.
- Q5. The majority of the time, Alaska is an afterthought when it comes to electric vehicle charging infrastructure. How can we install a comprehensive network of electric vehicle charging stations on Alaska's Railbelt electric grid to spur electrical vehicle deployment?
- A5. The Administration has set a goal to help install 500,000 EV charging outlets nationwide, including in rural areas that may not normally attract a commercially driven project. Our experience is that these communities are just as interested in clean energy solutions and we are committed to serving all of America as we help deploy new energy technology. DOE encourages Alaskan entities to take advantage of the best practices and experiences

¹¹ <https://cleancities.energy.gov/coalitions/>

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of other states that are creating charging station networks in their communities. Projects such as the recently-completed WestSmart EV effort to create a network of electric vehicle charging stations in Utah in collaboration with the local utility (PacifiCorp) can serve as guiding examples for similar collaborative efforts in largely rural states with dispersed populations. We would welcome an Alaska Clean Cities Coalition, however, there is currently none at present. The Clean Cities community would welcome dialogue to share information about how they have successfully worked with utilities to deploy electric vehicle charging. DOE has funded several FOA projects that address electric vehicle infrastructure in rural and cold-weather regions whose learnings would be relevant, including a project to deploy electric refuse trucks in Anchorage and a project to deploy electric shuttles and box trucks in Minnesota. Also, communities across Alaska are encouraged to stay connected with the Vehicle Technologies Office to be aware of any funding opportunities in this space for which they may be eligible.

Q6. Last year, mineral imports cost the U.S. \$177 billion. While this is a significant cost to the American taxpayer, it also presents an opportunity for the U.S. to capitalize on this growing market. Some reports estimate the global demand for graphite, lithium, and cobalt, key inputs for lithium-ion batteries, to increasing 450 percent by 2050. Given the importance of minerals to clean energy technologies and our reliance on imported minerals, how is the Department of Energy facilitating and prioritizing the domestic extraction and processing of critical minerals, including those that are produced as byproducts of a non-critical mineral?

A6. DOE continues to fund research, development, and demonstration to address risks in domestic critical mineral supply chains by diversifying the supply, developing substitute or alternative materials, and driving reuse, recycling, and more efficient use of critical minerals. In January 2021, DOE's Office of Energy Efficiency and Renewable Energy (EERE) announced the selection of 15 projects on field validation and demonstration, as well as next-generation extraction, separation, and processing technologies, for battery critical materials. This included four projects to pilot technologies at the demonstration scale to produce battery-grade lithium from claystone and geothermal brines as well as to

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produce battery-grade synthetic graphite at lower temperatures using novel furnace technology. The Critical Materials Institute (CMI), an Energy Innovation Hub led by Ames Laboratory, also selected two new R&D projects in the fall of 2020 titled, Improvements to Cobalt Beneficiation from Domestic Ore at the Iron Creek Deposit, Central Idaho, and Unlocking Missouri's Cobalt Potential, to improve the concentration of cobalt from unconventional domestic sources in partnership with industry.

- Q7. Currently the United States is reliant on a major supply of the critical minerals necessary for the further expansion of clean energy and battery technologies. Is DOE concerned that increased reliance on foreign supplies of critical minerals could affect our ability to meet clean energy goals?
- A7. President Biden's Executive Order on America's Supply Chains directs the Secretaries of Energy and Defense to submit respective reports within 100 days to identify risks in the supply chain for high-capacity batteries and critical minerals and other identified strategic materials. On March 26th, DOE published a notice for public comment in the Federal Register¹² and is currently supporting DOD's efforts to do the same for critical minerals. This will build on DOE's ongoing engagement with a wide range of stakeholders that include the USG, DOE national labs, academic, industry, and trade associations spanning domestic supply chains, and allied international partners like Natural Resources Canada (NRCAN) to understand risks to critical minerals supply chains and develop risk mitigation strategies to address them.
- Q8. In 2011 the prices of rare earth elements skyrocketed as China, who produced 97% of the world's rare earth elements at the time, cut its exports as the result of a trade dispute, which causes prices to soar. The U.S. is still heavily reliant on foreign sources for a number of minerals that are critical for renewable energy and battery technologies, how would the renewable energy and electric car industry be affected, if a similar situation that happened in 2011 occurred again today?

¹² <https://www.federalregister.gov/documents/2021/03/29/2021-06337/notice-of-request-for-information-rfi-on-risks-in-the-high-capacity-batteries-including-electric>

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A8. Efforts to diversify raw mineral production for lithium and rare earth elements have been successful, Australia ranked first in lithium (Li) and the U.S. ranked second in rare earth element (REE) mine production globally in 2020, but refinement of these critical minerals is almost entirely concentrated in China. Additionally, the U.S. does not have economically viable endowments of natural graphite or cobalt for commercial mining. We are taking steps to address these risks.

The U.S. is actively pursuing to partner with Canada to develop a North American battery supply chain to establish both raw mineral extraction and material refinement to mitigate the risk of supply disruption. We are working on similar efforts with Australia, and we are cooperating with Japan and the European Union to address these shared risks and to best leverage our collective resources.

Within DOE, we are addressing critical materials supply chain vulnerabilities through mitigation strategies, including diversifying supply; sourcing; developing alternatives and substitutes; and the reuse, recycling, and more efficient use of critical materials. This approach is included in the various DOE Critical Materials Strategies, the Federal Strategy on Critical Minerals.

Finally, DOE is utilizing its responsibilities under E.O. 14017, namely the 100-day report on Advanced Batteries, to specifically address the concerns regarding supply chains related to electric vehicles and energy storage. We are also supporting the DoD-led report on Critical Materials. Both of these reports will draw from work undertaken by the Federal Consortium on Advanced Batteries and other referenced initiatives to provide the nation with a clear-eyed diagnosis of our current supply chains, and present policy recommendations on how best to improve resiliency. Furthermore, these whole-of-government efforts to diversify supply chains will foster responsible sourcing practices.

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develop sustainable processing methods, advocate for rules-based markets, and meet our projected demands for EV production and a renewable energy future.

Q9. As we heard last week, conventional fuels, most notably natural gas, will continue to be a part of the nation's energy mix for years to come. With this in mind, there are only four methods of transporting fossil fuels from production sites to refineries – trucks, rails, ships, and pipelines. What is the safest and most environmentally friendly way to transport fossil fuels? Which method of transporting fuel is the most cost-effective?

A9. As you know, sub-surface pipelines transport the majority of liquid fuels from production to processing/refining within North America. When we think about meeting our energy needs it must be with a carbon lens rather than a resource lens. Pipelines can support the transport of low-carbon and zero-carbon fuels like hydrogen and thus have a role moving forward. We need to focus on the energy mix needed across the economy and then consider the most environmentally prudent, safest, and cost-effective mode of transport.

Q10. The transportation sector is a diverse and wide-ranging sector that includes physical infrastructure like highway and rail networks, airports, ports, navigable waterways, pipelines, and supporting facilities and communication networks as well as the people that operate and maintain them. Enhancing the resiliency and sustainability of the modes of transportation and physical infrastructure will require a robust supply of minerals to support the proliferation and domestic manufacturing of new technologies. Secretary Granholm has committed to reviewing the Department of Energy's strategy for addressing critical minerals and materials.

How does the Department of Energy plan to consult with the U.S. Geological Survey to coordinate efforts to mitigate vulnerabilities that threaten our nation's ability to manufacture and deploy clean energy technologies?

A10. DOE actively coordinates with the U.S. Geological Survey (USGS) through the National Science & Technology Council (NSTC) Critical Minerals Subcommittee (CMS). For example, through the NSTC CMS, DOE has provided input and review to the methodology USGS developed to update the federal critical minerals list. DOE's Office of Energy Efficiency and Renewable Energy also collaborates with USGS on Geoscience

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Data Acquisition for Western Nevada (GeoDAWN) to collect lidar and geophysical data to identify hidden geothermal resources and locate critical mineral deposits. DOE has also led the formation of a multi-agency Federal Consortium on Advanced Batteries (FCAB) that is developing a comprehensive U.S. plan for the battery supply chain. USGS is a key partner in that consortium.

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QUESTION FROM SENATOR MAZIE K. HIRONO

- Q1. You noted in your testimony that DOE is investigating technologies that maximize the ability of electric vehicles to flexibly integrate on the electric power grid with variable power sources like solar and wind and could effectively allow vehicle chargers to be managed as a grid asset. Could you elaborate on EERE's plans for research and development and demonstration projects on this topic?
- A1. The Department is currently conducting a scenario analysis to better understand the national impact of electrifying the transportation sector and understand the impacts this will have on generation. In 2019, the U.S. DRIVE partnership published a comprehensive report on how the grid is impacted by large numbers of EVs.¹³ The report found that based on historical growth rates, sufficient energy generation and generation capacity are expected to be available to support a growing EV fleet as it evolves, even with high EV market growth. We are also investigating how EVs can provide more system flexibility through managed charging and vehicle-to-grid charging. Finally, we are investigating the implications of necessary grid upgrades at the distribution level where fleet electrification will be taking place soon.

Furthermore, DOE has conducted extensive R&D on Smart Charge Management technologies and systems that will maximize the use of distributed energy resources and minimize potential impacts on the grid by enabling EVs to provide grid services. In Fiscal Year 2020, DOE announced three cooperative research agreements to conduct research, development, and wide-scale demonstrations of utility-managed Smart Charge Management Systems for grid integrated EV charging infrastructure.

¹³

<https://www.energy.gov/sites/default/files/2019/12/f69/GITT%20ISATT%20EVs%20at%20Scale%20Grid%20Summary%20Report%20FINAL%20Nov2019.pdf>

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QUESTIONS FROM SENATOR CATHERINE CORTEZ MASTO

- Q1. By transitioning away from diesel buses to electric buses, the United States could immediately improve the air our children breathe on their way to and from school. It could also help reduce health issues that result from emissions exposure and impede a student's ability to learn.

For these reasons, I recently introduced the Clean School BUS Act, which would establish a Clean School BUS Grant Program at the Department of Energy (DOE) to invest in charging infrastructure to replace diesel buses and leverage partnerships with local utilities.

- Q1a. How can DOE use its expertise to assist schools, especially those in disadvantaged school districts, with electric school bus deployment, infrastructure, and technical assistance?

- A1a. The transition to electric vehicles, including school buses, transit buses, and other heavy-duty vehicles, will be critical to achieving the Administration's climate goals. Beyond reducing GHG emissions, a co-benefit of transitioning to electric vehicles is reducing harmful local emissions regulated under the Clean Air Act. As we work to deploy these technologies, we will ensure that disadvantaged communities and schools are a strong focus.

DOE will continue to lead the R&D to develop batteries, motors, and charging technologies that make EVs affordable, minimize the use of critical materials, and decrease charging times. DOE has worked to develop electrified school bus technology, including the use of school buses for vehicle-to-grid applications, which can help school districts improve affordability and resilience in the case of power outages.

DOE manages the Alternative Fuel Data Center (AFDC) which provides technical information and tools that school districts and school bus operators can utilize to understand electric school bus technology and charging infrastructure. The AFDC

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provides electric school bus availability, locations of electric vehicle charging stations nationwide, case studies, videos, and publications.¹⁴

DOE manages a network of Clean Cities coalitions in communities across the country that engage in discussions to help school districts make more sound choices in electric transportation, including disadvantaged school districts. The Clean Cities coalitions connect school districts to technical assistance, resources, and funding opportunities. Under a DOE FOA award, Virginia Clean Cities is conducting electric school bus demonstrations throughout the mid-Atlantic to provide real-world operating experience in a variety of urban and rural environments. DOE is also collaborating with the National Renewable Energy Laboratory on a targeted electric school bus education and technical assistance program to provide training modules to inform school bus fleet managers and the broader school transportation community about important electric bus topics.

- Q2. Many countries are investing in zero-emissions transportation to help build back their economies and respond to future global consumer demands as the world works to reduce transportation emissions in sectors like aviation, trucking, and maritime.

From research and development to commercial applications, DOE's Loan Program Office has been a key asset for companies working to pursue innovative technologies in transportation.

What steps is DOE taking to ensure that the Loan Program Office continues to spur innovation in the transportation sector?

- A2. Under current law, the Loan Programs Office is limited to financing manufacturing of eligible light-duty or ultra-efficient vehicles, eligible component manufacturing and eligible engineering integration services. To date, the ATVM program has issued more than \$8 billion in loans including successful loans to Ford Motor Company, Nissan North America, and Tesla Motors. ATVM projects have produced over 20 million cars, avoided

¹⁴ <https://afdc.energy.gov/vehicle-applications/school-transportation>

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a cumulative 25 million tonnes of CO₂, displaced 2.8 billion gallons of gasoline, and supported approximately 35,000 direct jobs across eight states, including California, Illinois, Michigan, Missouri, Ohio, Kentucky, New York and Tennessee. We believe, based on ATVM's current accomplishments, that we can catalyze the deployment of zero-emission technologies such as hydrogen, to fuel medium- and heavy-duty vehicles, and the next generation of passenger vehicles, if statutory changes are enacted. Moving forward, we will continue to focus on outreach and business development to seek out innovation in transportation sectors from companies that could benefit from our loans.

- Q3. Electric vehicles, especially medium- and heavy-duty vehicles, will be able to connect to the grid when not in use and assist with any load balancing or intermittency issues.
- Q3a. How can DOE help facilitate the education, training and cooperation needed between fleet operators, utilities, and grid operators to rapidly develop this potential?
- A3a. DOE continues to work on facilitating education, training, and cooperation regarding electric vehicles and has been conducting a workshop series entitled "Voices of Experience, An EV Future: Navigating the Transition", which has held 27 webinars with utilities, fleet operators, and other EV stakeholders to share and collect information on the integration of EV and charging infrastructure with the grid. Information from these webinars will be included in an educational publication for EV stakeholders that DOE plans to publish this year. DOE's funding opportunities and Clean Cities deployment efforts are designed to implement and facilitate education, outreach, and training projects focused on helping to accelerate the adoption of alternative fuels and other advanced vehicle technologies. These activities include workshops aimed at reducing barriers, sharing best practices, and identifying workforce development opportunities as well as coordinating with public safety officials, key stakeholders (like utilities), and essential industry allies. The national network of Clean Cities coalitions provides an efficient way to rapidly form alliances, disseminate critical information, and provide technical assistance.

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- Q4. How can the United States best prepare its workforce for future transportation technologies?
- A4. DOE's Office of Energy Efficiency and Renewable Energy (EERE) is particularly interested in developing a strong workforce trained in emerging technologies in the renewable power, sustainable transportation, and energy efficiency sectors, along with the fundamental science, research, and engineering to feed them. As one example, DOE has invested \$20 million in workforce development in emerging fields at the University of Tennessee (UT). DOE's investment in UT, Tennessee's flagship land-grant university, expands the University's partnership with Oak Ridge National Laboratory (ORNL) through the Oak Ridge Institute (ORI). Throughout the five-year interdisciplinary program, participating students will focus on research and development in evolving technical fields, including resilient energy systems, electrochemical energy systems, advanced science and engineering of materials and manufacturing, and predictive system biology for circular and sustainable economies.

DOE also recently announced five awardees in the Education Materials for Professional Organizations Working on Efficiency and Renewable Energy Developments (EMPOWERED) FOA focused on emergency response and resilience planning and safe DER building integration. The EMPOWERED funding program is a collaborative effort across the Solar Technologies Office (SETO), the Vehicles Technologies Office (VTO), and the Building Technologies Office (BTO). This program will provide educational materials and training resources for first responders, safety officials, and building managers and owners so they can be prepared to manage new energy technologies and continue their work safely and effectively.

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QUESTION FROM SENATOR CINDY HYDE-SMITH

- Q1. The Department of Energy has supported research and development (R&D) of advanced materials for use in transportation. DOE has also recognized the role that innovative materials play in the transition to a more connected, automated, and advanced propulsion future for vehicles as well as the potential economic development and high-skilled job creation associated with the manufacture of these materials and vehicles in the U.S. In particular, plastics and polymer composites manufactured in the United States have numerous applications for use in vehicles of the future and the infrastructure that will support them, from safely offsetting the weight of heavy vehicle features that enable advanced propulsion and automation, to housing the charging infrastructure that will enable increased deployment of electric vehicles. How will EERE continue to invest in R&D to support the U.S. manufacturing base of lightweight plastics and polymer composites in vehicle and infrastructure applications, including opportunities for advanced recycling of these components to enable increasing circularity in vehicle design?
- A1a. EERE's Vehicle Technologies Office (VTO) will continue to fund research on low-cost carbon fiber and lightweight, innovative polymer composites that make vehicles more efficient. The research will be funded through competitively selected and awarded funding opportunities that are open to industry and academia as well as direct-funded research conducted at the National Laboratories. On-going VTO funded research at five national laboratories includes novel efforts to improve the recyclability of polymer composites. The Carbon Fiber Technology Facility at Oak Ridge National Laboratory (ORNL) will continue to assist U.S. companies in scaling up the production of high-quality, low-cost carbon fiber. Also, two recent FOA awards on multi-functional polymer composites for automotive applications include team members from across the polymer composite manufacturing supply chain. We expect polymer composites to continue to play an important role in decreasing the weight of electric and autonomous vehicles by integrating composite structural materials with multi functionalities to minimize part counts, reduce costs, and enable new manufacturing processes and vehicle designs. EERE continues to invest in polymer composites research and development with projects at DOE's Manufacturing Demonstration Facility (MDF) and Carbon Fiber Technology

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Facility (CFTF) at Oak Ridge National Lab's (ORNL). The MDF is a world leader in additive manufacturing research and development. The CFTF is focused on developing low-cost carbon fiber precursor alternatives and the processing needs to make carbon fibers with highly desired mechanical properties. The Advanced Manufacturing Office (AMO) is also working to tackle the problem of composite recycling. AMO has made several recent investments, including projects in the BOTTLE Consortium and BOTTLE FOA, the Institute for Advanced Composites Manufacturing Innovation (IACMI), the Clean Energy Manufacturing Innovation Institute for Reducing Embodied-energy And Decreasing Emissions (REMADE) Institute, and with projects at the Department of Energy National Labs that are primarily focused on designing new polymers that are more easily recycled and removed from fibers and establishing and demonstrating novel processes for using shortened fiber for multi-cycle recycling.

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QUESTIONS FROM SENATOR ROGER MARSHALL

- Q1. What impact does biodiesel and renewable diesel have on decreasing the United States' carbon footprint?
- A1. Different feedstocks and upgrading pathways will have different greenhouse gas reduction potentials. Renewable diesel production from fats, oils, and greases can reduce emissions by 70 - 80% compared to a petroleum baseline. Utilizing different woody feedstocks such as forestry residues or woody energy crops such as hybrid poplar may result in emissions reductions of up to 90%. Additional pathways under investigation in the DOE Bioenergy Technologies Office have the potential to improve further on these reductions and greatly reduce transportation sector emissions.
- In total, 900 million gallons of renewable diesel were used in the United States in 2019 according to the Energy Information Administration. The U.S. total market for diesel was 47 billion gallons in 2019, suggesting a potential for more emissions reductions if the national capacity for producing renewable diesel were expanded. Renewable diesel can be used on its own as fuel or blended into petroleum diesel depending on the application.
- Q2. Does the Department of Energy have data showing the carbon footprint of building an electric vehicle compared to building a vehicle with a traditional internal combustion engine? How is it measured?
- A2. DOE funds Argonne National Laboratory's GREET model (Greenhouse Gases Regulated Emissions and Energy in Technology) for characterizing the life cycle energy and emissions for light-, medium- and heavy-duty vehicles. The life cycle tool has various stages: the vehicle production stage which estimates the energy and emissions of extracting materials and building the vehicles; the well-to-pump (WTP) stage which estimates the energy and emissions associated with producing fuel/energy to power the vehicle; and the pump-to-wheel stage which is the vehicle usage stage). More information about GREET is available at <https://greet.es.anl.gov/index.php>. In 2016,

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using GREET, the U.S. DRIVE partnership conducted a comprehensive analysis of multiple vehicle technologies, calculating the total life-cycle emissions including the production of fuels, production of vehicles, and the emissions during vehicle use. Overall, battery electric vehicles reduce emissions by approximately 20-30% compared to a similar midsize gasoline vehicle. This percent improvement will also increase over the life of a vehicle as the emissions from electricity production go down.

- Q3. Does the Department of Energy have data showing the carbon footprint of building an electric vehicle compared to building a vehicle using biodiesel or renewable diesel? How is it measured?
- A3. In 2016, using GREET, the U.S. DRIVE partnership conducted a comprehensive analysis of fuels and vehicles and found that biodiesel vehicles reduce total life-cycle emissions by approximately 15% compared to a similar midsize gasoline vehicle. One of the benefits of using renewable diesel or biodiesel is being able to use it in existing diesel engines. Therefore, the difference between the vehicle production emissions of a biodiesel and renewable diesel vehicle and those of a similar conventional diesel vehicle is negligible.¹⁵
- Q4. Does the Department of Energy have data showing the carbon footprint of the entire lifecycle of an electric vehicle compared to the carbon footprint of the entire lifecycle of a vehicle with a traditional internal combustion engine? How is it measured?
- A4. In 2016, using GREET, the U.S. DRIVE partnership conducted a comprehensive analysis of fuels and vehicles and found that electric vehicle emissions are slightly higher than gasoline vehicles during production and significantly lower during operations. Overall, battery electric vehicles reduce emissions by approximately 20-30% compared to a similar midsize gasoline vehicle.¹⁶

¹⁵ <https://greet.es.anl.gov/publication-c2g-2016-report>

¹⁶ <https://greet.es.anl.gov/publication-c2g-2016-report>

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- Q5. Does the Department of Energy have data showing the carbon footprint of the entire lifecycle of an electric vehicle compared to the carbon footprint of the entire lifecycle of a vehicle using biodiesel or renewable diesel? How is it measured?
- A5. In 2016, using GREET, the U.S. DRIVE partnership conducted a comprehensive analysis of fuels and vehicles and found that electric vehicles reduce total life-cycle emissions by 5–20% compared to similar biodiesel vehicles (BD20).¹⁷
- Q6. How do we measure the environmental impact of disposing of the batteries of electric vehicles?
- A6. The environmental impacts of batteries are typically associated with their first use. To address battery recycling and reuse challenges, DOE launched the ReCell Center in February 2019. This research center is leading research projects that aim for cost-effective lithium-ion battery recycling so valuable battery components such as cobalt and nickel compounds don't go to waste. Advancing lithium-ion battery recycling will ultimately bring down the cost of electric vehicle batteries for consumers and reduce our reliance on foreign sources of these materials.
- Q7. Do you have a different accounting method for carbon released as a part of the natural carbon cycle vs carbon released from mined carbons?
- A7. CO₂ emissions from fossil-based fuels (the mined carbons) are fully accounted for in GREET, as in other LCA models and emissions accounting schemes, and do not account for carbon released as part of the natural carbon cycle.

¹⁷ <https://greet.es.anl.gov/publication-c2g-2016-report>

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Questions from Chairman Joe Manchin III

Question 1: In your testimony, you stated that your company converts 8,000 used lead-acid batteries every hour of every day to build new batteries with up to 90 percent recycled content. You also mention the importance of consumer education in returning lead-acid batteries which is a big reason for the high recycling rate of lead-acid batteries. Given the sheer size of an EV battery compared to a lead-acid battery, I think we are in a whole new ball game and am concerned this is one of the factors contributing to the low recycling rate of lithium-ion batteries.

a. What worked to get the lead-acid battery recycling so high that it can be applied to lithium-ion recycling?

Right now, in the U.S. we have a 99% recycle rate of lead-acid batteries. This is accomplished through a balance of several factors; product and design, scale and volume, government regulations, recycling technology, standards logistic planning.

Clarios has established one of the world's most successful examples of a circular economy – designing, making, transporting, recycling and recovering vehicle batteries using more sustainable methods. We produce batteries in North America and Europe containing more than 80% recycled material. The reuse of metals from used batteries results in 99% fewer greenhouse gas emissions than processing primary ore. Using recycled plastics consumes 90% less energy than processing virgin plastic. Our reverse logistics network also reduces transportation miles.

We design our batteries to not only be recyclable, but to ensure the maximum amount of materials can be recovered to be reused to make new batteries. We make decisions in the design process to ensure circularity – not just for our products but our logistics and business design. We need the scale and volume to make the economics work; therefore, we have built into our agreements with our customers, feedbacks so that as we deliver new batteries to them, we get used batteries in return. Critical on top of this are government policies. Core fees (battery deposits) ensure that there is an incentive for people to bring their battery back. In almost every state when you buy a new battery, they either charge you a deposit fee or take your old battery. This supports reuse of materials in our cycle, and compliments government regulations that prohibit unlawful disposal of lead-acid batteries in landfills. The cycle depends on a careful balance and iteration of these factors. But this also means the cycle requires this balance to be monitored and maintained.

We are learning through our work with the Department of Energy (DOE) that it is essential to figure out the logistics channels as end-of-life (EOL) lithium-ion batteries will have different scenarios and physical locations to be collected than lead acid batteries. We have proposed a concept to address this need that includes service centers, auto scrap yards, manufacturing scrap collectors and processors, accidents and disaster recovery, and aftermarket retailers.

We are also learning that not all automotive lithium-ion batteries will experience the same EOL situation—some may be ready to be recycled, but some may be re-routed for second-life applications. As automotive

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lithium-ion EOL batteries will still retain 80% capacity and be good for other applications, it is important to coordinate innovations in the second-life applications and define the automotive 1st life ending and the “forever-life” ending. We also believe the best second life for purpose designed battery packs for vehicles is back in use in the vehicles they were used in after refresh or remanufacturing.

The logistics need to be built to address these complexities. For example, for the safe transport of used batteries, we need to have a solution to diagnose and sort those EOL lithium-ion batteries. Having innovative ways to diagnose whether a battery should be recycled or should be re-used in another application – across battery types and chemistries – will be key to building up and applying efficient logistics and transportation.

b. Who should be responsible for the removal and retrieval of EV batteries at the end of their useful life in a vehicle to ensure they are recycled? Given their size, this may be a heavy burden to place on consumers alone.

In the United States, policy and government regulations help guide this process. Most U.S. states have core fee laws (battery deposits), which ensure that there is an incentive for people to bring their battery back. In almost every state, when you buy a new battery, they either charge you a deposit fee or take your old battery. This supports reuse of materials in our cycle, and compliments government regulations that prohibit unlawful disposal of lead-acid batteries in landfills. This system create a financial incentive for the customer (or other logistical partner, such as a scrap collector) to return the battery – and for auto repair shops and aftermarket retailers to assume the logistical burden from the customers and collect these batteries for return. Government regulations that create the incentive for used batteries to be returned into the supply chain are critical to a circular economy.

Questions from Ranking Member John Barrasso

Question 1: To what extent is the electric battery manufacturing industry concerned about the child labor, human rights abuses, and local environmental degradation connected to the overseas production of minerals necessary for battery-powered electric vehicles?

Question 2: What, if any, specific steps are electric battery manufacturers taking to ensure they do not use minerals that are connected to child labor, human rights abuses, and local environmental degradation?

(Answer to Senator Barrasso 1 & 2)

Clarios is a member of the World Economic Forum’s Global Battery Alliance (GBA) “to catalyse, connect and scale-up efforts to ensure that the battery value chain is socially responsible, environmentally and economically sustainable and innovative.” To help companies and governments, the Global Battery Alliance designed 10 guiding principles for the creation of a sustainable battery chain by 2030. 42 organizations, including businesses from mining, chemicals, battery, automotive and energy industries, representing annual revenue of close to a

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trillion dollars, along with international organizations and global NGOs, have agreed on the 10 guiding principles.

These principles are intended as the first step in a responsible, sustainable battery value chain as set out in the GBA's "A Vision for a Sustainable Battery Value Chain in 2030". Implementing commitments will be based on existing standards such as the Organisation for Economic Co-operation and Development (OECD)'s Due Diligence Guidance and economically viable considerations for a circular and low carbon economy.

They include maximizing the productivity of batteries, enabling a productive and safe second life use, circular recovery of battery materials, ensuring transparency of greenhouse gas emissions and their progressive reduction, prioritizing energy efficiency measures and increasing the use of renewable energy, fostering battery-enabled renewable energy integration, high quality job creation and skills development, eliminating child and forced labor, protecting public health and the environment and supporting responsible trade and anti-corruption practices, local value creation and economic diversification.

The GBA is currently developing an initiative to immediately and urgently eliminate child and forced labor from the cobalt value chain, contribute to the sustainable development of communities, and respect the human rights of those affected by the cobalt supply chain.

Question 3: The 2019 UNCTAD report *Commodities at a Glance - Special issue on strategic battery raw materials* found that even if manufacturers are able to overcome existing challenges in recycling lithium-ion batteries, more mining will be necessary. Would increasing mineral production here in the United States help electric battery manufacturers responsibly obtain the minerals they need?

Much attention has rightly focused on ensuring supplies of critical minerals through domestic resource development and partnerships with mineral-producing countries. However, to complement these efforts, we need a U.S.-based advanced battery design, manufacturing, and recycling program — a true "battery economy" initiative, that takes the entire lifecycle into account — from initial extraction of minerals, to design and manufacturing, through lifetime use, collection and then recycling.

This would give us greater leverage in choosing from whom the U.S. buys raw battery materials, while also increasing our domestic materials refining and cell production capabilities. The policy of the U.S. should be to move toward creating a domestic "battery economy" by owning or controlling the process of making cells and batteries, here in the U.S.

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Questions from Senator Steve Daines

Question 1: In order to increase electric vehicle production you have to also increase the domestic development or the importation of critical minerals to build the batteries and components needed to deploy more EVs. If responsible production does not happen in the U.S. it will happen in countries with worse environmental and labor standards. For example, the Democratic Republic of the Congo produces the vast majority of the cobalt that is used in EV batteries.

- a) How can the U.S. reverse this and bring back domestic production and manufacturing of critical minerals?
- b) Does it concern you that the U.S. is reliant on foreign countries for critical minerals used in the transportation industry?
- c) How is the supply chain affected when we rely on China and foreign countries for critical minerals?
- d) We have seen recent moves by China to restrict Rare Earth Elements exports. Has this or will this affect EV production?
- e) What are the key critical minerals needed to reduce emissions in the transportation industry?

Today, the U.S. is heavily dependent on foreign sources of raw materials and battery components for lithium-ion batteries. China dominates lithium sourcing, refining, and cell manufacturing, accounting for approximately 75 percent of global li-ion battery production, and 92% of the global lithium supply chain. Today, even a U.S.-built EV battery is made predominantly of materials and components sourced from China or china-owned businesses.

This has profound implications for the future of EVs and stationary storage. It is also concerning from geopolitical standpoint – we do not want to build a new ecosystem in which the United States is dependent on foreign resources. The implications are that trade and other political disputes could have widespread supply chain impacts. The US should take deliberate action to ensure a sustainable and reliable supply chain for battery critical materials.

Much attention has rightly focused on ensuring supplies of critical minerals through domestic resource development and partnerships with mineral-producing countries. These are important and critical steps. However, to complement these efforts, we need a U.S.-based advanced battery design, manufacturing, and recycling program — a true “battery economy” initiative, that takes the entire lifecycle into account – from initial extraction of minerals, to design and manufacturing, through lifetime use, collection and then recycling.

This would give us greater leverage in choosing from whom the U.S. buys raw battery materials, while also increasing our domestic materials refining and cell production capabilities. The policy of the U.S. should be to move toward creating a domestic “battery economy” by owning or controlling the process of making cells and batteries, here in the U.S.

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Questions from Senator Lisa Murkowski

Question 1: Mr. Muellerweiss, your testimony states that battery recycling is an economic driver, which can protect our domestic supply chain of minerals. What about the recycling of electronics that contain critical minerals to retain these highly valued and limited resources?

Factors such as resource availability, geopolitical implications, supply-chain risk, human and environmental impacts, domestic manufacturing capacity, and recyclability should be key considerations across all technology development. The lessons learned from existing closed-loop, circular systems, can and should be applied across industries. Clarion looks forward to working with this Committee, the Department of Energy, and other industries to enable best practices, policies and solutions that will protect our supply chains, the environment, and people.

Question 2: The Backhaul Alaska Program is transforming the way Alaska's rural communities dispose of potentially hazardous waste material, including used lead-acid batteries. The program is helping to improve the health of local communities, mitigate environmental impacts from traditional waste removal processes, and protecting subsistence resources. I'm excited that more of Alaska's villages are participating in the Backhaul Alaska Program. Can you share the feedback you have received from the villages that have participated in the program?

Overview of the Back-Haul Alaska Program/PSA

1-minute PSA

<https://www.youtube.com/watch?v=UOOCBpqPaaQ>

4-minute PSA

<https://www.youtube.com/watch?v=zdP1CYhV3eq>

Feedback from villages that have participated in the Backhaul Alaska Program

Scammon Bay is a traditional Yup'ik community in Western Alaska that relies on fishing and subsistence activities. They are a Backhaul Alaska Pilot 2 community and attended the May 2019 training. See this video link for a statement from Homer Hunter from Scammon talking about how the training and program is helping his community and what he has learned about packaging hazardous materials.

Video and Transcript: https://www.rev.com/transcript-editor/Edit?token=tzCuBPPmevyJ-dH4vlig7d8QqWKbpxQmVV4jSm9gsil0PVR0z2M5MRYFixmfvbzi1XBM7vHupXsOb95KJYE_6M_vfb4&loadFrom=DocumentDeeplink&ts=0.34

Vanessa Tahbone is a Backhaul Alaska Regional Coordinator from Nome, Alaska. See this video to hear how the Backhaul Alaska program and training has helped Vanessa as a Regional Coordinator and the communities that her organization serves and the health and environmental benefits she sees from the program. **Video and Transcript:** <https://www.rev.com/transcript-editor/Edit?token=b-70FqebH->

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qFoinYb4fP7kg6WNPJEzwPX6ggltu2EPb86ZkhPcDOIYvtXChCOflm_nJTU4GC-TODRtOTJKuFXhX9l&loadFrom=DocumentDeepLink&ts=178.14 Kwigillingok is a traditional Western Alaska Yup'ik community. They are a Backhaul Alaska Pilot 2 community and attended the May 2019 training. See this video for a statement from Darrel John on the difficulties of shipping out of rural Alaska, and the positive impact the Backhaul Alaska program is having on their community. Video and Transcript: https://www.rev.com/transcript-editor/Edit?token=JnQxoHl0d88XlmVg-rVTcyOB5e00dlBp8XzYWDHKaxIvgWdarZZNOJU6NAceHb90i0Akq1SotVAaF9-QyIwcng8EZr0&loadFrom=DocumentDeepLink&ts=1.76 Pedro Bay is a Dena'ina Athabascan village with a subsistence lifestyle. See these video clips from Carla Jensen describing how the Backhaul Alaska training has helped her and their community. (Video only (no transcript)) http://www.zendergroup.org/docs/pedro1.mp4 http://www.zendergroup.org/docs/pedro2.mp4 Martha Turner is a Backhaul Alaska Regional Coordinator from Nulato, Alaska and has received training and supplies through the program. Nulato is an Athabascan village of 259 people. It lies on the Yukon River and is accessible only by small plane or summer barge. See this video for a statement from Martha on how the Backhaul Alaska Program has helped their community. Video: http://www.zendergroup.org/BAPP/nulato.mp4 Transcript: Backhaul Alaska has helped me a lot with the trainings that I attended and it has educated me and I'm a lot more knowledgeable on what's safe and not safe. Our plans this summer are waiting for the snow to melt and we're ready to start palletizing our E-waste and lead acid batteries. We've inventoried everything we know where everything is at and we are ready. We got all the supplies from Backhaul Alaska and we met with the City and we are ready to get everything out on the first couple of barges this year. Antonio Sisto is the Backhaul lead for Arctic Village which is a Backhaul Alaska Pilot 1 community and has received training, supplies, and Backhaul through the program. Arctic Village is a Gwich'in Athabascan village of 152 people. See this video for a statement from Antonio on how the Backhaul Alaska Program has helped their community. Video: http://www.zendergroup.org/BAPP/arctic.mp4 Transcript: (The Backhaul Alaska Program) helped us out a lot and trained me up on learning how to package and label and how to get stuff out properly. Before we didn't have a clue of how to get things out on a plane, MSDS was a big issue - Everts Air would get mad. Now we have an inventory and we know how to write the codes for MSDS and packaging and we know the right way to get stuff out. Helped us out a lot and it's a big learning tool and will help us out in the long run to get more stuff out because we have the knowledge now.
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Quotes from Backhaul Alaska Pilot 1 and 2 Communities:

- Scammon Bay: "I'll be able to properly package the hazardous waste or electronics the right way. That's something I have never done before." "We were so happy when we got an email that we are in the pilot

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two program...We have about 120 homes and more than half own a boat, ATVs, and snow machines. They all contain batteries."

- Ashik: "Our community's a fishing community, so keeping all that hazardous stuff from getting into the land will help with keeping subsistence and commercial fishing healthy...In 10 years everybody in community will have a better understanding of why these things are hazardous for our health and our land."
- Iliamna: "We want to be able to get it out of the village. You guys are going to help us get that out of our village ... Hopefully the backhaul will last forever. We will be able to clean out our dump from all the batteries and the e-waste."
- Noorvik: "Everybody's got 4 wheelers, trucks, and boats. We've got lots of batteries. Sometimes we find batteries burned in the landfill...It will leech out to our subsistence areas. We have a situation that is not healthy. That is not protecting our land. I think backhaul Alaska will help to get the hazmat out of our community."
- Ouzinkie: "We have gotten rid of so many batteries and so much more keep coming in...There is a lot of e-waste. You see that pile over here. We've had three or four of those kinds of piles and they just keep coming."
- Old Harbor: "We are a fishing community. A lot of the boats and vessels that come through actually leave their lead-acid batteries for us... It's helping me see other entities are getting involved in being responsible for some of the materials we do receive. Earlier this week a new signing of an MOU, which was greatly appreciated. It's nice to see there's partnerships out there that we can reach out to."
(Referring to the partnership with the Responsible Battery Coalition)
- Kwigillingok: "The Backhaul Alaska program has had huge impact to our land and our landfill. It has reduced the amount of hazardous waste entering our landfill and has helped clean up the environment. It has also helped our organizations save program dollars of these costs. It has had lot of positive impact to our tribe."
- Nome: "I believe that Backhaul Alaska has potential to reach communities that are generally neglected. Small rural communities have a lot of love for their communities and their children. They think about the next generation. They're the heart of Alaska. With this Backhaul Alaska program we're going to reach those communities. Show them that we are stewards of this land and take care of it."
- Hooper Bay: "At one time, somebody burned a few years ago those hazardous wastes. The wind blew the smoke in when they were drying fish on fish rack outside. They had to throw out the catch of about 100 fish hanging out to dry. Sad...We had old used convex vans and stored the hazardous materials in there like florescent lights, electronic waste and batteries."
- Unalaska: "We have about 12 years left on our landfill. According to ADEC, there is not another suitable place to put new one. We have just 12 short years. We've got to figure out how to do the recycling and getting stuff taken care of and taken back off the island."

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Questions from Senator Mazie Hirono

Question 1: What is your company learning as a participant in the Department of Energy's Lithium-Ion Battery Recycling Prize that could allow it and other businesses to scale up collection and recycling of lithium ion batteries?

Right now, in the U.S. we have a 99% recycle rate of lead-acid batteries. This is accomplished through several factors: product and design, scale and volume, government regulations, recycling technology, standards logistic planning.

Clarios has established one of the world's most successful examples of a circular economy – designing, making, transporting, recycling and recovering vehicle batteries using more sustainable methods. We produce batteries in North America and Europe containing more than 80% recycled material. The reuse of metals from used batteries results in 99% fewer greenhouse gas emissions than processing primary ore. Using recycled plastics consumes 90% less energy than processing virgin plastic. Our reverse logistics network also reduces transportation miles.

We design our batteries to not only be recyclable, but to ensure the maximum amount of materials can be recovered to be reused to make new batteries. We make decisions in the design process to ensure circularity – not just for our products but our logistics and business design. We need the scale and volume to make the economics work; therefore, we have built into our agreements with our customers, feedbacks so that as we deliver new batteries to them, we get used batteries in return. Critical on top of this are government policies. Core fees (battery deposits) ensure that there is an incentive for people to bring their battery back. In almost every state when you buy a new battery, they either charge you a deposit fee or take your old battery. This supports reuse of materials in our cycle, and compliments government regulations that prohibit unlawful disposal of lead-acid batteries in landfills. The cycle depends on a careful balance and iteration of these factors. But this also means the cycle requires this balance to be monitored and maintained.

We are learning through our work with the Department of Energy (DOE) that it is essential to figure out the logistics channels as end-of-life (EOL) lithium-ion batteries will have different scenarios and physical locations to be collected than lead acid batteries. We have proposed a concept to address this need that includes service centers, auto scrap yards, manufacturing scrap collectors and processors, accidents and disaster recovery, and aftermarket retailers.

We are also learning that not all automotive lithium-ion batteries will experience the same EOL situation—some may be ready to be recycled, but some may be re-routed for second-life applications. As automotive lithium-ion EOL batteries will still retain 80% capacity and be good for other applications, it is important to coordinate innovations in the second-life applications and define the automotive 1st life ending and the “forever-life” ending.

The logistics need to be built to address these complexities. For example, for the safe transport of used batteries, we need to have a solution to diagnose and sort those EOL lithium-ion batteries. Having innovative

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ways to diagnose whether a battery should be recycled or should be re-used in another application – across battery types and chemistries – will be key to building up and applying efficient logistics and transportation.

Question 2: What proportion of electric vehicle or grid-serving batteries does the Responsible Battery Coalition estimate it could feasibly be collected and recycled at the end of their lives?

The goal should be that 100% of batteries are collected and recycled ideally with the goal of recovering materials to make new batteries. The RBC is funding a joint research project with Argonne National Laboratory to ensure that the batteries of tomorrow are designed for maximum recyclability. The goal is to generate detailed information to help battery manufacturers design batteries with re-use and recycling in mind. The project aims create a platform to provide the battery industry the ability to assess the full lifecycle attributes of various battery technologies before they go into production. By modeling the full lifecycle in advance, a manufacturer has the opportunity to compare and contrast different battery chemistries “in the lab,” which reduces risks and production costs, and allows the design of batteries that are environmentally-responsible from initial materials selection through end-of-life.

Each battery technology has specific operational characteristics, such as chemistry, round-trip efficiency, and service life that make it suitable for a particular application. Different battery chemistries have different performance characteristics and may lead to significantly different life cycle environmental impacts. There is an entire periodic table at our disposal. We need to take a design side approach to advantage domestic capacity and sustainability. Factors such as resource availability, geopolitical implications, supply-chain risk, human and environmental impacts, domestic manufacturing capacity, and recyclability should be as important in the R&D choices we make today as performance and cost.

The University of Michigan’s School for Environment and Sustainability has developed a set of a set of ten principles to provide practical guidance on improving life cycle environmental performance of mobile battery systems that addresses the need for differences in strategies between stationary and mobile applications.

The principles are applicable to emerging battery technologies such as lithium-ion and can also enhance the stewardship of existing batteries.

The Green Principles for Mobile Applications are:

1. Choose battery chemistry to minimize life cycle environmental impact.
2. Minimize production burden per energy service.
3. Minimize consumptive use of critical and scarce materials.
4. Maximize battery round-trip efficiency.
5. Maximize battery energy density to reduce vehicle operational energy.
6. Design and operate battery system to maximize service-life and limit degradation.
7. Minimize hazardous material exposure, emissions, and ensure safety.
8. Market, deploy, and charge electric vehicles in cleaner grids.
9. Choose powertrain and vehicle type to maximize life cycle environmental benefits.
10. Design for EOL and material recovery.

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Question from Senator Cindy Hyde-Smith

Question: As the automotive sector looks to a more connected, automated, and electric future for vehicles, automated driver assist equipment, fully automated vehicle systems, and advanced propulsion systems, including batteries and hydrogen fuel cells will help to increase safety and fuel efficiency, but also add substantial weight to vehicles. Lightweight automotive materials that help to offset this added weight, including plastics and polymer composites, will become even more important in these vehicle designs. How are your companies incorporating these innovative materials, many of which are made in the U.S. and provide high-skilled manufacturing jobs for U.S. employees, in vehicle designs of the future?

A key challenge in technology innovation is balancing the tradeoffs required when considering new, advanced materials: the benefit they bring vs the added cost that gets passed down to consumers and potentially slow adoption. Clarion continues to innovate to support the vehicles and energy storage needs of today and tomorrow. We have long supported efforts to improve the fuel economy of vehicles. Our AGM batteries enable start stop technology which reduces emissions in combustion vehicles by 5%. Our 12-volt batteries are integrated into the EV platforms of most major automakers. At Clarion we have been very effective at using technologies that provided some of the best cost/benefit tradeoffs over the past 10 years with AGM for Start-Stop. We continue to research ways in which we can apply both our deep technical knowledge and our understanding of the cost-driven realities of the industry to provide the smartest solutions. This extends to our work with DOE on lithium recycling. As new materials and technologies are adopted, we need to make sure that those technologies are developed in ways that promote recycling, reuse, and overall sustainable supply chain development.

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Questions from Chairman Joe Manchin III

Question 1: In your testimony, you said the United States “does not possess some of the natural resources needed to fuel its green mobility.”

a. Can you please expand on that further?

One major determinant of successful green mobility is an affordable rechargeable battery. It consists of a cathode (positive electrode), an anode (negative electrode) and an electrolyte to conduct the flow of ions between the electrodes. The materials used in manufacturing these components vary with respect to the type of rechargeable battery. In green mobility, the lithium-ion battery is the common rechargeable battery used because of its high energy density, comparatively low weight, and slow self-discharge rate. Within the lithium-ion battery technology, there are various cathode chemistries, but the Lithium Nickel Manganese Cobalt (NMC) chemistry is favored by battery makers because of its high performance and relatively low cost. The principal elements used in the manufacturing of compounds for cathodes, anodes, and electrolytes in this type of battery are cobalt, lithium, manganese, and natural graphite.

Some deposits of these materials are found in the United States, but the resources and reserves are in small size, and in some cases not economically viable to mine. Manganese resources found in the United States are very low grade and have potentially high extraction costs.¹ The United States has not produced manganese ore containing 20% or more manganese since 1970.² According to the most recent statistics, the United States is 100 percent reliant on manganese imports. The main sources of imports are Gabon, South Africa, Australia, and Georgia. For natural graphite, the country relies fully on imports. The main exporters are China, Mexico, Canada, and India. With respect to cobalt, the US imports 76% of its consumption. The main exporters are Norway, Canada, Japan, and Finland. And half of the US consumption of lithium is imported. Major exporters are Argentina, Chile, China, and Russia.³

The following charts, based on data from the United States Geological Survey (USGS), show the countries with the highest reserves of these strategic minerals. According to the data, the United States does not seem to be a prominent producer.

¹ <https://pubs.usgs.gov/periodicals/mcs2021/mcs2021.pdf>

² <https://pubs.usgs.gov/periodicals/mcs2021/mcs2021-manganese.pdf>

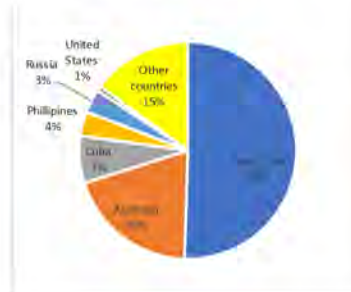
³ <https://pubs.usgs.gov/periodicals/mcs2021/mcs2021.pdf>

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World reserves of lithium, 2020



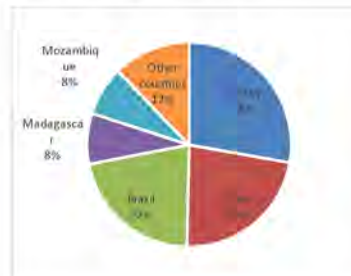
World reserves of cobalt, 2020



World reserves of manganese, 2020



World reserves of graphite, 2020



- b. *If the U.S would permit the mining of these critical minerals, with the reserves we have, how many electric vehicle batteries would we be able to produce domestically?*

Estimating the number of electric vehicle (EV) batteries that can be produced domestically with available resources depends on multiple factors including availability of infrastructure, amount of refined material recovered from the refining process, battery chemistry, and power/capacity of battery

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(watt-hours). Different battery chemistries require varying quantities of refined material. For example, the cathode in a NMC 622 lithium-ion battery is manufactured using lithium ions, with nickel, manganese, and cobalt (NMC) in various proportions (60 per cent nickel, 20 per cent manganese and 20 per cent cobalt). Other battery chemistries are possible, but they deliver different levels of performance. But cobalt is essential to the production of cathodes that strike a good balance between performance, energy density, charge time, charge life, safety, and cost. For example, a typical EV passenger vehicle with a NMC 622 cathode in a 55kWh battery pack contains 7.4 kg of lithium carbonate equivalent (LCE)⁴ and 12 kg of refined cobalt.⁵ This suggests that approximately 1000 tons of refined cobalt would be needed to manufacture about 83333 batteries.

Question 2: I'd like to follow up on your suggestion that the best opportunities for America to reduce our reliance on foreign supply chains and boost manufacturing are in processing and manufacturing of these minerals.

a. *Would you say our investment in technology development is well aligned to grow our processing and manufacturing of imported raw materials, or do we need to make adjustments to the focus of DOE's research efforts?*

Processing of raw materials is typically a technology-based business. Therefore, investing in processing technology could be critical to making the United States globally competitive in the processing industry, using imported raw materials. This would contribute to reducing risks associated with foreign supply chains and boost domestic manufacturing. The recent announcement by the Department of Energy to invest \$30 million for research to secure domestic supply chain of critical elements and minerals will contribute to improving operational efficiency in processing of raw materials and establishing domestic downstream manufacturing supply chains. However, for the country to become a key player in the production of the strategic minerals discussed in this note, more will need to be done. Indeed, as highlighted in the second paragraph of the first question by Chairman Joe Manchin III, the list of major producers of these materials does not include the United States. Hence, the country might need to deepen its technology development along these minerals' value chains (exploration, mining, refining, manufacturing, recycling); it will then benefit by internalizing these operations.⁶

⁴ Lithium Carbonate Equivalent refers to the different lithium compounds and production quantities used in the battery.

⁵ Azevedo M., Campagnol N., Hagenbruch T., Hoffman K., Lala A., Ramsbottom O. (2018). Lithium and cobalt – A tale of two commodities, Metals and Mining, McKinsey & Company

⁶ Internalizing here does not mean that all operations necessarily take place within the United States but rather that they are led by American firms

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Questions from Ranking Member John Barrasso

Question 1: In 2020, China controlled about 60 percent of the natural graphite and rare earths produced globally. To what extent is mineral production or processing in China associated with the human rights abuses against the Uighurs?

We do not have information linking Chinese human rights abuses against Muslim Uyghur workers in the Xinjiang province with production of natural graphite and rare earths.

Question 2: What is your organization doing to help companies with responsible sourcing of minerals?⁷

The United Nations provides several guidelines for companies to ensure that they are not complicit in financing conflict or human abuses with respect to sourcing of raw minerals. These include mineral traceability; certification mechanisms for conflict minerals; due diligence guidance for importers, processing industries and consumers of minerals regarding the purchase, sourcing, acquisition, and processing of mineral. For example, the United Nations Group of Experts on the Democratic Republic of the Congo provides “due diligence guidelines for the responsible supply chain of minerals from red flag locations to mitigate the risk of providing direct or indirect support for conflict in the eastern part of the Democratic Republic of the Congo; criminal networks and/or perpetrators of serious human rights abuses ...” (see Para 356 to 369, part IX of the final report S/2010/596).⁸

The United Nations Conference on Trade and Development (UNCTAD) has also developed the UNCTAD Investment Policy Framework.⁹ Fostering sustainable development and responsible investment particularly by foreign multinational enterprises are key elements of the framework.

Questions from Senator Lisa Murkowski

Question 1: The U.S. has strict labor standards in place through the Fair Labor Standards Act and stringent environmental regulations such as the National Environmental Policy Act, the Clean Air Act, the Clean Water Act, and so much more. Holding companies accountable to environmental regulations has advanced technologies that maximize production efficiency while mitigating impacts to the environment. Do you agree that the U.S. has the workforce and technology needed to extract and process minerals in an environmentally responsible way?

The United States has leading institutions in mining engineering such as Colorado School of Mines, Massachusetts Institute of Technology (MIT) and Stanford University, that prepare graduates for the

⁷ <https://www.oecd.org/corporate/mne/mining.htm>

⁸ <https://undocs.org/pdf/symbol/cn/S/2010/596>

⁹ https://unctad.org/system/files/official-document/djapcb2015d5_en.pdf

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mining industry. The graduates are highly respected worldwide for their work ethic and problem-solving ability. These institutions have a long history of research on metals and minerals, and they provide technological solutions to the mining industry that increase efficiency and productivity in operations and processes. For example, automation technologies have been used to enhance safety and lower operational costs, while truck automation has contributed to reducing fuel consumption and hence emissions. However, technological needs evolve particularly in a relatively new field such as green mobility. Therefore, United States research institutions stay ahead of the curve, there is no doubt that America's technological capacity could help steer the world towards a more environmentally friendly mining and minerals sector.

Question 2: Your testimony mentioned that foreign countries exploiting mineral resources are associated with undesirable environmental and social costs. Can you elaborate on the labor and environmental standards of foreign countries that are extracting and processing minerals?

Most countries have put in place labor and environmental laws and regulations to mitigate environmental and social risks in the mining sector. So, the problem is not the lack of standards but the fact that some actors do not respect them, especially when they operate in countries with weak institutions. For example, in the Democratic Republic of Congo, the new Mining Code and the Mining Regulations contain several environmental, health, as well as safety regulations that are supposed to ensure environmental compliance at every stage of a mining project. Labor working conditions, health and safety standards are also aligned to numerous international agreements, conventions, and policies. Similarly, foreign operators in the country have labor and environmental standards that should guide their activities. However, some basic obligations with which operators must comply are sometimes overlooked, leading to undesirable environmental and social costs. This is generally due to weaknesses in the host country's monitoring systems, and power asymmetries between the mining company and local communities who bear the brunt of consequences of poor compliance. Public Eye, a renowned independent Swiss NGO, has written several reports documenting multinational corruption involving multinational enterprises in the extractive sector, including in Africa.¹⁰ Moreover, in 2014, a report by the OECD found that even after the adoption of the OECD anti-bribery convention in 1999, one in five cases (19%) of transnational corruption took place in the extractive sector, an incidence higher than in arms dealing.

¹⁰ See, for example, https://www.publiceye.ch/fileadmin/doc/Rohstoff/2017_PublicEye_Trading_in_corruption_Report.pdf

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Questions from Chairman Joe Manchin III

Questions: West Virginia's proud tradition of transportation manufacturing will continue with the recent announcement that Hino will begin production of Cummins powered trucks at their plant in Mineral Wells, West Virginia in October 2021.

- a. What opportunities do you see for new manufacturing jobs within your companies as these transportation technologies emerge?
 - Cummins is honored to partner with Hino and support their work in West Virginia to provide our B6.7 and L9 engines in the medium-duty space. Cummins also employs over 60 people in our White Hall and Cross Lanes, WV, sales, service and distribution facilities. As the trucking industry serves a diverse array of customers with different power needs, we will continue to focus on strengthening our workforce by investing in education initiatives, apprenticeship opportunities and development programs focused on powering our current and future employees' potential. Existing and emerging transportation technologies provide opportunities to grow our workforce throughout the value chain, from skilled manufacturing, engineering, software development, sales, service and technician jobs, and supporting functions in areas like marketing, finance and supply chain. The [Diesel Technology Forum](#) estimates that Heavy-duty diesel engines manufactured in the U.S. in 2019 exceeded 900,000 units, providing over 1.3 million jobs and more than \$158 billion in economic value. The average wage in the industry exceeds the national average paying workers about \$78,000 per year, approximately 60 percent higher than the national average. Investing in innovation can spur demand for these jobs throughout the economy.
- b. How else can we ensure these jobs go to places that have been impacted by the energy transition?
 - We can ensure jobs go to the places that have been impacted by the energy transition by encouraging domestic innovation for global markets. Forging a path to zero emissions in the commercial vehicle market will strengthen American competitiveness, create good jobs that last, and combat climate change while providing cleaner air for all, especially our hardest-hit communities. Chairman Manchin's American Jobs in Energy Manufacturing Act of 2021 would provide tax credits for energy manufacturers to spur reinvestment in rural areas impacted by an economic downturn. This tax credit can support domestic investment from manufacturers focused on the energy transition.
- c. How can we ensure transportation manufacturing jobs do not get offshored?
 - Investing in innovation and infrastructure in the US is critical to ensuring American manufacturers have access to the talent, supply chains and resources needed to grow at home and export our products globally. By enacting robust and predictable funding for innovation

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in infrastructure, development and deployment of clean transportation technologies Congress can create the necessary conditions to ensure that American-made products are competitive globally.

Questions from Ranking Member John Barrasso

Question 1: Your testimony stressed the importance of keeping technology options open. Refueling infrastructure is a key concern for vehicles running on alternative fuels. What are the most urgent challenges with respect to refueling infrastructure for vehicles running on compressed natural gas (CNG), liquefied natural gas (LNG), or hydrogen?

- The best way to accelerate alternative fueling infrastructure is to incentivize demand for alternative fuel vehicles. Natural gas is abundant, efficient, and clean, and can be a smart, low-emission alternative to traditional transportation fuels. Natural gas allows for increased engine compression and combustion efficiency in vehicles and nonmobile sources in which it operates. One way to help stimulate demand for these vehicles is to ensure incentive parity for the vehicles via weight allowances, tax policy and grant opportunities. There is robust competition among fuel providers, and incentivizing demand for these cleaner vehicles will encourage rapid infrastructure buildout from the private sector. Ensuring a timely and functional permitting process will facilitate this build-out. Extension and expansion of the alternative fuels tax credit, the alternative fuel vehicle refueling credit, and ensuring policy parity with other clean technologies in areas like weight allowance and point of sale purchase incentives can create a virtuous cycle of supply and demand. For hydrogen, an investment or production tax credit incentivizing hydrogen production to address the supply side could incentivize demand and further infrastructure build-out, especially when paired with an enhanced section 30C tax credit for alternative fuel vehicle infrastructure.

Question 2: How far into the future do you see vehicles powered by internal combustion engines as being part of the global vehicle fleet? Are they going away any time soon?

- At Cummins, we see advanced internal combustion engines as critical enablers for decarbonization, and important tools for decades to come. Over the past two-plus decades, advanced diesel internal combustion technology has been adopted globally to meet increasingly stringent criteria emissions standards. During that timeframe, we embraced regulations and developed solutions that enabled us to meet standards that reduced particulate emissions in the diesel engine by 90 percent, and NOx by 95 percent while improving fuel-efficiency. This has been achieved in a progressive way, matching technology readiness with requirements to ensure costs have been manageable for the whole industry. Therefore, we expect diesel to be the power of choice, and necessity, for some of our customers for years ahead. Internal Combustion Engines (ICE) provide power density and efficiency that is unmatched and is a necessary technology on the path to zero emissions. When paired in a

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hybrid system with a battery, an ICE is capable of additional significant CO₂ and criteria emissions reductions, can improve range and increase applicability of a system beyond battery technology alone, and can provide customers with more flexibility for charging and refueling on their routes, improving productivity. Further, with larger scale adoption of low carbon fuels like biodiesel, renewable natural gas and hydrogen, additional benefits in both new and existing fleets can be realized. For these reasons, ICE technology will continue to be an important part of the path to zero emissions.

Questions from Senator Steve Daines

Questions: During the COVID-19 pandemic we saw a dramatic decrease in gasoline and diesel consumption as more people were staying at home. Experts, including the Energy Information Administration under DOE, expect demand to rise in 2021 and 2022 as travel increases. As we look towards innovation within the liquid fuels world, one product has already shown tremendous promise to bridge the gap between conventional fuel and renewable fuels. Refined Renewable Diesel is a 'drop in' fuel that can help lead to lower emissions while at the same time keeping and growing traditional refinery jobs. Montana is home to a number of small refineries that are an important part of our local communities and renewable diesel can play an increased role in Montana and throughout the U.S.

- a) Can you speak to the benefits of renewable diesel and how you think the U.S. can increase its production and use?
- Renewable diesel has significant benefits that are a "low-hanging fruit" for decarbonizing internal combustion. Large investments are being made in the refining sector to boost the supply of advanced biofuels including renewable diesel fuel and biodiesel fuel that, when used in diesel engines, yield substantial carbon reduction benefits at very low cost. Low-carbon fuel policies in California, and being considered in other regions, are realizing the cost savings and other benefits of using these fuels compared for example to zero emission vehicle alternatives. Switching to renewable diesel and other low carbon drop-in fuels are also another way to make an immediate impact in air quality and CO₂ emissions today, delivering immediate benefits to the communities who need them most.
- b) What regulatory barriers are there that may stop the growth of renewable diesel?
- Cost and availability are the main barrier to growth of renewable diesel. California's low-carbon fuel standard is a policy that has helped to remove those barriers to adoption of renewable diesel more broadly. According to the [EIA](#), currently California uses nearly all of U.S.-produced renewable diesel and imported renewable diesel mainly because of the economic benefits for its use under California's Low Carbon Fuel Standard. Enacting federal

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policies to incentivize low carbon fuel usage will accelerate adoption and take advantage of the environmental and supply chain benefits that exist with renewable diesel today.

Questions from Senator Martin Heinrich

Questions: New Tax incentives for Advanced Electric Vehicle Truck Technologies

Mr. Satterthwaite, what in your view would be an effective way to promote electrification of the medium and heavy-duty vehicle segments of the industry?

For example, would suspending the 12% federal excise tax on zero-emission trucks be helpful?

Would creating a new investment tax credit for medium and heavy duty EVs help drive the market?

- Suspending the 12% FET for all new trucks would be extremely helpful to promote innovation in transportation. Cummins supports a repeal of the 12% Federal Excise Tax on all heavy-duty trucks, which acts as a regressive tax on the cleanest available technologies and discourages fleet turnover. Ensuring our customers have the power of choice when purchasing a new truck allows them to pick the cleanest technology at the lowest cost that's right for their job. Beyond the FET, tax incentives for zero-tailpipe emissions trucks and infrastructure would quickly accelerate adoption of decarbonized transportation technologies. These sorts of policies would begin to address the disparity in incentives we see between the US, Europe and Asia for this industry. Cummins would also support expansion and extension for the 30B and 30C tax credits for alternative fuel vehicles and infrastructure. Further creating an Investment Tax Credit (ITC) specifically for medium and heavy-duty battery-electric, hybrid and hydrogen fuel cell powered vehicles will address the cost delta in adoption of these newer and more expensive technologies as we achieve manufacturing scale.

Questions from Senator Mazie Hirono

Question 1: In your testimony, you described some of the potential benefits of using hydrogen as a fuel in applications needing energy-dense fuels including trucking, rail, and marine transportation. What is your best estimate for when hydrogen-based fuel cells could reach commercial use in marine applications, and what are the important benchmarks you will look to determine if the technology is making progress toward commercial use in marine transportation?

- Cummins has invested significantly in hydrogen technologies because we think hydrogen is a critical enabler of decarbonization especially in the hard-to-abate sectors where our products operate, like marine. Fuel cells are an attractive solution for decarbonization of marine

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vessels for several reasons. They are zero emissions, silent and scalable. They are also flexible because the power from the fuel cells is transported through wires, and the fuel cells can be placed almost anywhere on the vessel. Today, Cummins hydrogen fuel cells are being integrated into North America's first commercial hydrogen fuel cell powered, zero emissions ferry (ZEF). Quiet and emissions free, the vessel, named "Sea Change," marks another crucial milestone in the commercialization of zero emissions marine vessel power. The 70-foot, 75 passenger high-speed ZEF will be the flagship for a planned future fuel-cell powered fleet, transporting commuters around the bay of San Francisco. It will also demonstrate and test the potential of commercialization of fuel-cell powered marine vessels to the global maritime industry. With continued policy focus on infrastructure, development and deployment, this technology can be scaled to broad commercial viability.

Question 2: Which federal policies or incentives would you recommend to accelerate the timeline for commercial adoption of hydrogen fuel cells or other lower emission fuel sources in marine transportation?

- Federal policies and incentives to accelerate infrastructure, development and deployment will be critical for commercial adoption of hydrogen fuel cells and other low-carbon fuel sources in marine transportation. Pilot programs, as suggested in President Biden's infrastructure proposal, run by the Departments of Energy and Transportation at cross-sectoral facilities like ports, where an entire ecosystem of vehicles and energy can be transitioned to hydrogen fuel can serve as proving grounds for wider-spread commercialization. Programs like the Diesel Emissions Reduction Act (DERA) also provide a technology neutral grant program where marine vessel and fleet operators can apply for funding to transition a fleet from older diesel technology to fuel cells or other low-emissions options.

Questions from Senator Catherine Cortez Masto

Question 1: In your written testimony, you stated that: "If the U.S. is to achieve a path to net-zero in a way that is cost effective, timely, and promotes U.S. jobs and manufacturing, significant public support is needed from DOE, our national labs, and other research institutions to innovate in infrastructure, development, and deployment."

- A.** How is Cummins working with stakeholders to ensure that its electric vehicles and infrastructure are deployed in a timely and cost-effective way?
- For over 100 years Cummins has worked with our customers to find the best solution for their application. One way we do this is partnering with our customers to understand the job they need to do. For example, we recently partnered with Blue Bird to unveil the first operational DC fast charge vehicle-to-grid (V2G) enabled school buses, allowing the buses not only to safely transport students, but also provide much needed power to the grid when

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there is demand and the bus is not in service. This milestone is the first where the V2G technology has moved beyond pilot phase and into full commercial production and operation for the school bus market. Cummins also has a long history of partnership with the Department of Energy and the National Labs to study everything along our product value chain- from basic research and development all the way to product demonstration and deployment. Successful public-private partnerships like the SuperTruck Program demonstrate the value of collaboration between government, industry and academia to advance our shared goals.

B. In particular, what government supported innovation measures would be most beneficial to the industry?

- Government-supported innovation measures that create partnerships throughout the value chain are critical to industry and government decarbonization goals. The 21st Century Truck Partnership (21CTP) is an example of a very successful model of that work. 21CTP is made up of partners from the truck and engine manufacturing industry, the Department of Energy and the National Labs and addresses the technical needs of the medium- and heavy-duty truck industry, as well as major policy goals for government agencies, through three main activities: accelerated technology development through collaborative, pre-regulatory, and pre-competitive R&D component and system-level projects; focus R&D efforts on topics of broad interest by providing a discussion forum; and organizing consensus building tools such as roadmaps and position papers that help Partnership members come to agreement on R&D topics and goals. The Partnership provides opportunities for collaborative discussion on research needs, and reference materials to maximize the productivity of these discussions. The 21CTP partnership was instrumental in the creation and successful completion of the SuperTruck 1 and 2 programs. Additionally, innovation measures should prioritize goals and let the technology compete to meet those goals. SuperTruck 2, for example, set a program-wide goal of achieving 55% brake-thermal efficiency, which the Cummins team met using a variety of technologies like waste-heat recovery, exploring different options than other teams. This creates competition and spurs innovation, supporting American competitiveness in technology globally.

Question 2: How can the United States best prepare its workforce for future transportation technologies?

- Employers around the world are experiencing critical shortages of skilled technical workers. The demand for these workers in our industry is expected to continue to rise over the next decade. Vocational education is also an important way to elevate standards of living. When government and industry join efforts to drive change, the result creates more impact than single companies working alone. This can mean partnering with academic institutions, upskilling existing workforce, and organizing special technology incubators within companies to meet the demands of advanced digital economies. Academic curriculum and vocational training programs focusing in data science, computer science, and machine

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learning will be key as the transportation industry transforms. Congress can support this by facilitating company investment in worker training through supportive tax policy. This approach ensures that workers can access the right resources at the right time and that investments in workforce training maximize worker benefit. Federal and state workforce preparedness policies should also promote completion of credentials that reflect proof of competency in high-demand skillsets. Students and workers should receive credit for mastery achieved in a range of environments and have access to high-quality certificate programs that efficiently deliver training resources. At Cummins diversity is a key part of our culture and workforce because we believe when you bring in people from different backgrounds and experiences you will be able to solve complex problems faster and more effectively through better ideation, creativity and execution. This is key for innovation to take place and scale successfully.

Question from Senator Cindy Hyde-Smith

Question: As the automotive sector looks to a more connected, automated, and electric future for vehicles, automated driver assist equipment, fully automated vehicle systems, and advanced propulsion systems, including batteries and hydrogen fuel cells will help to increase safety and fuel efficiency, but also add substantial weight to vehicles. Lightweight automotive materials that help to offset this added weight, including plastics and polymer composites, will become even more important in these vehicle designs. How are your companies incorporating these innovative materials, many of which are made in the U.S. and provide high-skilled manufacturing jobs for U.S. employees, in vehicle designs of the future?

- Cummins is committed to innovation throughout the technologies and materials in our products. In our battery and fuel cell powertrain work, there are emerging opportunities for these new materials and additive manufacturing. New materials are necessary in battery cells, battery modules and battery packs to address challenges in weight, cost, durability, thermal management and safety. Likewise, new materials are needed in fuel cell and electrolyzer membranes and the fuel cell power plant. We also see polymer composites as critical enabler to the H2 fuel tanks weight and cost. Continued research and development from the Department of Energy into these areas will increase American competitiveness and promote US leadership in these technologies while also improving performance and reducing transportation emissions.

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Questions from Chairman Joe Manchin III

Question 1: The Toyota plant in Buffalo, West Virginia employs over 2,000 West Virginians in Putnam County. And our proud tradition of transportation manufacturing will continue with the recent announcement that Hino will begin production of Cummins powered trucks at their plant in Mineral Wells, West Virginia in October 2021.

a. What opportunities do you see for new manufacturing jobs within your companies as these transportation technologies emerge?

Toyota's investment in manufacturing operations is contingent on demand side fundamentals to ensure sustainment of manufacturing jobs during times of growth and also during periods of downward pressure on markets. As the market demand for hybrid-electric, battery electric and fuel cell electric vehicles increases in the U.S., we see an opportunity for manufacturing growth for light, medium and heavy-duty vehicles. However, we think it is premature to predict the net growth of manufacturing jobs because elements of existing work force will naturally shift from assembly of internal combustion engine (ICE) vehicles to assembly of the newer zero emission vehicles over time.

b. How else can we ensure these jobs go to places that have been impacted by the energy transition?

The availability of a skilled workforce and establishment of advanced manufacturing training (AMT) program pipelines through partnerships with vocational schools and community colleges is essential to the success of our manufacturing operations. The West Virginia Federation for Advanced Manufacturing Education (WV FAME) in partnership with BridgeValley Technical and Community College is an exemplar model for those regions impacted by the energy transition who are looking to attract manufacturing operations.

c. How can we ensure transportation manufacturing jobs do not get offshored?

Sustaining a long-term competitive advantage in transportation manufacturing requires a commitment to innovative designs, the highest quality, just-in-time inventories, waste elimination, and team member participation. OEMs can best design, develop and build high quality transportation and mobility products in markets that provide durable economic conditions and competitive wage rates. Creating regulatory environments that are consistent and stable, along with ample access to a competitive workforce, will attract new manufacturing and ensure existing manufacturing operations remain in the United States. Additionally, hydrogen (H2) production for fuel cell vehicles can be

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entirely achieved domestically. This would ensure domestic jobs related to the production of H₂, delivery of H₂ and H₂ fueling infrastructure would be preserved.

Questions from Ranking Member John Barrasso

Question 1: Your testimony stressed the importance of keeping options open. Refueling infrastructure is a key concern for vehicles running on alternative fuels. What are the most urgent challenges with respect to refueling infrastructure for vehicles running on compressed natural gas (CNG), liquefied natural gas (LNG), or hydrogen?

At Toyota, we are focused on the customer experience. Convenience is critical. If fueling and operating a vehicle does not meet the lifestyle needs of the customer, they will purchase a vehicle that does meet their lifestyle needs. Fueling locations must be in proximity to customers' homes or travel locations, and the fuel must be readily available for customers to purchase. In order to satisfy these two conditions for vehicles running on alternative fuels, we need investment in downstream public retail fueling locations, midstream distribution infrastructure and upstream production. Many of these investments are happening now. Companies are expanding the number of fueling stations and making investments in new distribution and production assets.¹ The federal government can facilitate by providing tax incentives to support the expansion of fueling stations, investments in production and distribution. Further, the federal government can support consumer purchase incentives, which would provide investment certainty that encourages manufacturers to finance even more production and build out infrastructure.

Question 2: The United States is the world's largest producer of natural gas, an ideal feedstock for hydrogen. Your company also is making big investments in hydrogen fuel cells. Is it fair to say that Toyota sees a commercial future where American consumers have technology choices beyond battery-powered electric vehicles?

Toyota has long maintained that hydrogen fuel cell electric vehicle (FCEV) technology could be a zero-emission solution across a broad spectrum of vehicle types. We will continue to develop and launch FCEVs fueled by hydrogen, which is regarded as a highly promising energy carrier for the future.

¹ See *Electric Vehicle Charging Infrastructure Trends from the Alternative Fueling Station Locator: First Quarter 2020*, NATIONAL RENEWABLE ENERGY LABORATORY (Oct. 2020), <https://www.nrel.gov/docs/fy20osti/77508.pdf>; *Global Market for Hydrogen Fueling Stations, 2021 - Distribution of Stations Will Be More Even by 2035*, BUSINESS WIRE (Mar. 8, 2021), <https://www.businesswire.com/news/home/20210308005510/en/Global-Market-for-Hydrogen-Fueling-Stations-2021---Distribution-of-Stations-Will-Be-More-Even-by-2035-but-APAC-Will-Continue-to-Lead-the-Market-Followed-by-Europe---ResearchAndMarkets.com>.

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Question 3: Can you compare the differences, from the consumer's perspective, in the refueling experience of a hydrogen fuel cell, natural gas powered vehicle, and a battery-powered electric vehicle?

From a customer experience perspective, fueling a hydrogen fuel cell electric vehicle is very similar to fueling a gasoline vehicle today.² According to the Office of Energy Efficiency & Renewable Energy (EERE), a consumer can drive to a hydrogen fueling location, typically a traditional gasoline station, refuel in about 5 minutes, and drive away.³ Whereas, the EERE reports that the charging of a battery electric vehicle typically occurs at home.⁴ The customer plugs the vehicle into a typical 120 volt outlet ("Level 1" charging) or into an upgraded 240 volt outlet ("Level 2" charging).⁵ Most customers that utilize Level 1 or Level 2 at their residence rarely recharge from empty, but instead, they just top off. Customers who do a significant amount of driving, need to charge away from their residence, or do not have access to charging at their residence, however, will need access to public retail charging. And, according to Kelley Blue Book, charging times at public charging locations will depend on battery capacity, the amount of energy that could be delivered at that location, and the queuing time associated with competing battery-powered electric vehicle (BEV) drivers also trying to recharge.⁶ Times can vary from tens of minutes (for a high power fast charger) to multiple hours (for lower power delivery chargers).⁷

Question 4: Responsible sourcing of critical materials used in the batteries and other components of electric vehicles (e.g., magnets) is an increasing area of concern. Are there any sourcing issues associated with minerals used in fuel cells, such as platinum, which as you testified is used in both fuel cells and catalytic converters?

Similar to the production of catalytic converters, the production of platinum group metals (PGMs) is needed for the manufacturing of fuel cells.⁸ Palladium (average 15 ppb) is the most abundant PGM, followed by platinum with 5 ppb and rhodium with about 1 ppb. Currently, we have not experienced degradation of supply-side availability of PGMs for manufacturing of catalysts or fuel cells. And the outlook for mining production PGMs is better for the year ahead and projected to

² See *Fueling the Toyota Mirai*, TOYOTA, https://www.toyota.com/content/ebrochure/2021/mirai_fueling_V11.pdf.

³ See *Hydrogen Basics*, DEPARTMENT OF ENERGY'S ALTERNATIVE FUELS DATA CENTER, https://afdc.energy.gov/fuels/hydrogen_basics.html (last accessed on April 12, 2020).

⁴ See *Charging at Home*, DEPARTMENT OF ENERGY'S OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY, <https://www.energy.gov/eere/electricvehicles/charging-home> (last accessed on April 12, 2020).

⁵ See *id.*

⁶ See Chanel Lee, *How Long Does It Take to Charge an Electric Car*, KELLEY BLUE BOOK, (MAR. 15, 2021) <https://www.kbb.com/car-advice/how-long-does-take-charge-electric-car/>.

⁷ See *id.*

⁸ See *Fuel Cells*, DEPARTMENT OF ENERGY'S OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY <https://www.energy.gov/eere/fuelcells/fuel-cells> (last accessed on April 13, 2020).

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rebound to near 2019 levels.⁹ Though the outlook has brightened, the South African platinum supply remains contingent on the path of the pandemic and recovery from COVID-19.¹⁰

Question 5: How do the sourcing issues associated with the minerals used in fuel cells compare to sourcing issues associated with minerals used in the internal combustion engine, and, separately, battery-powered electric vehicles?

The emergence of hydrogen FCEVs have contributed to the growing demand for platinum.¹¹ Both FCEVs and traditional ICE vehicles use PGMs. A FCEV engine, however, requires about six times more platinum than an ICE engine.¹² Recent studies show that fuel cell electric vehicles (FCEVs) contain 30-60g of platinum per vehicle, with a long-term target reduction to 10-15g of platinum.¹³ Compared to an FCEV, an ICE vehicle uses 2-7g of total PGM content; high palladium, low to no platinum and low rhodium.¹⁴

China has become the dominant producer of rare earth minerals. It is expected that Chinese chemical companies will continue to control much of the world's total output of the 17 rare earth minerals used in the manufacture of advanced batteries through 2021.¹⁵ The sourcing of advanced battery raw materials represents a challenge for U.S. manufacturing of BEVs. However, if the U.S. emerges as a leader in manufacturing investments, a long-term and sustainable U.S. market for the rare earths, and other critical components required for fuel cell and battery manufacturing, is possible.

Question 6: How far into the future do you see vehicles powered by internal combustion engines as being part of the global vehicle fleet? Are they going away any time soon?

We anticipate hybrids and plug-in hybrid vehicles, both of which utilize ICEs, will continue to play a key, strategic role for many years to come based on current market conditions, consumer demand and industry-wide battery capacity constraints for BEVs.

Question 7: Does the push for EVs in light-duty reduce market penetration of hybrid vehicles?

⁹ See Shree Kargutkar, *Pandemic Provides Catalyst for Higher Platinum Prices*, SPOTT, (Mar. 29, 2021) <https://spott.com/insights/pandemic-provides-catalyst-for-higher-platinum-prices/>.

¹⁰ See *id.*

¹¹ See World Platinum Investment Council, *Is Automotive Demand for Platinum Increasing or Decreasing?* CME GROUP, (Aug. 11, 2020), <https://www.cmegroup.com/education/articles-and-reports/is-automotive-demand-for-platinum-increasing-or-decreasing.html>.

¹² See *id.*

¹³ See *id.*

¹⁴ See *id.*

¹⁵ See *China Dominates the Global Lithium Battery Market*, INSTITUTE FOR ENERGY RESEARCH, <https://www.instituteenergyresearch.org/renewable/china-dominates-the-global-lithium-battery-market/> (last accessed on April 12, 2020).

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We believe that each powertrain technology has a role to play in developing the alternative fuel vehicle market. Some technologies are better suited for certain applications than others and ultimately, the consumer will – and should – decide which powertrain technology is right for their lifestyle. As stated in my previous testimony, “[O]ur collective destination is a carbon free transportation system and I believe we can get there. But our experience tells us it won’t happen overnight, and it won’t be a single technology.” That is why Toyota will continue to provide a portfolio of powertrain options, and why we remain very confident for the future of hybrid vehicles. Hybrid vehicles are essential in getting to a zero-carbon future. We have sold over 4 million hybrids in the U.S., which saved 9.3 billion gallons of fuel over the life of these vehicles. Those hybrids, over their lifetime, also prevented 38 million tons of CO₂ from entering the atmosphere. We believe that hybrids will continue meeting customer needs and continue to contribute leading transportation to ever lower carbon emissions.

Questions from Senator Steve Daines

Question 1: Historically the United States has relied on the private sector to provide fuel for vehicles and motorists. I believe the private sector is the most efficient and best fit to provide the same services to the next generation of motor vehicles.

- a. Do you believe that the private sector or the federal government should lead in deploying charging stations for EVs?**

While the private sector is best positioned to deploy charging sector infrastructure, the federal government should take steps to enable EV market expansion by incentivizing the adoption of EVs. Essential components of federal policy should include investments to assist communities in building grid to charger infrastructure and efforts to raise consumer awareness of the benefits of low and zero emission vehicles.¹⁶

- b. If the federal government is to get involved in providing charging stations, do you believe that there should be a level playing field between government owned and subsidized charging stations and private owned charging stations?**

Together with reducing costs of EVs and increasing consumer awareness, there is a need to address the “convenience parity” for charging BEVs and fueling FCEVs.¹⁷ Increasing consumer access and availability electric charging and hydrogen fueling infrastructure are

¹⁶ See Letter from Alliance for Automotive Innovation, *et al.* to President Biden (Mar. 29, 2021), <https://www.autosinnovate.org/posts/communications/Auto%20Industry%20EV%20Policy%20Letter%20to%20President%20Biden%20March%2029%202021.pdf>.

¹⁷ See *id.*

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necessary in this effort to increase EV market expansion.¹⁸ Federal policy should promote an all-of-the-above approach to charging infrastructure and ownership. An emphasis on the development of public charging infrastructure, however, could assist in reducing concerns over “range anxiety” and help build consumer confidence in electrified technologies.¹⁹ Stakeholders should work together on a variety of public policy efforts, including federal tax incentives, grants, and rebates to stimulate refueling infrastructure development.²⁰ Approaches should focus on developing charging and fueling infrastructure for homes, workplaces, along federal highways and in other public locations.²¹

c. What federal and state obstacles do you see as hindering private deployment of charging stations?

At present, the economics of charging stations remains challenging due to a combination of low rates of utilization and an emphasis on increasingly technologically advanced high power/fast charging. State or federal mandates requiring very high-power chargers or uniform deployment of charger technologies (e.g. ISO 15118, Plug and Charge) may further increase costs, decreasing private sector investor interest.

Question 2: In order to increase electric vehicle production you have to also increase the domestic development or the importation of critical minerals to build the batteries and components needed to deploy more EVs. If responsible production does not happen in the U.S. it will happen in countries with worse environmental and labor standards. For example, the Democratic Republic of the Congo produces the vast majority of the cobalt that is used in EV batteries.

a. How can the U.S. reverse this and bring back domestic production and manufacturing of critical minerals?

EV supply chains will require investments in the manufacturing of batteries (extraction of rare earth minerals, refinement, battery cell production, and recycling) and fuel cell stacks.²² A comprehensive approach focused on manufacturing and supply chain resiliency is needed to support the anticipated growth of electric vehicles globally. The environmental and sustainability considerations around mining, extraction, refinement and processing of rare earth minerals and the recycling of depleted batteries highlight the need for further critical studies around the complete life-cycle impact of batteries.

¹⁸ *See id.*

¹⁹ *See id.*

²⁰ *See id.*

²¹ *See id.*

²² *See id.*

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Manufacturing grant programs may help incentivize vehicle manufacturers and component suppliers to expand and re-tool existing operations to manufacture batteries and components, but investments will continue to be based on free-market principles, which include demand side growth, regulatory environment, tax and workforce considerations. International compliance measures are likely needed to address environmental and labor standards in developing countries extracting rare earth minerals. These measures should address global supply chain security, harmonization, transparency and assurances to international environmental and labor standards.

b. Does it concern you that the U.S. is reliant on foreign countries for critical minerals used in the transportation industry?

Historically, Toyota has worked hard to develop a durable supply base to serve its manufacturing operations for key regional and localized markets. Reliance on regional supply bases for critical materials and components can significantly impact the automotive industry.

c. How is the supply chain affected when we rely on China and foreign countries for critical minerals?

A durable and sustainable supply chain for BEVs and FCEVs requires investments in manufacturing of batteries (i.e., extraction of rare earth minerals, refinement, battery cell production, and recycling) and fuel cell stacks.²³ We believe our global manufacturing operations are best served by localized supply chains that are not critically reliant on one single regional supplier for essential components needed to complete vehicle assembly.

d. We have seen recent moves by China to restrict Rare Earth Elements exports. Has this or will this affect EV production?

In 2010, China temporarily cut off Japan from its supply of rare earth elements. Based on this event, Toyota began investing in technologies to reduce rare earth elements needed for electric motors.²⁴ Although we have not seen supply-side degradation by recent moves by China to restrict rare earth elements, we recognize that there may exist challenges to U.S. manufactures if there were a rapid adoption and growth of BEVs beyond the current global production capacity. Although we anticipate transition to battery electric and fuel cell technologies over time, it is important that Congress

²³ See *id.*

²⁴ See *New Toyota magnet cuts dependence on key rare earth metal for EV motors*, REUTERS (Feb. 20, 2018), <https://www.reuters.com/article/us-toyota-magnet/new-toyota-magnet-cuts-dependence-on-key-rare-earth-metal-for-ev-motors-idUSKCN1G413F>.

U.S. Senate Committee on Energy and Natural Resources
March 16, 2021 Hearing: *Ways to Strengthen Research and Development in Innovative Transportation Technologies with a Focus on Solutions that Decrease Emissions, Reduce our Reliance on Foreign Supply Chains, and Increase Manufacturing in the United States*
Questions for the Record submitted to Mr. Robert Wimmer

considers implementing the policy considerations suggested above to enhance U.S. domestic supply chain, R&D and manufacturing.

e. What are the key critical minerals needed to reduce emissions in the transportation industry?

The transition to battery electric and fuel cell electric vehicles, is likely to increase demand on critical minerals including lithium, copper, nickel, cobalt and platinum group metals (PGM) including palladium, platinum and rhodium.²⁵ Additionally, terbium and dysprosium are other materials used to produce powerful magnets in electric motors.²⁶

Questions from Senator Martin Heinrich

Question 1: Effectiveness of existing EV tax incentives for passenger vehicles (26 USC 30D) Mr. Wimmer, to meet emissions goals we must accelerate the deployment of electric vehicles. What in your view is the number one thing Congress could do immediately to promote sales of EVs?

A comprehensive approach focused on consumers, infrastructure, R&D, manufacturing and supply chain is needed to accelerate the deployment of EVs.²⁷ We believe that focusing on just one area may not be enough to drive wide-scale adoption of EVs. Toyota is a market leader in hybrid-electric vehicles. Even with the relatively low-cost technology of a hybrid, early consumer tax incentives, no new infrastructure needed, no consumer behavioral changes, and very long (600 mile) ranges, it has taken 20-years for industry to reach 3.5% annual sales share for hybrid-electrics. Despite the combined efforts of the public and private sectors to promote the adoption of EVs, there are only 1.5 million EVs registered on U.S. roads today out of 278 million light-duty vehicles.²⁸ While consumer interest is growing and close to 50 models are now available to consumers in the U.S., EVs only made up roughly 2% or roughly 300,000 of the 14.5 million new vehicle sales last year.²⁹ Accelerating the development of electric vehicles in the U.S. requires a comprehensive approach beyond just consumer tax incentives and vehicle rebates.³⁰

²⁵ See Ernest Scheyder, *To go electric, America needs more mines. Can it build them?*, REUTERS (Mar. 1, 2021), <https://www.reuters.com/article/us-usa-mining-insight/to-go-electric-america-needs-more-mines-can-it-build-them-idUSKCN2AT39Z>; World Platinum Investment Council, *Is Automotive Demand for Platinum Increasing or Decreasing?* CME GROUP (Aug. 11, 2020), <https://www.cmegroup.com/education/articles-and-reports/is-automotive-demand-for-platinum-increasing-or-decreasing.html#>.

²⁶ See Jeremy Hsu, *Don't Panic about Rare Earth Elements*, SCIENTIFIC AMERICAN, (May 31, 2019), <https://www.scientificamerican.com/article/dont-panic-about-rare-earth-elements/>.

²⁷ See Letter from Alliance for Automotive Innovation, *et al.* to President Biden (Mar. 29, 2021), <https://www.autosinnovate.org/posts/communications/Auto%20Industry%20EV%20Policy%20Letter%20to%20President%20Biden%20March%2029%202021.pdf>.

²⁸ See *id.*

²⁹ See *id.*

³⁰ See *id.*

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a. For example, should Congress expand or restructure the existing consumer incentives to purchase an EV?

We believe a comprehensive strategy is required to establish the U.S. as a leader in the next generation of clean transportation innovation, and consumer incentives are key. As stated in my previous testimony, “The policy with the greatest immediate impact on sales is consumer purchase incentives. These incentives should be structured to promote all electrified vehicles, allow consumer choice, and provide greater opportunity for GHG reductions than a single pathway can provide. And these incentives can’t sunset too quickly or they won’t provide investment certainty manufacturers need.”

Additionally, we suggest Congress implement the following policy approaches to drive consumer adoption of EVs, which are endorsed by the Alliance for Automotive Innovation and other trade groups:

- Expand and extend the 30B Fuel Cell Motor Vehicle Tax Credit to help equalize the upfront cost to consumers and increase the credit for medium and heavy duty fuel cell vehicles;
- Prioritize additional R&D investment (federal and private) to reduce costs and improve performance of batteries, fuel cells, and hydrogen fuel generation;
- Expand and extend the 30D Federal Tax Credit for PHEVs and BEVs.³¹

Question from Senator Catherine Cortez Masto

Question: How can the United States best prepare its workforce for future transportation technologies?

The availability of a skilled workforce and establishment of AMT program pipelines through partnerships with vocational schools and community colleges is essential to the success of our manufacturing operations. Growth of workforce training programs like the FAME, can assist in preparing regional workforces to meet the future of transportation technologies. FAME provides best-in-class workforce development through strong technical training, integration of manufacturing core competencies, intensive professional practices and intentional hands-on experience to build the future of the modern manufacturing industry.³²

³¹ See *id.*

³² See *Toyota Transitions National Apprenticeship Program to The Manufacturing Institute*, TOYOTA (Sept. 10, 2019), <https://pressroom.toyota.com/toyota-transitions-national-apprenticeship-program-to-the-manufacturing-institute/>.

U.S. Senate Committee on Energy and Natural Resources
 March 16, 2021 Hearing: *Ways to Strengthen Research and Development in Innovative Transportation Technologies with a Focus on Solutions that Decrease Emissions, Reduce our Reliance on Foreign Supply Chains, and Increase Manufacturing in the United States*
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Question from Senator Cindy Hyde-Smith

Question: As the automotive sector looks to a more connected, automated, and electric future for vehicles, automated driver assist equipment, fully automated vehicle systems, and advanced propulsion systems, including batteries and hydrogen fuel cells will help to increase safety and fuel efficiency, but also add substantial weight to vehicles. Lightweight automotive materials that help to offset this added weight, including plastics and polymer composites, will become even more important in these vehicle designs. How are your companies incorporating these innovative materials, many of which are made in the U.S. and provide high-skilled manufacturing jobs for U.S. employees, in vehicle designs of the future?

Toyota Motor North America is finding ways to partner with its North American outside suppliers to find innovative and safe ways to implement new lightweight automotive technologies and materials. One recent example involves the all-new 2021 Sienna minivan. Produced in Princeton, Indiana at Toyota Motor Manufacturing Indiana, Inc., the 2021 Sienna won the *Enlighten Award* for achievements in vehicle weight savings for reduced mass of the third-row seat.³³ We achieved this by partnering with BASF and incorporating 35% glass-reinforced and impact-modified polyamides, which were used to supplement portions of the traditional steel seat frame.³⁴

³³ See *The All-New 2021 Sienna is Already Winning Awards*, TOYOTA (Aug. 5, 2020), <https://pressroom.toyota.com/the-all-new-2021-sienna-is-already-winning-awards/>.

³⁴ See *id.*



March 18, 2021

The Honorable Joe Manchin, Chairman
Senate Committee on Energy and Natural Resources
304 Dirksen Senate Office Building
Washington, District of Columbia 20510

The Honorable John Barrasso, Ranking Member
Senate Committee on Energy and Natural Resources
307 Dirksen Senate Office Building
Washington, District of Columbia 20510

Dear Chairman Manchin and Ranking Member Barrasso,

We applaud you for holding a full-Committee hearing regarding innovative transportation technologies "with a focus on solutions that decrease emissions, reduce our reliance on foreign supply chains, and increase manufacturing in the United States."¹ As you contemplate Congress' role in enabling and supporting tech-driven advancements in transportation and energy distribution, we urge you to prioritize safeguarding competition and consumers against anticompetitive conduct involving technical standards. Across committee jurisdictions in the Senate, there is clear bipartisan interest in more aggressive assertion of competition law where warranted, and standard-essential patent (SEP) abuse is one such category of activities that could seriously harm innovation in the transportation sector.

In your respective states and districts, the ability for innovators to create jobs and produce cutting-edge products and services in an increasingly broad set of industry verticals—including in advanced manufacturing, transportation, environmental monitoring and remediation, and energy applications and supply chains—depends on strong technical standards like USB, Wi-Fi, 4G, and 5G. However, in order to safeguard the continued growth and success of these key industries and to protect the consumers of their end products and services (including state and local governments purchasing new transportation technologies and many small and medium manufacturers), Congress must ensure that the law effectively prevents SEP licensing abuses. Incorporating a patent declared as essential into a standard typically confers market power on a SEP owner, so SEP owners make voluntary commitments pursuant to those declarations to license those SEPs on fair, reasonable, and nondiscriminatory (FRAND) terms.² These commitments balance the market power SEP owners obtain with the need for innovators to license the patented inventions essential to use the standard. When kept, FRAND commitments prevent anticompetitive licensing behavior. But some SEP owners break these FRAND promises and engage in activities that harm competition and consumers by

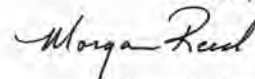
¹ Press Release, "Full Committee Hearing on Transportation Technologies," Senate Comm. on Energy and Nat. Resources (Mar. 2021), available at <https://www.energy.senate.gov/hearings/2021/3/full-committee-hearing-on-transportation-technologies>.

² See Brian T. Yeh, "Availability of Injunctive Relief for Standard-Essential Patent Holders," CONG. RESEARCH SERV. Summary (Sept. 7, 2012), available at https://www.everyscrreport.com/files/20120907_R42705_9c71ac36b1c0030at0d1bd97b53e8b7ba6fd3a73.pdf.

increasing prices, reducing the quality and variety of products and services, and reducing innovation.³ Breaking these promises implicates antitrust law, in addition to other sources of law.

Unfortunately, as internet connectivity and computing capacity revolutionize emerging and established industries, from auto manufacturing to connected waste management services, stakeholders in those industries are discovering that SEP abuse accompanies the arrival of these capabilities. As overly-aggressive licensors continue to systematically chip away at the applicability of antitrust law to their harmful licensing activities, the Senate Energy and Natural Resources Committee could play an important role in ensuring that federal law and policy protects innovators and consumers from this conduct in the transportation sector. We urge you to closely examine what policy levers are available, from oversight to legislative opportunities and agency guidance, to create changes where necessary to protect consumers and promote innovation in the environment, energy, and transportation sectors. We stand ready to assist in these endeavors and hope that you will draw on our expertise and perspective as you consider this as part of your broader antitrust and consumer protection agendas.

Sincerely,



Morgan W. Reed
President
ACT | The App Association

³ See Findings of Fact and Conclusions of Law, *Fed. Trade Comm'n v. Qualcomm, Inc.*, Case No. 17-CV-00220-LHK (N. D. Cal., 2019), available at https://www.essentialpatentlog.com/wp-content/uploads/sites/64/2019/05/2019-05-21-Findings-dckt-1490_0.pdf; *Broadcom Corp. v. Qualcomm Inc.*, 501 F.3d 297 (3d Cir. 2007), available at <https://caselaw.findlaw.com/us-3rd-circuit/1069408.html>.



February 7, 2021

The Honorable Pete Buttigieg
Secretary
U.S. Department of Transportation
1200 New Jersey Ave., SE
Washington, D.C. 20590

The Honorable Michael Regan
Administrator-designate
U.S. Environmental Protection Agency
1200 Pennsylvania Ave., NW
Washington, D.C. 20004

The Honorable Jennifer Granholm
Secretary-designate
U.S. Department of Energy
1000 Independence Ave., SW
Washington, D.C. 20585

The Honorable Gina McCarthy
National Climate Advisor
Executive Office of the President
1650 Pennsylvania Ave., NW
Washington, D.C. 20502

Dear Secretary Buttigieg, Secretary-designate Granholm, Administrator-designate Regan, and Climate Advisor McCarthy:

The nation's investor-owned electric companies, public power utilities, and electric cooperatives—which our organizations proudly represent—look forward to working with you and to leveraging the investments our members are making to help meet your Administration's goal of deploying electric vehicle charging stations across the country.

Our members provide safe, reliable, and affordable energy to more than 300 million Americans. The electric power industry supports more than 7 million American jobs and contributes \$880 billion annually to U.S. gross domestic product, about 5 percent of the total. Each year, our industry invests more than \$110 billion to make the energy grid stronger, smarter, cleaner, more dynamic, and more secure. These investments enable us to integrate more clean energy and new technologies into our electric systems, including electric vehicles (EVs), to benefit customers.

Our members are proud of the progress that has been made in deploying clean energy resources. As the Administration turns to electrifying transportation, we are committed to working with you to leverage our industry's investments to deploy electric vehicle charging infrastructure and to accelerate electric transportation adoption that will grow the economy and benefit the environment.

To get more EVs on U.S. roads, it is important that we invest in and deploy more charging infrastructure. Building this infrastructure will require public-private partnerships, and our members are critical to that effort, in part because they employ a highly skilled workforce that builds and maintains the energy grid. A collaboration between the federal government and our sector will help to create additional jobs and will help spur economic recovery.

Charging stations are one piece of a vast system with implications for the grid. Our members are a crucial partner in building and maintaining the infrastructure to deploy EV charging stations at all the locations where EVs charge. These investments are structured to best serve communities and customers.

Our members already own and operate EV charging stations in a variety of locations and for all types of customers. These arrangements are particularly beneficial to consumers who prefer not to procure and maintain charging infrastructure and seek a turnkey solution. Some of our members install the “make-ready” infrastructure that connects to the charging equipment, leaving it to the consumer to own and maintain the charging station. And other members offer rebate programs to offset the costs to install charging infrastructure.

Regardless of the approach, each of these solutions is critical to building charging infrastructure that helps to spur the EV market and benefit communities. This is particularly true in regions where private investment in EV charging stations historically has been difficult.

It is important that all communities have access to the benefits of EVs, and our members are investing in underserved communities, in electrifying car-sharing and public transportation systems that serve those who do not own vehicles, in electrifying commercial vehicles such as delivery trucks that operate within neighborhoods, and assuring that Americans can charge their vehicles coast-to-coast in urban, suburban, and rural communities. Each community may have a different model that works best. Providing flexibility will ensure that more communities can participate in charging programs, leading to more EV charging stations across the country.

Local decision-making will help ensure charging stations meet the needs of each community. Our members continue to work with local stakeholders and are best-positioned to understand and to maximize the value of different technologies and systems that can help optimize the operation of the grid, integrate EVs, and recover more quickly from natural disasters.

However, the federal government is a key partner in the research and development related to EVs and the associated charging infrastructure, and technical and financial assistance can help accelerate deployment. Existing programs across federal agencies have been effective in deploying alternative-fuel vehicles and infrastructure, while other programs should be updated to reflect current advancements in technology.

Today, nearly 40 percent of the nation's electricity comes from carbon-free sources, and carbon emissions from the U.S. power sector are at their lowest level in more than 30 years—and continue to fall. The electric power sector's significant leadership in reducing carbon emissions can help drive carbon reductions in other sectors, especially transportation, through increased electrification.

We look forward to working with you and to our continued partnership in advancing clean energy technologies and electric vehicle infrastructure.

Sincerely,



Joy Ditto
President & CEO
American Public Power
Association



Tom Kuhn
President
Edison Electric Institute



Jim Matheson
CEO
National Rural Electric
Cooperative Association



The electric vehicle revolution critics can't dispute

By Joe Britton, opinion contributor — 02/19/21 03:00 PM EST 562

The views expressed by contributors are their own and not the view of The Hill

Each year, electric vehicles (EVs) are delivering consumers better torque and performance, lower fuel and maintenance costs, and dramatically less pollution and carbon emissions.

So why are critics launching campaigns that spread misleading narratives to convince us otherwise? Because transportation electrification poses a threat to the world's dependence on oil, and well-financed special interests will go to any length to protect their profits. While those interests have accelerated efforts to sow doubts about EVs, it's incumbent on us to see past the misdirection and set the record straight.

- **Efficiency**

No matter how you slice it, EVs are cleaner than gas-powered cars and will only get cleaner as our electricity generation does the same. While EVs have zero tailpipe emissions, opponents are quick to point out that the manufacturing and charging process is not carbon-free.

While it is true that no manufacturing or power generation is yet reliably emissions-free, it does not change the fact that EVs are clearly cleaner than gasoline-powered cars. When we evaluate the entire process of manufacturing an EV and sourcing the electricity, EVs generate up to 67 percent lower greenhouse gas emissions (GHGs) over their lifetime than their gas-powered counterparts.

Put simply, [an EV powered by coal-fired electricity is still cleaner](#) than an automobile powered by gas. And unlike gas-powered cars whose carbon footprint is set, as the power sector continues adopting less costly renewable energy, EVs become cleaner and cheaper too.

- **Ethical Supply Chains**

Another favorite half-truth of the special interests tries to link EVs to unethical mining practices for critical materials. This is an important, though deceptive, concern. The global demand for lithium, cobalt and other critical materials is set to grow whether or not a single additional EV is produced. The reason is because of the continued rapid adoption of batteries for personal technology devices that require these critical materials. Yes, including the phone, tablet or computer you're reading this on.

Dampening the demand for EVs may be good for oil refineries, but it does nothing to address critical materials supply sourcing. Rather than denying the inevitable and growing need for these critical minerals, we must seize the transition to EVs as an [opportunity to establish robust domestic supply chains](#) with ethical and humane practices. Including groundbreaking recycling work being done by American companies that has the potential to [reclaim up to 95 percent of critical materials](#) from scrapped batteries.

With smart policy, a strong EV sector will create thousands of good paying critical materials and manufacturing jobs and improve our national security. We must remain focused on solutions, instead of getting distracted by the misinformation campaigns of incumbent, polluting special interests.

- **Affordability & Equity**

Anti-EV campaigns have also accused EV customers of unfairly benefitting from federal benefits that don't accrue equitably to all Americans. These campaigns, ironically, are commonly led by wealthy interests who have uniquely and disproportionately benefited from decades of oil subsidies. Like any new technology's product cycle, the first EVs were more expensive but have evolved into a market far more diverse and affordable.

Now the market offers [many EVs below the average cost](#) of a gas-powered car, and nearly all electrics have a lower [total cost of ownership](#). Resilient batteries and a growing charging network make the rationale for [going electric even more compelling](#). As more and more Americans experience this reality of accessibility, we must advocate for policies that meet every community's needs and drive benefits for those most affected by air pollution and emissions.

In the Northeast and Mid-Atlantic region, people of color breathe in an average of [66 percent more vehicle pollution](#). Transportation electrification stands as a promising solution to cleaning up air quality in these areas and protecting public health. But resigning ourselves to EV critics who want to lock our economy into decades of carbon-intensive transportation is the worst possible outcome for those most affected.

- **Charging Buildout**

It is also absolutely critical to build out a stronger public charging system that meets every community's needs. We'll all be served by deploying EV chargers in transportation corridors, workplaces, retail settings, municipal parking and rural areas. Equitable charging investments must incentivize medium- and heavy-duty fleet vehicles and better support harder-to-serve disadvantaged populations.

Utility companies are natural partners for many communities seeking to build out critical charging infrastructure to enable EV deployment. Yet critics have resorted to scare tactics about the potential of skyrocketing monthly bills if utilities also invest in vehicle charging infrastructure. These talking points are not rooted in fact.

If the related costs of charging infrastructure were passed on to utility consumers, the impact on monthly bills would be a matter of cents rather than dollars. In almost all cases, utility investments will leverage other public and private financing, further minimizing costs to ratepayers. And widespread vehicle electrification increases grid efficiency, which instead [applies downward pressure on rates](#) over time. The truth is that in order to meet every community's needs, we need the federal government, local leaders, third-party charging companies, site hosts, and utilities working together.

The electric vehicle revolution is well under way. While EVs continue to innovate, so too will the attacks from EV critics as they fight to maintain their carbon supremacy over our economy. But the real truth is that transportation electrification continues to drive value for American consumers and communities alike, and we continue to work to ensure that everyone benefits equally.

Joe Britton is executive director of the Zero Emission Transportation Association.



March 15, 2021

The Hon. Joe Manchin
Chairman
Committee on Energy and Natural Resources
U.S. Senate
304 Dirksen Senate Building
Washington, DC 20510

The Hon. John Barrasso
Ranking Member
Committee on Energy and Natural Resources
U.S. Senate
304 Dirksen Senate Building
Washington, DC 20510

In Re: Ways to Strengthen Research and Development in Innovative Transportation Technologies with a Focus on Solutions that Decrease Emissions, Reduce Our Reliance on Foreign Supply Chains, and Increase Manufacturing in the United States; Hearing March 16, 2021

Dear Chairman Manchin and Ranking Member Barrasso:

As the Committee considers investments in transportation innovation to decrease emissions and promote U.S. supply chains, manufacturing and employment, we respectfully request and appreciate your consideration of the following:

Summary:

Thanks to their widescale penetration throughout the global economy, continued innovation and investment in advanced diesel engines is essential for achieving near-term and long-term progress in meeting national climate and environmental objectives. Today, diesel engines and fuels are the backbone of the U.S. economy, with one out of every two economic sectors relying on diesel technology to move freight on land, water and rail, to build transportation and energy infrastructure, to generate electrical power, and farm the land, among other uses.

- After decades of innovations, today's diesel engines across the board achieve near-zero emissions and are growing in the national population of work trucks, machines and equipment. The innovations save fuel, reduce greenhouse gas emissions, and generate clean air benefits for all communities, particularly those located near high-density freight and industrial operations.

While zero-emissions solutions for some applications are planned for the future, few are available today, making continued investment in diesel power essential to sustain national progress. Manufacturers are working to develop new power options for their customers in a number of applications, that could include battery-storage/electrification and hydrogen. The adoption of these solutions could be well into the future, according to many analysts. This underscores the importance of continued innovation, investment and progress in advanced diesel engines.

- The steady introduction of the newest generation of diesel technology in fleets and on jobsites today is delivering vital progress on reducing greenhouse gas emissions (GHG) and improving national air quality.

Diesel Technology Forum's Comment on U.S. Senate Committee on Energy and Natural Resources March 16, 2021 Hearing Concerning Transportation Solutions

- Industry supports further progress on lowering emissions from diesel engines like the Cleaner Trucks Initiative that is currently in the EPA regulatory pipeline, with a proposed rule anticipated this year that will further reduce allowable emissions likely beginning in the 2027 timeframe.

Heavy-duty diesel engines manufactured in the U.S. in 2019 exceeded 900,000 units, providing over 1.3 million jobs and more than \$158 billion in economic value.

- Producing and servicing diesel-powered equipment affords many Americans a well-paying job and benefits communities across the country, an estimated 1.3 million jobs and \$158 billion in economic value. The average wage in the industry exceeds the national average paying workers about \$78,000 per year, approximately 60 percent higher than the national average.

The use of advanced biofuels in diesel engines is growing and is an important opportunity that leverages existing vehicle technology and infrastructure while also delivering meaningful greenhouse gas emissions reductions.

- Large investments are being made in the refining sector to boost the supply of advanced biofuels including renewable diesel fuel and biodiesel fuel that, when used in diesel engines, yield substantial greenhouse gas emissions benefits at very low cost. Low-carbon fuel policies in California, and being considered in other regions, are realizing the cost savings and other benefits of using these fuels compared for example to zero emission vehicle alternatives.

Advanced Generation of Diesel Technology is Part of a National Climate Solution

The diverse nature and significance of the challenge to reduce global greenhouse gas emissions dictates that it is not a one-size fits all problem, but instead one where many solutions will be needed. An effective climate policy is also one that balances near term strategies for greenhouse gas emissions reductions alongside investments in future zero-emissions solutions.

	National	West Virginia	Wyoming
Estimated Size of the Commercial Vehicle Fleet (Class 3-8 commercial trucks)	~ 14 Million	75,000	70,000
Percentage of Fleet that is Diesel	75.4 percent	75.6 percent	80 percent
Percentage of diesel commercial vehicles in operation that are 2011 and newer that achieve near-zero emissions: national average 43%	43 percent	35 percent	45 percent

Diesel Technology Forum's Comment on U.S. Senate Committee on Energy and Natural Resources March 16, 2021 Hearing Concerning Transportation Solutions

Background

By way of background, the Diesel Technology Forum is a not-for-profit educational advocacy raising awareness of the environmental and economic benefits of diesel technology. Our members represent the leaders in diesel technology including engine, truck and equipment manufacturers, component suppliers and fuel and biofuel producers.

Introduction

A. Diesel Powers Key Sectors of the Economy

When it comes to key sectors of the economy like commercial vehicles, off-road equipment, locomotives and workboats, diesel is the dominant powertrain today. As manufacturers innovate to introduce zero-emissions solutions to these heavy-duty applications, the latest innovations in near-zero emissions performance from diesel are readily available today. More efficient diesel engines are available today that meet stringent fuel economy and tailpipe emissions standards established by U.S. Environmental Protection Agency (EPA), that reduce greenhouse gas emissions and bring clean air benefits directly to frontline communities near freight facilities.

B. Domestic Manufacturing Benefits of Diesel Technology

One out of every two sectors of the U.S. economy relies on heavy-duty diesel engines many of which are manufactured in production facilities across the U.S. 75 percent of commercial trucks are powered by diesel engines, and 97 percent of the large Class 8 trucks are diesel, along with the wide variety of construction and agricultural equipment types and much larger engines that power marine vessels and locomotives. Diesel technology delivers products to store shelves, inputs to factories, completes public works projects and delivers our agricultural bounty to markets in the U.S. and across the globe.

Over 900,000 heavy-duty diesel engines were manufactured in production facilities across the U.S. These engines power the fleet of trucks and equipment that keep our economy moving and tied to global markets. As the economy expands, the need for diesel powered vehicles and equipment expands as well and many of these engines entering the market will have been made in the U.S.

Diesel Technology Forum's Comment on U.S. Senate Committee on Energy and Natural Resources March 16, 2021 Hearing Concerning Transportation Solutions

Ranking	State	Number of Heavy-Duty Diesel Engines
#1	NC	327,500
#2	IN	160,985
#3	MI	109,000
#4	OH	70,000
#5	NY	76,400
#6	MD	40,000
#7	TX	29,800
#8	IA	28,750
#9	MS	28,700
#10	GA	12,700
#11	AL	7,200
#12	UT	1,600
#13	SC	940

SOURCE: Rhein & Assoc.

C. Clean Air Benefits of the Latest Diesel Innovations

Today, near-zero emissions diesel solutions are widely available in commercial vehicles and off-road equipment along with large engines that power locomotives and marine workboats. Replacing older generations of technology with these latest advancements can generate big clean air benefits. Beginning in model year 2010, EPA requires that all commercial vehicles meet a stringent standard for ozone forming compounds (NOx) and fine particle emissions (PM 2.5). The combination of catalysts and filters allows these near-zero emissions diesel trucks to reduce emissions by 98 percent relative to an older generation of technology.

Diesel Technology Forum's Comment on U.S. Senate Committee on Energy and Natural Resources March 16, 2021 Hearing Concerning Transportation Solutions



Replacing a single older generation Class 8 truck with a new near-zero emissions diesel option available today can eliminate over 2 tons of NOx emissions and 250 lbs. of PM emissions. As an example of the benefits of these near-zero emissions diesel trucks, PM 2.5 truck emissions in the massive port complex in southern California were reduced by over 80 percent as the Ports of L.A. and Long Beach require all trucks meet near-zero emissions requirements. In 2005, port trucks were the second leading contributor to PM emissions generating 185 tons per year. By 2019, trucks were the second smallest contributor generating only seven tons per year.¹ These are direct and immediate clean air benefits delivered to many communities surrounding the port complex and warehouse districts in southern California.

Unlike passenger vehicles, turnover in the commercial truck sector is relative slow. After a decade, roughly less than half of all commercial vehicles on the road today do not come with solutions to meet the most recent tailpipe standard. While zero-emissions solutions are being planned for the future, with a few models in a few smaller truck categories available today, it will be some time before these technologies enter the commercial vehicle fleet in large numbers to generate benefits. Meanwhile, significant clean air benefits may accrue to communities across the country by transitioning these older and higher mileage commercial trucks to near-zero emissions solutions quickly.

D. Climate Benefits Are Here Now from More Efficient Diesel Engines and Vehicles

Much like cars, commercial vehicles are now subject to stringent fuel economy and greenhouse gas emissions standards. A single new Class 8 diesel truck can eliminate almost 10 tons of greenhouse gas emissions in a single year when replacing an older less efficient model. Just imaging the climate

¹ 2019 Emissions Inventory, Port of Long Beach, <https://polb.com/environment/air/#emissions-inventory>

Diesel Technology Forum's Comment on U.S. Senate Committee on Energy and Natural Resources March 16, 2021 Hearing Concerning Transportation Solutions

benefits of transitioning many of the nation's older trucks to new diesel models available on dealer lots today.

Over the lifetime of the fuel economy rule for trucks, between 2021 and 2027, more efficient diesel-powered commercial vehicles are expected to **reduce greenhouse gas emissions by over 1 billion tons** and save record amounts of fuel.² Beginning this year, a more stringent fuel economy standard known as Phase 2 rules, is required for all new commercial vehicles. The new rule applies to all truck types from a heavy-duty pickup to a tractor-trailer combination truck. While engines are expected to become more efficient, a variety of other technologies such as lightweight materials, aerodynamics and innovative transmissions, are designed to boost the fuel sipping properties of the already efficient diesel engines. Future technologies, like zero-emissions solutions, are expected to be introduced (while a few are available today) in a few truck types, yet the overwhelming majority of these new more efficient trucks will be diesel.³

E. Climate Benefits Can Be Enhanced Through Expanded Use of Biodiesel and Renewable Diesel Fuel

The diesel engine, patented by Rudolph Diesel over 160 years ago, was designed to operate on biofuels. Today, the same holds true as diesel engines – old and new – may operate on renewable diesel fuel and high-quality blends of biodiesel and in doing so generate substantial climate benefits. These are fuels that are considered advanced biofuels, capable of reducing greenhouse gas emissions by at least 50 percent and in the case of renewable diesel fuel upwards of 80 percent. These are low-cost solutions that do not require additional investments in new engines, vehicles or charging stations, unlike other low carbon transportation solutions.

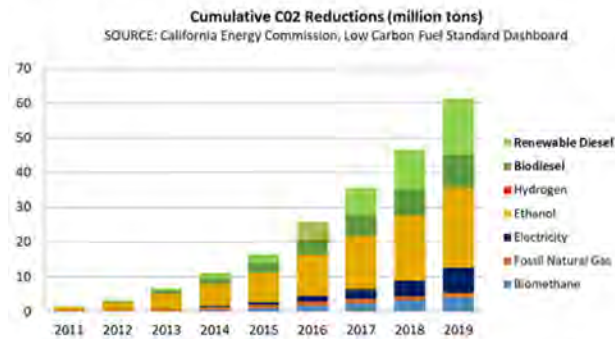
The use of these fuels is already achieving substantial and low-cost greenhouse gas reductions where they are used. In California, the use of biodiesel and renewable diesel fuel have eliminated the most greenhouse gas emissions cumulatively in the transportation sector between 2011 and 2019, according to the California Air Resources Board.⁴ The benefits of renewable diesel fuel and biodiesel exceed that of electrified cars, trucks and buses by nearly 4-to-1.

² <https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-phase-2-greenhouse-gas-emissions-standards-and>

³ "Reinventing the Truck", IHS Markit (2020), <https://ihsmarket.com/products/reinventing-the-truck.html>

⁴ Low Carbon Fuel Standard Dashboard, California Air Resources Board, <https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm>

Diesel Technology Forum's Comment on U.S. Senate Committee on Energy and Natural Resources March 16, 2021 Hearing Concerning Transportation Solutions



According to the National Biodiesel Board (NBB), 2.8 billion gallons of renewable diesel fuel and biodiesel were sold in 2019, the last year for which data is estimated. Between 2018 and 2019, renewable diesel sales grew by 50 percent. NBB estimates that there are enough readily available feedstocks to produce six billion gallons of these fuels by 2030.

Interest in the sector is expanding as many high-profile petroleum refiners are retooling petroleum facilities to produce renewable diesel fuel. According to Stratas Advisors, an energy sector consultancy, if actual production equates to announced capacity, renewable diesel production in the U.S. could displace all petroleum diesel fuel consumed in California.⁵ This is a low carbon fuel derived largely from feedstocks in the U.S. and produced by a skilled and well-paid U.S. workforce.

Examples of planned renewable diesel fuel investments include:

- **Valero and Darling** invest in Diamond Green Diesel in Norco, LA to produce 1.2 billion gallons of renewable diesel fuel at the conclusion of the project.⁶
- **ExxonMobil** will convert its Bakersfield, CA refinery to produce 2.5 million gallons of renewable diesel fuel annually.⁷
- **HollyFrontier** will convert its Cheyenne, WY petroleum refinery to produce renewable diesel fuel. The facility currently produces 52,000 b/d of refined petroleum products.⁸

F. Conclusions

⁵ "Overcapacity Looms as More and More U.S. Refiners Enter the Renewable Diesel Market", Stratas Advisors, June 2020,

<https://stratasadvisors.com/insights/2020/06112020LCFS-RD-Investment>

⁶ <https://www.spglobal.com/platts/en/market-insights/latest-news/oil/012821-valero-darling-to-move-forward-with-port-arthur-diamond-green-diesel-project>

⁷ <https://corporate.exxonmobil.com/News/Newsroom/News-releases/2020/0811-ExxonMobil-and-Global-Clean-Energy-Holdings-sign-agreement-for-renewable-diesel>

⁸ <https://www.reuters.com/article/us-hollyfrontier-refining-cheyenne/hollyfrontier-to-convert-oil-refinery-into-renewable-diesel-plant-idUSKBN23831F>

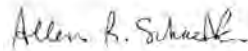
Diesel Technology Forum's Comment on U.S. Senate Committee on Energy and Natural Resources March 16, 2021 Hearing Concerning Transportation Solutions

Thank you for the opportunity to provide these comments.

- The latest advancements in diesel technology that power heavy-duty applications including trucks and equipment generate significant climate and clean air benefits particularly for communities located near freight facilities. The immediate-term benefits of ready-to-go near-zero emissions technologies like diesel should be a part of a climate policy that seeks to maximize reductions today alongside investments in future zero emissions solutions.
- With about half of the U.S. truck fleet powered by older generations of technology, there are significant and immediate term clean and climate benefits that can be achieved overnight with near-zero emissions diesel options. These benefits may be delivered quickly to communities most in need of clean air benefits as manufacturers continue to invest in zero-emissions solutions for the future.
- Significant advancements are being made in clean and low carbon fuels including renewable diesel and biodiesel fuels. Fleets that have made the switch are generating big climate benefits at low-cost relative to other low carbon transportation options.
- Many of these diesel solutions are homegrown as production facilities in 13 states turned out over 900,000 heavy-duty diesel engines in 2019. The production of these engines takes a skilled and well-paid workforce and the leaders in diesel technology are ready to support U.S. economic recovery.

Please feel free to contact me with any questions or concerns at (301) 514-9046 or aschaeffer@dieselforum.org.

Very truly yours,



Allen R. Schaeffer
Executive Director



JRC TECHNICAL REPORT

Responsible and sustainable sourcing of battery raw materials

*Insights from hotspot
analysis, company disclosures
and field research*

Mancini, L., Eslava, N. A., Traverso, M., Mathieux, F.

2020



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Contact information
 Name: Lucia Mancini
 Address: via E. Fermi 2749, Ispra, Italy
 Email: lucia.mancini@ec.europa.eu
 Tel.: +39 0332 78 5428

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Authors

Lucia Mancini

Nicolas A. Eslava

Marzia Traverso

Fabrice Mathieux

Abstract

Used in e-mobility and electronics, batteries are essential to achieve the EU objective of decarbonisation of the economy and other challenges related to sustainable development. Several policy initiatives have been issued and others are under discussion to promote sustainable and competitive production of batteries in the EU.

Recently, various stakeholders highlighted social risks related to supply chains of batteries and in particular in regard to the provision of raw materials. Cobalt is especially concerning when it comes to human rights abuses, child labour and life-threatening working conditions in the Democratic Republic of the Congo (DRC). That country provides around 60 % of the global supply, a significant proportion of it originating from artisanal and small-scale mining (ASM) operators. Reports from non-governmental organisations (NGOs), international organisations and media on this topic have increased in number since 2016, and the issue is now more visible than in 2007, when the first reports on the sector emerged. At the same time, responsible sourcing initiatives have been launched and implemented for cobalt and other materials, most of them aligned with the OECD (Organisation for Economic Co-operation and Development) due diligence guidance for responsible supply chains of minerals from conflict-affected and high-risk areas (OECD Guidance). Among them, EU Regulation 2017/821 will require EU importers of tin, tungsten, tantalum and gold (3TG) to perform due diligence on their supply chain, according to the OECD Guidance. The strategic battery action plan proposed by the European Commission identifies some clear work streams on responsible sourcing. A battery-specific regulation including requirements for the ethical sourcing of materials is also currently under discussion.

The objective of Chapters 2 and 3 is to identify potential risks in the mining stage of battery materials' production, using data at country and corporate levels. Chapter 2 presents a hotspot analysis of primary raw materials used in batteries. It combines data on the mining stage (including global supply, EU sourcing, and reserves and resources) with indicators considered relevant to the responsible sourcing of batteries (i.e. on governance, conflict risk, human and social rights, environmental performance and water risk). These are complemented by insights from the Environmental Justice Atlas, which documents information about conflicts and struggles over the exploitation of natural resources and the related production processes. The analysis resulted in the identification of three main groups of countries that could present risk as global suppliers, as EU suppliers and for future materials supply.

Chapter 3 investigates what information about social sustainability is available at corporate level. Applying an original methodology, it scrutinises publicly available sustainability reports by large-scale and multinational mining companies that produce materials for batteries, taking into account the impact categories proposed in the social life-cycle assessment (S-LCA) framework and the key principles described by the EU Guidelines for non-financial reporting. Although sustainability reporting practice has been increasing in recent years, the level of disclosure is very heterogeneous between companies and only a few sustainability reports are audited by third-party organisations.

Chapters 4 and 5 focus on the initiatives implemented to mitigate the risks identified in the previous chapters, using both data from the literature and primary data. As companies are increasingly asked to perform due diligence on their supply chains, several initiatives, schemes and company strategies have been developed. They are reviewed in Chapter 4, which compares the different requirements and risk categories that have to be scrutinised under the various initiatives. Most of them are aligned with the requirements of the OECD Guidance, while approaches towards artisanal mining differ. Four initiatives are implemented on the upstream phase, and three of those engage with the ASM sector and work on the ground in order to improve working conditions in the DRC. The impacts of two initiatives (those implemented for at least 1 year) are assessed through a field investigation.

The analysis in Chapter 5 is based on a comparison of two visited pilot projects with the general conditions of the cobalt and copper ASM sector in Lualaba and Haut-Katanga provinces in the DRC. The characterisation of pilot sites is based on the collecting of qualitative information through information matrices. These are based on the OECD Guidance and other relevant standards for responsible and sustainable supply, which include the S-LCA framework. This information gathering was complemented by a visit to a third ASM site, where no pilot was implemented. It was chosen as representative of the general ASM sector, and used as a baseline. Given the nature of this work and the amount of primary data collected, an extensive analysis and detailed description of the contexts under investigation are provided. Results show that the systems analysed are rather effective at

implementing the changes that they are designed to implement. This is especially visible when it comes to issues of life-threatening working conditions and child labour. However, risk categories addressed by these projects are dictated by downstream expectations and do not necessarily correspond to the demands of the miners they are designed to protect. For instance, price calculation and income are particularly salient aspects and are not captured by the evaluations. The S-LCA methodology offers a promising avenue to expand the scope of enquiry in a structured manner. Traceability is another key point, as the systems are applied only in small areas of the mining sites. Companies' participation in the pilots could be used to burnish their reputation as a whole, out of proportion to the contribution of the pilot sites to the companies' overall supply. Moreover, the scalability of these pilots within a short time frame is unknown, as the availability of local skilled professionals, among other challenges, might be a critical bottleneck. Overall, the positive results of the systems analysed warrants an appeal to further facilitate (e.g. through funding) the development of similar initiatives.

This study is a first step towards the understanding and quantification of the main risks in battery supply chains at mining stage, and the assessment of the impact of current initiatives implemented on the ground. It sets the stage for a more complete understanding of the concept and practice of responsible sourcing, and proposes a methodology that could be replicated for other materials, other sectors and other applications.

1. Introduction

1.1. Policy context

One of the priorities under the agenda of the new von der Leyen Commission is to ensure 'free and fair trade' ⁽¹⁾. In this context, trade should be a means to deliver prosperity and to export the EU's values around the world. Moreover, trade agreements should include 'higher standards of climate, environmental and labour protection, with a zero-tolerance policy on child labour' ⁽²⁾. In the same document, the 'European Green Deal' chapter draws up ideas and policy objectives for Europe to become 'the first climate-neutral continent' ⁽³⁾. The Green Deal Communication ⁽⁴⁾ defines in more detail the European Commission's commitment to tackling climate and environmental-related challenges, through key policies and measures. The shift to sustainable mobility and the supply of clean energy are two building blocks of this strategy, which also encompasses socioeconomic objectives such as competitiveness, fairness and inclusiveness.

Batteries are strategic technologies that, used for instance in e-mobility, renewables and electricity provision in off-grid communities, are expected to enable the transition towards a low-carbon economy. Moreover, lithium-ion batteries (hereafter called simply batteries) are widely used in electronics, medical devices and power tools. Demand for them grew by 30 % annually in the period 2010 to 2018 and is expected to grow by 25 % annually till 2030 ⁽⁵⁾, especially because of their use in electric vehicles ⁽⁶⁾. Given the importance of batteries for the EU economy and for environmental objectives, the Commission adopted the strategic action plan ⁽⁷⁾, a comprehensive set of concrete measures to develop an innovative, sustainable and competitive battery 'ecosystem' in Europe. These measures could include the promotion of ethical sourcing of raw materials for the battery manufacturers and the setting of sustainability requirements for batteries (e.g. on safety, recyclability, life-cycle impacts, responsible sourcing, etc.) ⁽⁸⁾. These requirements are seen as necessary to meet market expectations for clean battery value chains and also as drivers for the EU's competitiveness in sustainable battery production.

The disclosure of information on aspects of sustainability is already a legal obligation for large companies with more than 500 employees, as required by Directive 2014/95/EU ⁽⁹⁾. Companies are asked to use existing widely accepted reporting frameworks or to follow the Guidelines on non-financial reporting of the European Commission ⁽¹⁰⁾. Thematic aspects to be considered include environmental matters (e.g. emissions, waste, water, energy), social matters (e.g. employment, health and safety, diversity issues, trade union relationships), respect for human rights, anti-corruption and due diligence on conflict minerals, according to the Organisation for Economic Co-operation and Development (OECD) due diligence guidance for responsible supply chains from conflict-affected and high-risk areas (OECD Guidance) ⁽¹¹⁾.

1.2. Conflict minerals and responsible sourcing

The issue of 'conflict minerals' relates to materials (usually tin, tungsten, tantalum and gold, also referred to as 3TG) whose extraction and trade, in politically unstable areas, can be used to finance armed groups, fuel forced labour and other human rights abuses, and support corruption and money laundering ⁽¹²⁾. These minerals, used in a variety of devices such as mobile phones, cars and jewellery, are extracted in several locations in the world, including the Democratic Republic of the Congo (DRC). The profits from the sale of these minerals have financed

⁽¹⁾ von der Leyen, U. (2019), Chapter 5, 'A stronger Europe in the world', page 17.

⁽²⁾ von der Leyen, U. (2019), 'A stronger Europe in the world', page 17.

⁽³⁾ von der Leyen, U. (2019), Chapter 1, A European Green Deal, page 5.

⁽⁴⁾ European Commission (2019a).

⁽⁵⁾ WEF (2019).

⁽⁶⁾ Tsiropoulos et al. (2018).

⁽⁷⁾ European Commission (2018a), Annex.

⁽⁸⁾ European Commission (2019b).

⁽⁹⁾ Directive 2014/95/EU of the European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups.

⁽¹⁰⁾ European Commission (2017a).

⁽¹¹⁾ OECD (2016).

⁽¹²⁾ European Commission (2017b).

fighting in the Second Congo War and ongoing follow-on conflicts⁽¹³⁾. Moreover, in this region armed groups were controlling mines⁽¹⁴⁾. In order to stem the flows of conflict minerals, the United States issued a provision on conflict minerals in 2010⁽¹⁵⁾, requiring specific disclosures for companies importing 3TG from the DRC and neighbouring countries, to make sure they are not funding armed groups or human rights abuses. Similarly, the EU Conflict Minerals Regulation⁽¹⁶⁾, which will come into force on 1 January 2021, requires that EU operators importing 3TG from high-risk and conflict-affected areas will have to carry out due diligence on their supply chains, in accordance with the OECD Guidance. Due diligence is defined as 'an on-going, proactive and reactive process through which companies can ensure that they respect human rights and do not contribute to conflict'⁽¹⁷⁾. Unlike the US provision, which focuses on imports from the DRC and neighbouring countries, the EU regulation applies to all 'conflict-affected and high-risk areas' (CAHRAs), which mean regions 'in a state of armed conflict or fragile post-conflict as well as areas witnessing weak or non-existent governance and security, such as failed states, and widespread and systematic violations of international law, including human rights abuses'⁽¹⁸⁾. Recommendations on how to identify CAHRAs were published in 2018⁽¹⁹⁾.

1.3. The case of cobalt

In the last years, similar concerns to those about 3TGs have been raised about cobalt, a material contained in batteries and consequently in electric vehicles. Various stakeholders have highlighted supply chain risks related to raw materials in batteries, identifying cobalt as the material presenting the highest risk, especially concerning human rights abuses, child labour and poor working conditions⁽²⁰⁾ in the DRC, where most of the global cobalt production comes from. Moreover, in the DRC artisanal and small-scale mining (ASM) is a central source of revenues for about 2 million people, according to World Bank estimates⁽²¹⁾.

NGOs and research institutes have been denouncing socioeconomic consequences of artisanal cobalt mining in the DRC since at least 2007⁽²²⁾. An Öko-Institut study came out in 2011⁽²³⁾. Violence against women and child labour in artisanal mining sites in the region of cobalt extraction were described in a report from the Good Shepherd Sisters⁽²⁴⁾. In 2016, an Amnesty International report⁽²⁵⁾ brought the issue to wide public attention, stressing the link between undignified conditions on the ground and environmental objectives that batteries are supposed to contribute to. Other reports published from 2016 onwards addressed the social conditions in artisanal cobalt and copper mines (as the two materials are often mined together). A report from the Dutch Centre for Research on Multinational Corporations (SOMO) focuses on environmental pollution and human rights violations⁽²⁶⁾. Findings from a survey covering the economic well-being and health of households as well as the role of artisanal mining in their livelihoods were published in 2017⁽²⁷⁾. The Canadian International Institute for Sustainable Development (IIISD) published in 2018 an analysis of materials needed to enable the transition to a low-carbon economy, and the level of governance, conflicts and state fragility in producing countries⁽²⁸⁾.

⁽¹³⁾ Global Witness (2009).

⁽¹⁴⁾ The control of armed groups over mines can be of three different types: (i) armed groups physically control mines or force civilian labourers to mine, transport or sell conflict minerals; (ii) they tax, extort, or control any part of trade routes for conflict minerals; (iii) they tax, extort or control trading facilities, in whole or in part, including the point of export from the DRC or an adjoining country (US Congress 2010).

⁽¹⁵⁾ Dodd-Frank Act, Section 1502.

⁽¹⁶⁾ Regulation (EU) 2017/821 of the European Parliament and of the Council of 17 May 2017 laying down supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold originating from conflict-affected and high-risk areas.

⁽¹⁷⁾ OECD (2016).

⁽¹⁸⁾ Regulation (EU) 2017/821.

⁽¹⁹⁾ Commission Recommendation (EU) 2018/1149 of 10 August 2018 on non-binding guidelines for the identification of conflict-affected and high-risk areas and other supply chain risks under Regulation (EU) 2017/821 of the European Parliament and of the Council.

⁽²⁰⁾ RCS Global (2017).

⁽²¹⁾ Delve (n.d.).

⁽²²⁾ Swedwatch (2007).

⁽²³⁾ Tsunakawa et al. (2011).

⁽²⁴⁾ Good Shepherd Sisters (2013).

⁽²⁵⁾ Amnesty International (2016).

⁽²⁶⁾ SOMO (2016).

⁽²⁷⁾ Faber et al. (2017).

⁽²⁸⁾ Church and Crawford (2018).

On the other hand, some reports describe impacts linked to of Large Scale Mining (LSM) operations, e.g. related to corruption and bribery, and observe how the exclusion of artisanal miners leads to increasing tension and hostility between ASM and LSM ⁽²⁹⁾.

In 2019, BGR conducted an inventory of the cobalt and copper sector through an artisanal mines survey in the key cobalt-producing provinces of Lualaba and Haut-Katanga in the DRC ⁽³⁰⁾. The OECD, focusing on the same areas, analysed prevalent risks and strategies for building more responsible mineral supply chains in a report published in 2019 ⁽³¹⁾.

Some initiatives and standards for the responsible sourcing of cobalt have been launched and implemented in the last few years. They have different scopes, and can be applied at different stages in the supply chain (mining, smelting/refining, manufacturing, etc.). Moreover, some of them aim at responsible sourcing, i.e. ensuring and demonstrating that the minerals used in supply chains are produced by responsible mining practices and handled responsibly, according to specific demands of responsible mining/sourcing standards. Others have a wider scope and embrace sustainability issues.

In this report we refer to responsible sourcing as encompassing all the risk categories included in the OECD Guidance, which mainly regard serious human rights abuses, corruption, money laundering, tax evasion and other aspects strictly related to mineral supply chains. By sustainable sourcing/supply we mean a broader concept, in which both environmental and social aspects are important. In this context, however, we focus mainly (but not exclusively) on social sustainability, as defined by the main widely accepted sustainability frameworks. In particular, we refer to S-LCA methodology ⁽³²⁾ and to the International Finance Corporation's (IFC's) Performance Standards on Environmental and Social Sustainability (PS) ⁽³³⁾. While the latter define the IFC clients' responsibilities for managing their environmental and social risks and are therefore designed for investment projects, S-LCA was developed in an academic context to evaluate social impacts mainly at product level, taking into account the various steps of the supply chain ⁽³⁴⁾. In these frameworks (and also others not under consideration here, for instance the Global Reporting Initiative – GRI), social sustainability denotes a variety of aspects that range from working conditions (e.g. health and safety, wages, benefits) to local communities' rights and also include most of the aspects characterising the concept of responsible sourcing, e.g. human rights abuses, corruption, child labour. However, these frameworks are designed to be applied to any economic activity and therefore specific aspects related to conflict minerals (such as the presence of armed groups and control of mines by them) are not taken into account.

1.4. Research questions and structure of this report

This report explores the topic of responsible sourcing for raw materials used in batteries, focusing on the mining stage and using different kinds of data: country-based indicators, self-reported company disclosures, information from literature and primary data collected at mining sites. These data, having different natures, granularities and sources, are complementary and make it possible to (i) explore the set of potential risks, drawing a big picture of social risks in the extraction of battery materials (Chapters 2 and 3) and (ii) scrutinise the initiatives launched to prevent such risks, investigating more specifically those related to cobalt extraction in the DRC. The report is structured in four chapters (plus introduction and conclusions), each one seeking to address different questions. This structure and the different scopes, natures of data and objectives of the chapters are also illustrated in Figure 1.

⁽²⁹⁾ E.g. Global Witness (2014); Resource matters (2019); OECD (2019)

⁽³⁰⁾ BGR (2019).

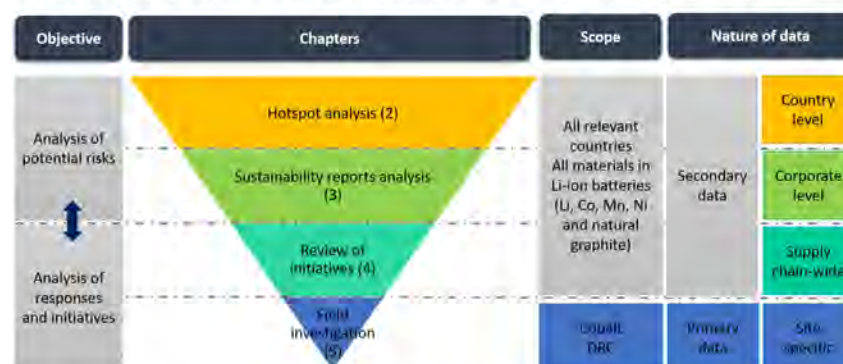
⁽³¹⁾ OECD (2019).

⁽³²⁾ UNEP/SETAC Life Cycle Initiative (2009).

⁽³³⁾ International Finance Corporation (2012).

⁽³⁴⁾ A new approach to implementing the methodology is the social organisational life-cycle assessment.

Figure 1 Structure of the report, including objectives, scope and nature of data used in the various chapters



Chapter 2 scrutinises which are the materials and the countries presenting the highest risks in battery supply chains, from a responsible and sustainable sourcing point of view. Supply data are matched with risk scores assigned to a set of relevant country-based indicators on governance, conflict risk, social and human rights, environmental performance and water risk. Even though some studies have been published on this topic (e.g. Church and Crawford, 2018), the hotspot analysis described in this report both considers important global players as battery material suppliers and also looks from an EU perspective at the main EU trading partners. Moreover, countries that own reserves and resources and thus have a potential risk for future supply are considered.

Passing from country to company level, Chapter 3 reviews sustainability reports and websites of the main mining companies that produce materials used in batteries, in order to explore the levels of disclosure of these corporations and their usability for a social impact assessment. Indicators used by companies to monitor their social impacts are matched against those proposed by the S-LCA framework and the principles of the European Commission Guidelines on non-financial reporting.

As many companies have started to adhere to responsible sourcing initiatives, or to produce their own strategies to manage risk in the supply chain, Chapter 4 reviews the main standards and initiatives for responsible and sustainable sourcing, promoted by international organisations, industries and other entities. Given the variety of existing sustainability schemes, only a few of them are mentioned in this review, although it aims to be exhaustive about the responsible sourcing initiatives focusing on cobalt.

While some of the responsible sourcing initiatives and companies' strategies aim to avoid 'dirty' materials ending up in their supply chains, few initiatives have the ambition of improving social conditions on the ground and engage with the artisanal mining sector in the DRC. Using a qualitative research method, Chapter 5 presents an investigation into two of them that have been implemented for more than 1 year. Questionnaires, typically used in social science investigation, are replaced here by information matrices, considered more suitable to informal contexts. This chapter aims to answer the following questions: What is the impact of these responsible sourcing initiatives on the ground? What are the risk categories where improvements can be registered? What are the main challenges?

The conclusions of the report summarise the main lessons learned from the above chapters concerning the responsible and sustainable sourcing of battery materials and suggest next steps to improve the understanding of responsible sourcing.

2. Hotspot analysis of battery supply chain

A hotspot analysis is a screening tool, which allows potential critical issues to be detected in a large set of quantitative or qualitative data ⁽³⁵⁾. It can be used in various disciplines, but is particularly suitable to studying sustainability in complex supply chains ⁽³⁶⁾. When applied to life-cycle assessment, it assists in the identification of areas (life-cycle stage/actor/type of impact) to be prioritised for action ⁽³⁷⁾. In the case of a social life-cycle assessment methodology, for example, it highlights sectors, countries, stakeholders and impact categories to be further investigated through the collection of primary data.

In this study, we applied a hotspot analysis to the supply of primary raw materials used in batteries, combining data on the supply of battery materials with indicators considered relevant to the responsible sourcing of batteries. The materials under consideration are cobalt, lithium, nickel, manganese and natural graphite.

The objective of the analysis is to detect potential criticalities in the materials value chain, thus using country-based data to identify which material supplier countries can be at risk in relation to the selected aspects. The goal of the analysis is to shed light on the country-material combinations potentially critical from a responsible sourcing point of view in the battery value chain. Therefore, similar analysis could be used as a starting point for a supply chain due diligence process.

The chosen indicators and the methodology are described in the next section, while Section 2.2 shows the results and Section 2.3 describes their interpretation. Section 2.4 summarises the main findings of the chapter.

2.1. Methodology

The hotspot analysis has been performed following three main steps:

- selection of risk aspects that are material for responsible sourcing, related indicators and sources of data,
- selection of countries involved in the battery supply chain,
- data gathering, attribution of risk levels to the selected countries and identification of hotspots.

2.1.1. Selection of relevant risk aspects, related indicators and sources of data

Concerning the first step, existing frameworks and programmes for responsible sourcing take into account various social aspects, some of them also including environmental aspects. In most cases, responsible sourcing initiatives aim to ensure that the extraction of materials does not imply, or is not linked with, human rights violations and conflicts.

Responsible sourcing is usually more challenging when importing from countries that have weak governance, high levels of corruption and conflicts in their territories. Several data sources provide information on these aspects at country level that, combined with data on material supply, can be used to perform a first screening of potential risks in terms of country-material combinations.

In order to select relevant indicators linked to responsible sourcing, the OECD Guidance on responsible mineral supply chains indicates the relevant aspects to be taken into account ⁽³⁸⁾. It includes:

- serious abuses associated with the extraction, transport or trade of minerals,
- torture, cruel, inhuman and degrading treatment,
- forced or compulsory labour,
- the worst forms of child labour,
- other gross human rights violations and abuses such as widespread sexual violence,
- war crimes or other serious violations of international humanitarian law, crimes against humanity or genocide,

⁽³⁵⁾ Liedtke et al. (2010).

⁽³⁶⁾ Rohm et al. (2014).

⁽³⁷⁾ Barthel et al. (2017).

⁽³⁸⁾ OECD (2016).

direct or indirect support to non-state armed groups,
 public or private security forces in the mining sites,
 bribery and fraudulent misrepresentation of the origin of minerals,
 money laundering,
 payment of taxes, fees and royalties due to governments.

The abovementioned aspects are considered the reference guidance for companies performing due diligence and for most of the responsible sourcing programmes.

However, to be able to characterise all these aspects, it is necessary to have access to trustable sources of data and databases, and unfortunately most of these aspects are not covered by global and harmonised databases. Reviewing the existing data sources and building on previous studies on social risk in the raw material sectors ⁽³⁹⁾, we identified the following data sources as relevant to our analysis.

1. **Worldwide Governance Indicators** ⁽⁴⁰⁾ include an indicator on corruption and one on the rule of law, which can be considered proxies for the components on bribery and money laundering listed in the OECD Guidance.
2. The **Resources Governance Index** ⁽⁴¹⁾ measures the quality of resource governance.
3. The **Inform** ⁽⁴²⁾ human hazard component assesses conflict risk and is supposed to reflect the second point of the OECD Guidance, on direct or indirect support to non-state armed groups. In addition, to better characterise conflict risk, we add in the analysis the **Global Peace Index (GPI)** and **Fragile State Index**. The latter defines fragility using 12 indicators relating to internal cohesion, the economy, politics, cross-cutting factors including demographic pressures, refugees and internally displaced persons, and external intervention. The GPI is developed by the Institute for Economics & Peace and ranks 163 countries according to 23 qualitative and quantitative indicators on peace ⁽⁴³⁾.
4. Databases used in S-LCA (**Social Hotspot Database** ⁽⁴⁴⁾ and Product Social Impact Life Cycle Assessment – **PSILCA** ⁽⁴⁵⁾ include data on some of the serious abuses listed in the OECD Guidance (e.g. forced labour, child labour, human rights violations).

In addition, we selected other aspects that, even though not mentioned by the OECD Guidance, are relevant to the sustainability of the extractive sectors. These include two indicators on environmental aspects (the **Environmental Performance Index** ⁽⁴⁶⁾ and the **Water Risk Index** ⁽⁴⁷⁾). They allow the ecological dimension to be included in the responsible sourcing concept, recognising that severe environmental impacts and water scarcity can imply other social impacts (e.g. affecting human health) and in some cases can generate conflicts ⁽⁴⁸⁾.

Conflicts arising over the extraction of natural resources, as documented in the **Environmental Justice (EJ) Atlas** ⁽⁴⁹⁾, are also taken into account. This database provides an insight into the social acceptance of mining projects by local communities, and also reports social and environmental impacts of mining and other industrial projects. However, as it is a community-driven tool some biases should be acknowledged. For instance, it requires communities to be informed and literate enough to submit the case. Developing countries with low Human Development Index scores are therefore likely to be under-represented.

⁽³⁹⁾ Mancini and Sala (2018); Manoni et al. (2018).

⁽⁴⁰⁾ Kaufmann et al. (2010)

⁽⁴¹⁾ NRGi (2017)

⁽⁴²⁾ Marin-Ferrer et al. (2017)

⁽⁴³⁾ Institute for Economics & Peace (n.d.).

⁽⁴⁴⁾ Benoit-Norris et al. (2012)

⁽⁴⁵⁾ Eisfeldt (2017)

⁽⁴⁶⁾ Wending et al. (2020)

⁽⁴⁷⁾ WRI (2019)

⁽⁴⁸⁾ Kemp et al. (2010)

⁽⁴⁹⁾ <https://ejatlas.org/>

The indicators chosen to perform the hotspot analysis and their relevance to responsible sourcing are described in Section 2.1.3.

2.1.2. Selection of relevant countries in the battery supply chain

Concerning the second phase of the analysis, data on supply of raw materials for batteries have been collected using the data sources described in Table 1. They regard (i) reserves and resources, which give an indication of potential future suppliers; (ii) global production, the main producing countries shown in Figure 2; and (iii) EU sourcing^(*), which reflects the suppliers to the EU. The values, provided in tonnes by the original sources, have been converted into percentages of totals. A cut-off rule of > 10 % has been applied to the three categories: only countries having more than 10 % in at least one category (reserves and resources, global supply, EU sourcing) have been considered hotspots.

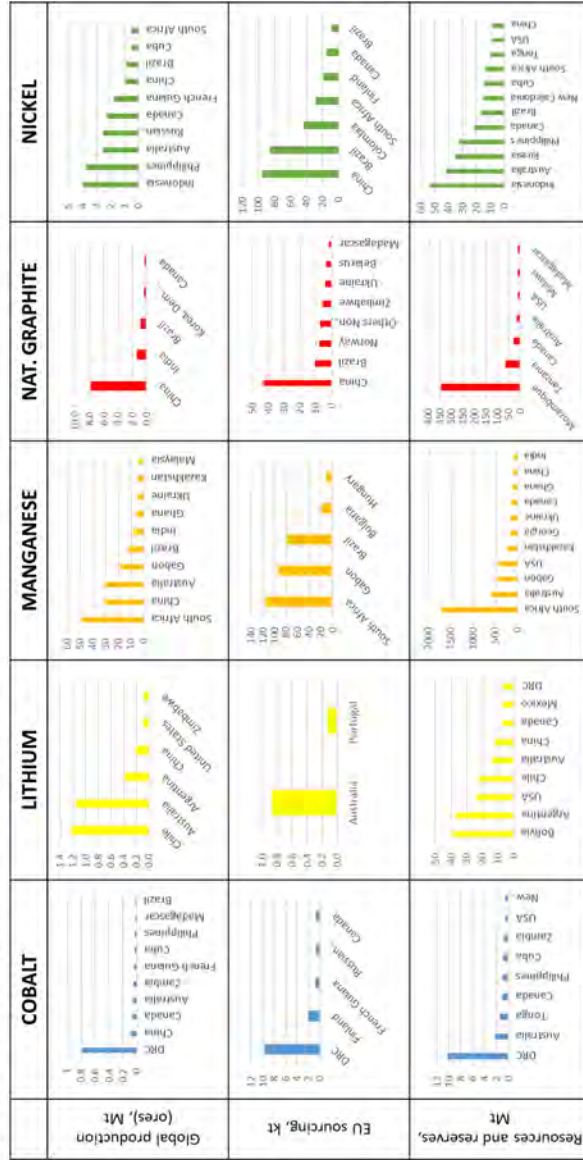
Table 1 Data on raw materials supply and related data sources

Category	Description	Unit of measurement	Data source	Reference year
Reserves and resources	Sum of resources and reserves reported by materials and by country	Percentage of total (by country)	S&P Global Market Intelligence Database	Assessed in 2019
Production	Mine production of materials	Percentage of total (by country)	World Mining Data	Average 2012–2016
EU sourcing	Sum of import and raw material production (at mining stage) from EU countries	Percentage of total (by country)	World Mining Data, Eurostat, UN Comtrade	Average 2012–2016

Note: See methodological notes in Annex 1 for definitions and further explanation of data sources.

^(*) Please note that EU sourcing refers to raw or raw refined materials at the mining stage. Materials entering the EU at a refined stage or in components and semi-manufactured products are not taken into account here.

Figure 2 Main players in the production of materials for batteries



[Note: Cut-off criteria: < 2 %. EU sourcing (raw in the middle) refers to direct raw (or raw refined) material and not to sourcing of (semi-)finished products and components that incorporate materials.]

2.1.3. Attribution of risk levels to the selected countries and identification of hotspots

In the third phase of the analysis, the value of each indicator/index was transformed to a risk level (from low to very high), as explained in the corresponding sections. Sections 2.1.1 to 2.1.5 describe the chosen indicators in detail, including the data sources and the assigned risk levels.

Governance

Resource-rich countries can benefit from their natural resource endowment, which can lead to economic growth and development. Yet, in other cases, countries rich in natural resources tend to grow more slowly, and experience conflicts and deindustrialisation⁽⁵¹⁾. According to several studies, governance and institutions are very relevant factors in determining one outcome or the other⁽⁵²⁾. Looking at the governance of material supplier countries can therefore provide a first insight into the risk that countries present to responsible sourcing.

The Worldwide Governance Indicators (WGI) project reports on six broad dimensions of governance for over 200 countries and territories over the period 1996–2017⁽⁵³⁾:

- voice and accountability,
- political stability and absence of violence,
- government effectiveness,
- regulatory quality,
- rule of law,
- control of corruption.

The WGI are produced by the Natural Resource Governance Institute, the Brookings Institution and the World Bank Development Research Group. The project compiles and summarises information from different types of data sources, e.g.:

- surveys of households and firms,
- commercial business information providers,
- NGOs,
- public-sector organisations.

The WGI are widely used to assess countries' governance at global level, and provide yearly updates of governance estimates and country ranking. These indicators are also used in the assessment of critical raw materials for the EU⁽⁵⁴⁾ in order to estimate country risk. To our knowledge, this is the most reliable and widely acknowledged source for governance data at global level.

The values of the WGI range from –2.5 to 2.5 (higher values corresponding to better performance). In this analysis the risk levels have been assigned by dividing the range into four equal parts, as shown in Table 2, and considering the average of the six components of the WGI.

Table 2 Risk levels for Worldwide Governance Indicators

Score	Risk level	WGI values (- 2.5 to 2.5)
1	Low	1.25 to 2.5
2	Medium	0 to 1.24
3	High	-1.24 to 0
4	Very high	-1.25 to -2.5

⁽⁵¹⁾ See, for example, Anderson (1998); Sachs and Warner (2001).

⁽⁵²⁾ See, for example, van der Ploeg, F. (2011); Sachs and Warner (2001).

⁽⁵³⁾ <https://info.worldbank.org/governance/wgi/>

⁽⁵⁴⁾ Blengini et al. (2017).¹

In order to look more specifically into the management of natural resources, we also took into account the Resource Governance Index (RGI). This index measures the quality of governance in the oil, gas and mining sector in 58 countries. The RGI scores and ranks the countries, relying on a detailed questionnaire completed by researchers with expertise in the extractive industries. The index assesses the quality of four key governance components: institutional and legal setting; reporting practices; safeguards and quality controls; and enabling environment. We complemented the WGI analysis using RGI values for mining only (we did not use the data on the oil and gas sector).

Even though the RGI is available only for some countries, we consider this information very relevant because it investigates the functioning of the extractive sector, determining whether or not society benefits from resource extraction. This is done analysing the procedures and the legislations in the countries under investigation. Therefore, the RGI complements the general information on governance provided by the WGI with sector-specific knowledge.

The risk levels are assigned using the conversion values shown in Table 3.

Table 3 Risk levels for Resource Governance Index

Score	Risk level	RGI values (0 to 100)
1	Low	≥ 60
2	Medium	45 to 59
3	High	30 to 44
4	Very high	< 30

Conflicts

Raw material extraction can be linked to conflicts, especially in developing and low-governance countries. This has been true of diamonds, the illicit trade in which has funded brutal wars in Angola and other African countries such as the Central African Republic, the DRC, Liberia and Sierra Leone, resulting in the death and displacement of millions of people⁽²⁵⁾. Similarly, conflict minerals came to the public's attention in the 2000s, when some NGOs denounced the fact that profits from the illegal extraction of and trade in coltan were financing the activities of armed groups and protracting the wars in the DRC.

In response to the conflict diamond issues, the Kimberley Process Certification Scheme (KPCS) was set up in 2003 to prevent the flow of conflict diamonds, and EU Regulation 2017/821⁽²⁶⁾ set due diligence obligations for importers of tin, tantalum and tungsten, their ores and gold from conflict-affected and high-risk areas. In the US, Section 1502 of the Dodd-Frank Act was signed into law in July 2010 and requires publicly traded companies to disclose the source of 3TG. The law is aimed at dissuading companies from continuing to engage in trade that supports regional conflicts in the DRC.

Looking at conflict risk makes it possible to detect which suppliers could potentially be more critical than others for responsible sourcing, and which countries should be prioritised in an in-depth analysis.

The indicator chosen to analyse this aspect is a component of the composite indicator Index for Risk Management (Inform)⁽²⁷⁾. Inform is designed to support decisions about prevention, preparedness and response. Developed by the JRC, it is a global, open-source risk assessment for humanitarian crises and disasters. The model used to calculate the final indicator combines three main dimensions and six risk categories (Figure 3). The component used in our assessment is human hazard, and is a combination of data on the current conflict intensity (for countries experiencing conflicts in the reporting year) and the projected conflict intensity (for countries without conflict in that year) (Figure 4). The data sources for the two components are the following:

⁽²⁵⁾ Global Witness (1998).

⁽²⁶⁾ Regulation (EU) 2017/821 of the European Parliament and of the Council of 17 May 2017 laying down supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold originating from conflict-affected and high-risk areas.

⁽²⁷⁾ European Commission (n.d.).

1. The **Conflict Barometer**⁽⁵⁸⁾ of the Heidelberg Institute for International Conflict Research. The conflict intensity is determined by two criteria: instruments on the use of force (use of weapons and use of personnel) and the consequences of the use of force (casualties, refugees and demolition). Inform clusters these data in three different groups, distinguishing (i) conflicts over national power in a country (national power), (ii) conflicts over intrastate items other than national power, such as secession (subnational), and (iii) interstate conflicts⁽⁵⁹⁾.
2. The **Global Conflict Risk Index**. If a country does not experience highly violent conflict in the year of observation, Inform estimates the projected risk of conflict using the Global Conflict Risk Index⁽⁶⁰⁾. It is based on a quantitative model developed by the JRC that uses structural indicators to determine a given country's risk for conflict. It uses 26 quantitative variables including, among others, a country's regime type, its conflict history and other socioeconomic, political, geographic and security variables that contribute to the outbreak of civil war.

Figure 3 Risk components of the composite indicator Inform

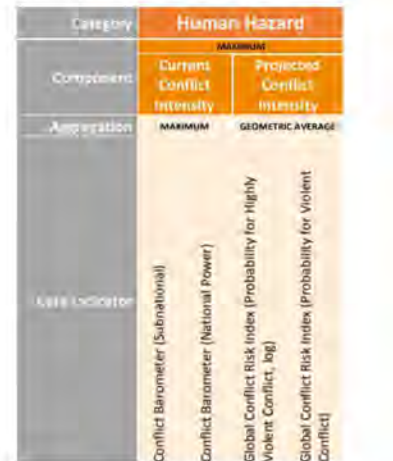
Risk	INFORM														
Dimensions	Hazard & Exposure				Vulnerability				Lack of Coping Capacity						
Categories	Natural		Human		Socio-Economic		Vulnerable Groups		Institutional	Infrastructure					
Components	Earthquake Tsunami Flood Tropical cyclone Drought	Current Conflict Intensity	Projected Conflict Intensity	Development & Deprivation (50%)		Inequality (25%)		Aid Dependency (25%)		Uprooted People	Other Vulnerable Groups	DRR		Governance Communication	Physical Infrastructure Access to Health System

Source: Marin-Ferrer et al. (2017)

⁽⁵⁸⁾ Heidelberg Institute for International Conflict Research (2013).

⁽⁵⁹⁾ Details of the elaboration of conflict data in Inform are available in Marin-Ferrer et al. (2017)

⁽⁶⁰⁾ Halkia et al. (2017).

Figure 4 Influence of each variable in each concept on the overall score

Source: Marin-Ferrer (2017)

The risk level assigned to the human hazard component of Inform for our assessment is described in Table 4.

Table 4 Risk levels for the Inform component human hazard

Score	Risk level	Inform – human hazard
1	Low	0 to 2.49
2	Medium	2.5 to 4.99
3	High	5 to 6.99
4	Very high	7 to 10

In addition to the Inform component, we added two indices related to conflicts.

1. The **Fragile State Index**⁽⁶¹⁾, developed by the Fund for Peace, an independent non-profit organisation. It defines fragility using 12 indicators relating to internal cohesion, the economy, politics, cross-cutting factors including demographic pressures, refugees and internally displaced persons, and external intervention. Applied risk levels are shown in Table 5.

Table 5 Risk levels for the Fragile State Index

Score	Risk level	Fragile State Index
1	Low	< 30
2	Medium	31 to 60
3	High	61 to 90
4	Very high	> 90

⁽⁶¹⁾ Fund for Peace (2019).

2. The **GPI** ⁽⁶²⁾, produced by the Institute for Economics & Peace, which ranks 163 independent states and territories according to their level of peacefulness. The GPI measures the state of peace using three thematic domains: the level of societal safety and security; the extent of ongoing domestic and international conflict; and the degree of militarisation. Applied risk levels are shown in Table 6.

Table 6 Risk levels for the Global Peace Index

Score	Risk level	Global Peace Index
1	Low	< 2.00
2	Medium	2.01 to 2.29
3	High	2.30 to 2.80
4	Very high	> 2.80

Human rights and social risks

Social impacts strongly depend on the local context where goods are produced and the raw materials are extracted. Indeed, in some regions, cultural and local working conditions can be not compliant with the International Labour Organization (ILO) conventions and human rights. Furthermore, social impacts are also strongly related to companies' behaviour and can be positive and negative. Workers, local community, supply chain actors and society are the main stakeholder categories used in literature and recommended by the guidelines for S-LCA ⁽⁶³⁾.

Several databases on social conditions are available in the literature, from the World Bank, the ILO, Unicef, EcoVadis ⁽⁶⁴⁾ and Maplecroft ⁽⁶⁵⁾, as well as the Social Hotspot Database ⁽⁶⁶⁾ and PSILCA ⁽⁶⁷⁾. Most of them include data on social aspects related to welfare of local communities and refer to ILO conventions. The most common risk categories are child labour, forced labour, fair salary, discrimination, social benefits and so on. Most of these databases have data only at country or regional level, such as the ILO, Maplecroft and World Bank databases.

In this analysis, we choose PSILCA as a data source for two risk categories: child labour and fair salary. PSILCA is a repository of data for S-LCA developed by GreenDelta GmbH. It provides information on social aspects of countries and sectors in a wide range of social categories, using internationally recognised data sources. For each data point provided in PSILCA, a data quality assessment and a risk evaluation (based on documented risk assessment schemes) are provided.

The categories and indicators chosen from the PSILCA set and considered most relevant for this analysis are the following:

1. child labour, country-based data on children in employment, based on data from the World Bank ⁽⁶⁸⁾,
2. fair salary, country- and sector-based data on wages (for the mining sector), retrieved from ILOstat 2014.

For these indicators, we used the risk levels provided by PSILCA, which are transparently documented in the database documentation ⁽⁶⁹⁾ and in Annex 1 of this report. Other relevant indicators on, for example, health and safety or bargaining rights, were not included because of insufficient coverage or low data quality.

In addition, the analysis includes an indicator on forced labour, using country-based data from the Global Slavery Index ⁽⁷⁰⁾, an independent assessment of modern slavery in the world. Risk levels assigned here are based on forced labour prevalence and government response (see Table 7).

⁽⁶²⁾ Institute for Economics & Peace (2019).

⁽⁶³⁾ UNEP/SETAC Life Cycle Initiative (2009).

⁽⁶⁴⁾ <https://www.ecovadis.com/>.

⁽⁶⁵⁾ <https://www.maplecroft.com/>.

⁽⁶⁶⁾ Benoit-Norris et al. (2012).

⁽⁶⁷⁾ Eisfeldt (2017).

⁽⁶⁸⁾ <https://info.worldbank.org/governance/wgi/>.

⁽⁶⁹⁾ Croth and Eisfeldt (2017).

The risk levels have been assessed considering the quartiles of the values assigned to each country in the two components prevalence and government response.

Table 7 Risk levels assigned to forced labour indicators

Quartile	Prevalence (victims per 1 000 population)	Government response (score)	Risk level
First	0.3–2.2	58 to 80	Low
Second	2.3–4.1	42.9 to 57.9	Medium
Third	4.2–6.9	42.8 to 31	High
Fourth	7.0–104.6	30.6 to – 7.4	Very high

Child labour and forced labour are listed in Annex 2 of the OECD Guidance as relevant aspects to be taken into account in responsible mineral supply chains. Salaries, in contrast, are not included in most of the responsible sourcing guidelines, but are usually part of social sustainability frameworks and sustainability reporting, e.g. S-LCA and the GRI.

Environmental risk

Responsible sourcing is usually related to avoiding human rights abuses and other social impacts occurring in the materials' extraction. However, environmental management also has a prominent role for responsible sourcing. Indeed, environmental impacts can entail serious health impacts on local communities and can compromise livelihoods of indigenous populations⁽⁷¹⁾. In particular, water-related risks play a major role and contribute to political instability, violent conflict, human displacement and migration, and acute food insecurity⁽⁷²⁾. Given the fact that material extraction and processing are highly water-intensive economic activities, water risk is a very important aspect to include in a hotspot analysis.

In order to take environmental aspects into account in the hotspot analysis, we selected two country-based indices.

1. The **Environmental Performance Index (EPI)**⁽⁷³⁾, produced jointly by Yale University and Columbia University in collaboration with the World Economic Forum. The EPI ranks 180 countries on 24 performance indicators across 10 issue categories covering the two components environmental health and ecosystem vitality. These metrics provide a gauge at a national scale of how close countries are to established environmental policy goals⁽⁷⁴⁾. The scale used by the EPI goes from 0 (worst performance) to 100 (best performance).
2. The **Water Risk Index (WRI)**, developed by the World Resources Institute. This composite index aggregates 12 indicators, using a combination of publicly available datasets and modelling techniques. The components of water risk are (i) physical risk – quantity; (ii) physical risk – quality; (iii) regulatory and reputational risk. The results are shown in the Aqueduct Water Risk Atlas (Aqueduct)⁽⁷⁵⁾, a publicly available global database and interactive tool that maps indicators of water-related risks. Aqueduct enables comparison across large geographies to identify regions or assets deserving closer attention⁽⁷⁶⁾. Values of the WRI range from 0 (lowest risk) to 5 (highest risk).

In this assessment, the values of the EPI and WRI have been translated into risk levels according to the framework shown in Table 8.

⁽⁷¹⁾ <https://www.globalwaternindex.org/>

⁽⁷²⁾ Mancini and Sala (2018).

⁽⁷³⁾ Gleick and Iceland (2018).

⁽⁷⁴⁾ <https://epi.envirocenter.yale.edu/>.

⁽⁷⁵⁾ Wendling et al. (2020).

⁽⁷⁶⁾ <https://www.wri.org/aqueduct>.

⁽⁷⁶⁾ Gassert et al. (2014).

Table 8 Risk levels applied to the EPI and WRI

Score	Risk level	Environmental Performance Index	Water Risk Index
1	Low	100 to 75	0 to 1.25
2	Medium	74 to 50	1.26 to 2.5
3	High	49 to 25	2.51 to 3.75
4	Very High	24 to 0	3.76 to 5

Conflict over the use of natural resources

In mining communities, conflicts and social tensions can arise from the inequitable distribution of benefits and costs or to the limited access to resources for the indigenous population. Similarly, industrial sites for processing or manufacturing the material can face the opposition of local communities, which experience environmental contamination, compromised access to water supplies and consequent health impacts. Events such as these are described in the *Environmental Justice Atlas* ⁽⁷⁷⁾, a tool documenting and systematising information about conflicts and struggles over the exploitation of natural resources and the related production processes. The tool was set up and is managed by the Universitat Autònoma de Barcelona, Spain. It started in 2012 with funding from the seventh framework programme for research on 'Science in Society' for the Environmental Justice Organisations, Liabilities and Trade project ⁽⁷⁸⁾.

The EJ Atlas is an online database and interactive map documenting socioenvironmental conflicts and mobilisations against particular economic activities whose environmental impacts are a key element of the grievance. The criteria applied for the identification of conflict cases are the following:

economic activity or legislation that has actual or potential negative environmental and social outcomes;

claims by environmental justice organisation(s) that such harm has occurred or is likely to occur as a result of this activity, and mobilisation;

reporting of that particular conflict in one or more media stories ⁽⁷⁹⁾.

The contents in the database are structured according to the form shown in Table 9. Therefore, for each documented conflict, a set of information is provided, including the commodities produced by a certain economic activity (e.g. mineral ore exploration, building material extraction, mineral processing, manufacturing activities), the intensity of the conflict, the related impacts and its duration.

⁽⁷⁷⁾ <https://ejatlas.org/>.

⁽⁷⁸⁾ <http://www.ejolt.org/>.

⁽⁷⁹⁾ Temper et al (2015).

Table 9 Main categories included in the EJ Atlas database form

Category	Detail
Basic data	Name of conflict Location and area Global positioning system coordinates and degree of accuracy Type of population involved (e.g. rural, urban)
Source of conflict	Type of conflict Commodities involved Description of conflict
Project details and actors	Level of investment Technical details Companies and state enterprises involved International and financial institutions involved Number of people affected Environmental justice organisation involved
The conflict and the mobilisation	Intensity History of mobilisation Groups mobilising (e.g. indigenous people) Forms of mobilisation Cross-involvement with other conflicts
Environmental impacts	E.g. deforestation, mine tailings spills
Health impacts	E.g. accidents, malnutrition
Socioeconomic impacts	E.g. increase in corruption, loss of livelihood
Outcome	Current status Conflict outcome (e.g. repression) Proposal of alternatives Perception of success
Source and material	Relevant legislation Academic sources Journalistic sources Multimedia sources
Contributor data	Author contact information Contact of local activists Other comments
Multimedia	Upload of relevant photos, video, PDFs, etc.

Source: EJ Atlas

The database allows browsing and filtering of the information according to various criteria, e.g. country, commodity, type of industrial activity.

In order to explore the conflicts related to the batteries supply chain, we first filtered the data using the category 'mineral ores and building materials extraction'. This filter allows all the conflicts linked to the mining and quarrying sector to be visualised. This set was further refined, selecting only the cases where materials used in batteries (i.e. cobalt, lithium, nickel, manganese, natural graphite) were involved and mentioned in the 'specific commodities' field.

In a second search, we applied the filter 'industrial and utilities conflicts' in order to extract the cases of conflicts related to plants for smelting/processing and manufacturing battery materials.

The information provided in this database is considered important for a responsible sourcing analysis. First of all, this kind of information can give hints of the social acceptance that production processes receive in the territories

where they operate. Moreover, countries experiencing high frequency of conflicts related to certain commodities could be considered at higher risk in a responsible sourcing analysis and deserving of further investigation. Listing cases of struggles, demonstrations and conflict reported by organisations, activists and media, the EJ Atlas provides bottom-up information, which can complement the results of the top-down indicators used in the hotspot analysis.

Given the qualitative nature of this information, the risk of environmental conflicts is not included in the hotspot analysis, but insights from the EJ Atlas are included in the interpretation of the results.

2.2. Results of the hotspots analysis

Table 10 shows the results of the hotspot analysis and the relevant countries that have a role as global suppliers or as EU suppliers, or have a high proportion of reserves and resources, for cobalt, lithium, nickel, manganese and natural graphite. We selected countries with at least 10 % in one (or more) of these categories.

Table 10 Hotspots analysis results for battery materials

		Materials supply (mining stage)				Governance		Conflicts		Human and social rights			Environment	
Material	Country	% reserves resources	% global production	% EU sourcing	Resource Governance Index	Worldwide Governance Indicators	WGI-QM-ITI	Fragile State Index	Global Peace Index	Child labour*	Fair salary*	Global Slavery Index	Environmental Performance Index	Water Risk Index
COBALT	Australia	10	4	1	1	1	1	3	1	1	1	1	2	3
	Congo DR	46	57	69	3	4	4	4	4	4	2	4	3	1
	Finland	1	1	14	n.a.	1	1	1	1	1	1	1	1	1
	Argentina	20	12	5	n.a.	2.5	1	2	1	2	1	1	2	2
LITHIUM	Australia	8	36	65	1	1	1	1	1	1	1	1	2	3
	Bolivia	21	0	0	n.a.	3	3	3	1	3	1	3	2	1
	Chile	12	38	0	1	2	2	2	1	2	2	1	2	3
	Portugal	0	0	10	n.a.	1	1	1	1	2	2	2	2	3
MANGANESE	USA	13	3	0	1	1	1	2	1	1	1	1	2	2
	Australia	34	17	1	1	1	1	1	1	1	1	1	2	3
	Brazil	1	7	37	n.a.	3	3	3	2	2	2	1	2	1
	China	2	17	0	n.a.	3	3	3	2	2	2	2	2	3
NATURAL GRAPHITE	Chadon	10	10	20	n.a.	3	3	3	2	4	1	3.5	3	1
	South Africa	41	28	25	2	2.5	3	3	1	n.a.	1	2	3	2
	USA	10	0	12	1	1	3	2	3	3	1	1	2	2
	Brazil	0	7	12	n.a.	3	3	3	2	2	2	1	2	1
	China	0	64	47	n.a.	3	3	3	2	3	2	2.5	2	3
	India	0	11	0	n.a.	2.5	3	3	3	2	2	2.5	3	5
	Mozambique	68	0	0	n.a.	3	2	3	2	4	1	3	3	2
	Tanzania	13	0	0	2	3	2	3	1	4	1	3	3	3
NICKEL	Australia	13	11	0	1	1	1	1	1	1	1	1	2	1
	Canada	7	10	7	n.a.	1	1	1	1	1	1	1	2	1
	China	3	4	47	n.a.	3	3	3	2	3	2	2.5	2	3
	Greece	3	1	10	n.a.	2.5	2	2	1	1	1	1	2	3
	Indonesia	17	18	0	1	3	3	3	1	2	1	2.5	3	3
	Philippines	10	17	0	2	3	4	3	1	2	1	1	2	3
	Russian Federation	11	11	0	n.a.	3	3	3	1	2	1	1.4	2	1
	South Africa	0	0	0	1	1	3	3	1	n.a.	1	2	3	3
	South Africa	0	0	0	1	1	3	3	1	n.a.	1	2	3	3

1, low risk; 2, medium risk; 3, high risk; 4, very high risk; n.a. not available

(*) Risk levels provided by PSILCA database. Numbers in *italics* in the child labour category mean that original estimates are older than 2010 (China 2009, Mozambique 2007).

2.3. Interpretation of the results

Analysing the risk indicators individually, we find that the DRC has the lowest levels of governance and the highest risk of conflict, child labour and forced labour. Several countries, including Brazil, Russia, India, China and South Africa (the BRICS), have high risk scores for governance. Unfortunately, many data gaps exist for the governance of natural resources (RG). Concerning conflict, the DRC and the Philippines have very high risk levels, while for several other countries (including the BRICS) the risk level is high. Concerning the last two columns of Figure 5, on environmental aspects, Gabon, South Africa, Indonesia and the DRC have the lowest environmental performances. High water risk affects many countries, including important material providers such as Australia, Chile and some European countries (Greece and Portugal).

Looking at the results by country, we can identify four groups, based on their average risk scores (Table 11) as described below (also illustrated in Figure 5).

Table 11 Average risk score of the main players in the production of battery materials (mining stage)

Country	Average risk score	Cobalt	Lithium	Manganese	Natural graphite	Nickel
DRC	3.30	x				
Philippines	2.77					x
China	2.61	x	x	x	x	x
Gabon	2.61			x		
India	2.56				x	
South Africa	2.50			x		x
Mozambique	2.50				x	
Tanzania	2.50				x	
Russia	2.50	x				x
Bolivia	2.44		x			
Indonesia	2.22					x
Brazil	2.00			x	x	x
Greece	1.94					x
United States	1.73		x	x		
Portugal	1.72		x			
Argentina	1.61		x			
Chile	1.60		x			
Australia	1.30	x	x	x		x

x, global production, EU sourcing or reserves and resources is higher than 5 %.

• Countries at highest risk

These countries have the highest average risk scores: 3.30 (DRC) and 2.77 (Philippines). The average risk score for a country is calculated as the average of the scores for each risk category ⁽⁶⁾.

The **Democratic Republic of the Congo** is the main global producer of cobalt. It also owns 46 % of global reserves and resources of this material and provides 69 % of EU sourcing. Moreover, DRC cobalt is contained in intermediate products and manufactured goods produced in China that are likely to be imported into the EU. Very

⁽⁶⁾ The weights assigned to each component (governance, conflict, environmental performance and water risk) are equal. Aggregating the scores in different ways, or applying different cut-off criteria in the material supply data, can produce changes in the interpretation of the results, which are discussed in Annex 1.

high risks emerge in terms of conflicts, governance, child and forced labour, while risk to the environmental performance is high. Conflicts related to cobalt extraction (together with coltan, gold and other materials) are also reported by the EJ Atlas.

The **Philippines** produces 17 % of the global nickel supply and 10 % of global reserves and resources (but does not provide any nickel to the EU). It is characterised by very high risk of internal conflicts and high water risk. The EJ Atlas reports 12 conflicts related to nickel extraction in this country, happening since 1993. Environmental degradation is often pointed to as the main cause of conflicts in the Philippines, together with land competition, disputes over the use of ancestral lands and other conflicts with indigenous communities. In most cases, these conflicts relate to the extraction of nickel and other materials (especially cobalt and other materials classified as rare metals in the EJ Atlas database).

▪ **Countries providing the EU with several materials for batteries**

This group includes important EU suppliers of one or more materials for batteries. China has the highest risk level (2.61), followed by South Africa and Russia (2.5), and then Brazil (2.0).

China provides 47 % of the EU's supplies of both natural graphite and nickel, 17 % of global production of manganese and 7 % of the global lithium supply (not shown in Figure 5, which applies a cut-off criterion of 10 %). It presents a high risk of conflicts, weak governance and high water risk. The number of environmental conflicts linked to the battery supply chain is the highest among the countries under consideration (14, according to the EJ Atlas). Most of them concern the smelting industry and the battery-manufacturing sector. Underlying reasons for these conflicts concern mainly lead pollution affecting the local communities' health.

South Africa is an important supplier of manganese and nickel to the EU (respectively 26 % and 14 %). It also owns a significant proportion of reserves and resources of manganese (41 %) and of the global supply (28 %). It is characterised by a high risk for the two environmental indicators, but also a high risk of internal conflicts. Conflicts reported in the EJ Atlas concern other materials (e.g. platinum, sand and asbestos) than those used in batteries.

Russia provides 11 % of the global nickel supply and 5 % of the EU's supply of cobalt (not shown in Figure 5, which includes only shares above 10 %). The main risks concern conflicts and low levels of governance. Two conflicts in nickel and cobalt extraction sites are reported by the EJ Atlas, one of them occurring in the Arctic area and caused by high pollution levels.

Brazil provides the EU with manganese, natural graphite and nickel (respectively 17 %, 12 % and 4 %). It has weak governance and a high risk of internal conflicts. Several conflicts are reported by the EJ Atlas in this country (27 in total), in many cases due to struggles with indigenous communities. Two conflicts are related to battery materials (nickel and manganese).

▪ **Countries at risk regarding future material provision**

This group includes countries with high proportions of global reserves and resources for battery materials, which could therefore become important suppliers of battery materials in the future. Their risk scores range from 2.61 (Gabon) to 2.20 (Indonesia).

Gabon is an important supplier of manganese, and owns 10 % of the total reserves and resources of this material. Child labour is the category presenting the highest risk for this country, while worldwide governance, environmental performance and two indices related to conflicts (the Inform component and the Fragile State Index) have high risk levels. The EJ Atlas reports one conflict related to iron ore and another related to uranium.

Tanzania's average risk score is 2.5. It has high risk scores for environmental performance and water risk (EPI and WRI). Governance risk is also high, while the risk level for the resource governance index is medium. Environmental conflicts reported in this country and related to mining are not linked to materials for batteries (they concern gold and uranium extraction). The country has 13 % of the world reserves and resources of natural graphite.

Mozambique has 68 % of global reserves and resources of natural graphite, and has weak governance and low environmental performance. The EJ Atlas does not report any conflict related to the mining sector ⁽⁶¹⁾. Its average risk score is 2.5.

Bolivia has 21 % of global reserves and resources of lithium, and has weak governance and high risk of conflicts for one of the indicators. The average risk score is 2.44. Only one conflict linked to lithium extraction is reported in the EJ Atlas, but many other conflicts have occurred in mining sites for other commodities, especially gold, silver and copper. As according to official statistics the actual production of lithium is negligible ⁽⁶²⁾, the development of the lithium extraction sector could drive a surge in other conflicts, as has happened for other materials.

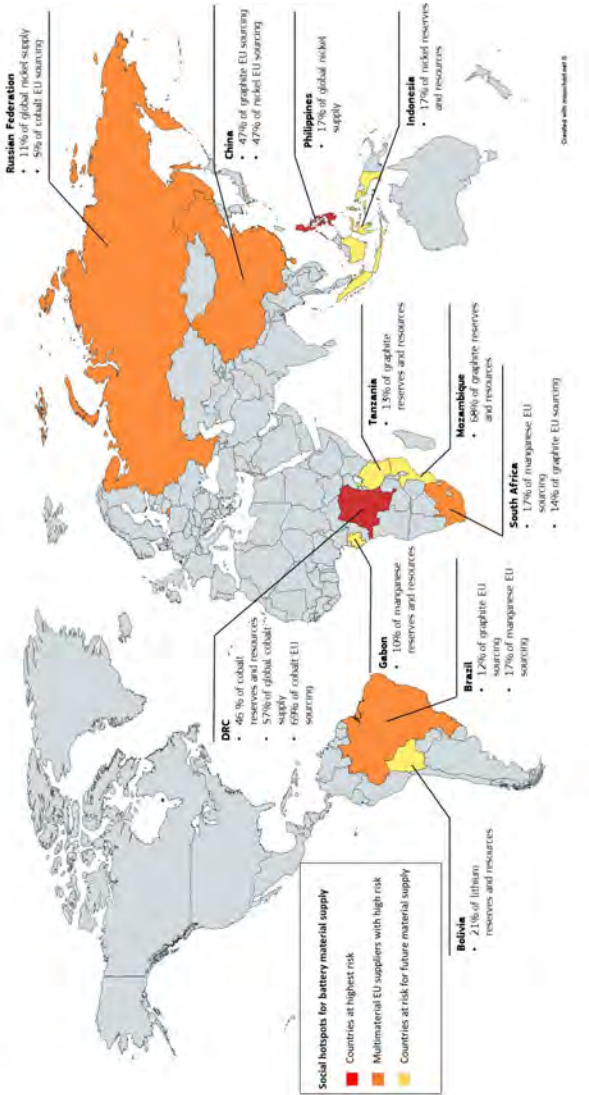
Indonesia, despite its good level of governance in the extractive sector as assessed by the RGI, has high risk levels for all the other governance components. Indonesia is a global supplier of nickel and owns 17 % of the global reserves and resources of this material. The EJ Atlas describes nine conflicts related to the mining sector. One of them, classified as of high intensity, was between the nickel production activity of the Vale company and indigenous communities.

- **Others**

India has a peculiar role and does not fit any of the above clusters. The average risk score of this country is quite high (2.56), with low performance in the environmental and water risk indicators as well as in the conflict ones. The EJ Atlas documents more than 30 conflicts related to the mining sector, and especially related to illegal sand extraction, iron ore plants, quarries and other materials that are not those included in this analysis and used in batteries. The country produces 11 % of the global supply of graphite and 5 % of global manganese supply.

⁽⁶¹⁾ As mentioned in the description of the methodology, the fact that the EJ Atlas is community driven could imply under-representation of conflicts in developing countries. For instance, several cases of human rights abuses in the gemstone-mining sector are reported; see Cronje (2019).
⁽⁶²⁾ USGS (2019).

Figure 5 Hotspots in the production of battery materials, considering mining stage



2.4. Main findings of the chapter

As has emerged in previous studies, the mining sector has a key role in contributing to or hindering sustainable development ⁽⁸³⁾. According to a review study, land-use-related impacts, environmental impacts affecting human health and human rights appear to be the most concerning social aspects in the mining sector ⁽⁸⁴⁾.

In recent years, many studies and news stories have described serious human rights abuses linked to the extraction of cobalt in the DRC. Less is known about social impacts in the extraction phase of other materials used in batteries.

The objective of this chapter was to screen potential hotspots in the battery materials' mining phase, using open-source country-based information on aspects relevant to responsible sourcing and available statistics on raw material production, reserves and resources. We also used the indicator 'EU sourcing', which adds EU domestic production to imports of raw materials at mining stage, in order to represent the importance of countries as EU suppliers (even though materials imported in components and semi-finished products are not considered in this analysis). Hotspots were detected considering both the countries' performances for the selected indicators and their roles as material suppliers.

The hotspot analysis results confirm that the DRC is, by far, the country at highest risk, especially concerning conflict, child labour, forced labour and governance. However, the Philippines, which supply nickel and natural graphite, also have a high average risk score. Another cluster of countries was identified as being at lower risk than the first group but having important roles as EU suppliers. Indeed, each of these countries provides various materials to the EU (and other materials relevant to other low-carbon technologies, e.g. rare earths and platinum group metals). The common factors of these countries are the high risk in the WGI indicators average and in the indicators on conflicts. In the case of South Africa, environmental performance and water stress also appear critical, while for Brazil conflicts with the indigenous communities are an issue of concern. The third group of countries could have a role in future materials supply, as they own high proportions of global reserves and resources of materials used in batteries. For instance, with 68 % of global reserves and resources, Mozambique could compete with China as a graphite supplier in the near future. Bolivia could also become a key player in lithium supply, as could Gabon for manganese. These three countries show high risk levels for child labour.

Given the nature of the data used in this hotspot analysis, the results should be considered only a rough assessment of potential risks to the responsible supply of materials for batteries. Indeed, uncertainty behind each data point can be high, especially in child labour estimates provided by the World Bank, some of which are older than 2010 ⁽⁸⁵⁾. Moreover, country-based indicators and indices are appropriate for communication and global comparisons, but regional (interstate) differences can be very significant, especially in big countries. For instance, the area of production of cobalt in the DRC is not affected by conflicts, as in the case of 3TGs area of production. Geopolitical situations can change very rapidly and some conflicts that occurred in the last few months (in Bolivia, Chile, etc.) are not captured in this analysis.

The analysis, however, is a useful exercise to screen country-material combinations that could be critical from a responsible sourcing perspective. In the next chapter, a more detailed analysis scrutinises the social performance of the main mining companies that produce materials for batteries, using as data sources their publicly available sustainability reports.

⁽⁸³⁾ Mancini et al. (2019).

⁽⁸⁴⁾ Mancini and Sala (2018).

⁽⁸⁵⁾ In Figure 5, when data are older than 2010, risk values are in italics.

3. Corporate-level social data disclosure

Sustainability data disclosure is an important tool for ensuring transparency and promoting responsible business conduct. As described in the Raw Materials Scoreboard 2018, the number of companies publishing sustainability reports has increased in the last decade. This indicator is also used to monitor progress towards the UN Sustainable Development Goals (SDGs)⁶⁶. Within this framework, target 12.6 is to 'Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle'.

In 2014, the EU issued Directive 2014/95/EU, requiring large companies to disclose certain information regarding the way they operate and manage social and environmental challenges. Non-binding guidelines on non-financial reporting were also developed and published in 2017 to better define the information that should be disclosed in non-financial reporting and how to report this information in a consistent and comparable way (COM/2017/4234). The guidelines specify some key principles for the disclosure of non-financial information. For instance, they specify the importance of assessing the materiality of the information, i.e. its relevance in the context under investigation. Disclosed information should allow the 'understanding of the undertaking developments, performance, position and impact of its activity' ⁽⁶⁷⁾. Companies are asked to consider the actual and potential severity and frequency of impacts related to their products, services and related supply chains. Moreover, information must be assessed in a context that takes into account sectoral considerations and the expectations of relevant stakeholders (which may include, among others, workers, investors, consumers, suppliers, customers, local communities, public authorities and civil society). The guidelines provide a list of thematic aspects to be addressed in a sustainability report. These include:

- environmental issues,
- social and employee issues,
- respect of human rights,
- anti-corruption and bribery issues,
- others (supply chain, conflict minerals).

Social and labour matters include the following aspects:

1. implementation of fundamental conventions of the ILO,
2. diversity issues, such as gender diversity and equal treatment in employment and occupation regarding age, gender, sexual orientation, religion, disability, ethnic origin and other relevant aspects,
3. labour issues, including employee consultation and/or participation, employment and working conditions,
4. free association and collective bargaining rights, including respect of trade union rights,
5. human capital management including management of restructuring, career management and employability, remuneration system, holidays, training,
6. occupational health and safety,
7. consumer relations, including consumer satisfaction, accessibility, products with possible effects on consumers' health and safety,
8. impacts on vulnerable consumers,
9. responsible marketing and research,
10. community relations, including social and economic development of local communities.

The S-LCA methodology, introduced in the previous chapter, also offers a framework of stakeholders and related impact categories to take into account when assessing social impacts. According to the definition of S-LCA, we can measure positive and negative impacts if we can measure the difference between the current local

⁽⁶⁶⁾ UN 2015

⁽⁶⁷⁾ Directive 2014/95/EU, article 1

conditions and the hotspot analysis performed with generic data. Unlike the environmental life-cycle assessment, today no database is available at company or product level with primary data collected for S-LCA subcategories. However, corporate social responsibility data are produced and available through several schemes such as the GRI and databases on environmental, social and governance issues, such as Ecovadis® and Sedex®. These tools are currently used by companies looking to reduce their social impact and risk.

To understand what are the main impacts reported by the companies, and the level of public knowledge on the main producers of battery materials, a screening of their sustainability reports has been done and the main results are reported in the following sections. The detailed list of information published by each company is reported in Annex 2. Assessing the social impacts at company level is important in order to have more detailed information than the country level of the hotspot analysis presented in the previous chapter. In fact, a country/sector assessment delivers only an overview of the possible main social risks, but national-level risks do not necessarily result in negative impacts at the project/product level. Indeed, as was mentioned before, if a company working in a high-risk country implements appropriate policies, it has the potential to improve local conditions and create positive changes, resulting in positive social impacts.

3.1. Methodology

The methodology developed for this chapter first required the identification of the main players in the global battery material supply chain for the materials considered in this study: cobalt, lithium, manganese, natural graphite and nickel. Niobium, which has shown vast potential in new battery technologies, is also included in this chapter.

The website and sustainability reports of each company have been screened and all information useful to assess the subcategories of an S-LCA has been collected. In particular, we looked at the nature of the information provided, if goals and targets are established and assessed through quantitative indicators, and if changes from the past years are monitored. The social issues considered are those reported in the guidelines and methodological sheets for S-LCA^(*) and in the Handbook of Product Social Impact Assessment^(**). The focus of the company was mainly on the stakeholder categories workers and local communities. The sustainability reports have been considered first; as an alternative the company website was scrutinised. In the sustainability reports, the presence of further aspects has been assessed, such as:

defined sustainability strategy and goals,

quantitative targets,

integration of SDGs and measurement of the company's contribution in relation to them,

type of social data published at worker and local community levels.

3.2. Analysis

The analysis of the sustainability disclosures from companies shows that the most prominent impact categories are health and safety, wages, gender balance, benefits for workers, type of contracts, investments and activities done for the local communities and these investments' and activities' impact on those communities, and taxes, royalties or contribution to the national revenue of host governments.

Table 12 summarises the main outcomes of the analysis, and Annex 2 contains detailed information for each material.

Out of the 14 companies assessed, 10 have a sustainability policy (a policy that describes which areas/topics are relevant to the company, on which area efforts will focus and if it has established specific targets) and 8 companies published a sustainability report for 2018. Sustainability goals are mentioned by most companies, but only four companies take into account the UN SDGs and only two establish measurable targets. The kind of information most frequently disclosed concerns health and safety (nine companies), activities promoted in local communities (eight), gender balance (seven) and data on taxes or royalties paid in host countries (seven).

(*) UNEP/SETAC Life Cycle Initiative (2009); UNEP/SETAC Life Cycle Initiative (2013).

(**) PRé Sustainability (2016).

Data on wages are reported by only two companies, and only four companies present information on impacts on local communities. Five companies disclose information on benefits provided to workers and type of contract. The most complete reports are published by big companies with already existing and underlying sustainability strategies.

Data often mainly focus on the health and safety aspects, including data on fatalities, injuries or lost-time injury rates. This indicator can show a positive impact only if a positive trend in reduction is measurable over several years. However, often the severity of the accidents or diseases is not specified. Another opportunity to understand the social impact value is comparing it with the average for that specific sector. Other published data are often related to gender composition of the workforce and the percentage of women in management roles.

EU guidelines for sustainability reporting recommend independent external assurance in order to publish more accurate and balanced information, thus allowing a clearer distinction between views and interpretations. Yet only 4 out of the 14 companies assessed provide third-party assurance of the content of the report; the others rely on internal auditing systems.

Table 12 List of social aspects addressed in the sustainability reports of the selected companies

Material	Cobalt	Graphite			Lithium			Manganese	Nickel		
Company	Glencore	China Carbon Graphite Group	Graphite India Ltd	South Star Mining Corp	Talison Lithium Inc.	SQM	Albemarle Corporation	Onocobre	VALE	VALE Indonesia	BHP Billiton
Sustainability policy	n.a.	n.a.	n.a.	n.a.	✓	✓	✓	✓	✓	✓	✓
Sustainability report	✓	n.a.	n.a.	n.a.	n.a.	✓	✓	✓	✓	✓	✓
Independent audit	selected aspects										
Consideration of SDGs	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	✓
Sustainability goals	✓	n.a.	n.a.	n.a.	n.a.	✓	✓	✓	✓	✓	✓
Quantitative sustainability targets	✓	n.a.	n.a.	n.a.	n.a.	✓	n.a.	n.a.	n.a.	n.a.	n.a.
Data on Health and Safety*	✓	n.a.	✓	n.a.	n.a.	✓	✓	✓	n.a.	✓	✓
Data on wages*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	✓	✓	n.a.	n.a.	n.a.
Data on gender balance*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	✓	✓	n.a.	✓	✓
Data on benefits for workers*	n.a.	n.a.	n.a.	n.a.	n.a.	✓	✓	✓	n.a.	✓	n.a.
Data on type of contracts (time limited, open ended)*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	✓	✓	✓	n.a.	✓
Data on impacts on local community*	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	✓	✓
Data on activities on local communities*	✓	n.a.	n.a.	n.a.	n.a.	n.a.	✓	✓	✓	✓	✓
Data on taxes, royalties, contribution to national revenue	✓	n.a.	n.a.	n.a.	n.a.	✓	n.a.	✓	✓	✓	✓

(*) Categories included in the EU Guidelines. (n.a.) not available

3.2.1. Cobalt

Glencore is the world's largest cobalt-mining company, achieving total production of 46 300 tonnes in 2018 ⁽⁹⁰⁾. Most of its production is as a by-product of copper mining in the DRC, and also as a by-product of nickel mining in Australia and Canada. Glencore is also one of the largest recyclers and processors of cobalt-bearing materials, such as used batteries.

Given the location of its operations, the main risks the company faces according to the hotspot analysis (Chapter 2) relate to weak governance, conflicts, child labour and forced labour. The EPI also has a high risk level, as does the RGI. Given these criticalities and the difficult context, more information on staff management systems and workers' rights and conditions in its DRC operations should be measured and declared by Glencore. Indeed, most of the indicators measured and disclosed in the sustainability report are not specific to the DRC operations but relate to the whole set of copper operations (including Australia, Canada and elsewhere). Moreover, the report mentions some activities to support local communities in the DRC, but does not disclose the share of investment spent in that region (see Annex 2 for more details).

3.2.2. Graphite

Natural graphite is also extracted in areas of high risk regarding child labour issues: Mozambique and Tanzania among others (see Chapter 2). Other countries where this material is produced present high risks in the governance and conflict category (Brazil, China).

Focusing on the main graphite miners in the countries singled out during the hotspot analysis yields a list of three players: China Carbon Graphite Group (China), Graphite India Ltd (India) and South Star Mining Corp (Brazil). Compared with other battery materials, awareness of social and environmental issues seems lower, as none of the three main producers has published a sustainability report.

3.2.3. Lithium

Lithium mining in Bolivia, which holds a fifth of the world reserves known to date, is also undertaken in a context of high risk in regard to child labour and fair compensation. Production has not yet started in Bolivia so imports of Bolivian lithium products into the EU have not taken place.

The companies assessed operate in other countries (Argentina, Australia, Chile and the USA) and are among the most prolific companies of the selected sample in regard to the information they share (see Annex 2 for details **Errore. L'origine riferimento non è stata trovata.**), which includes specific data on injuries, gender ratios, workers' benefits and community relations (see Annex 2 for details).

3.2.4. Manganese

In the case of manganese, data have been collected on one company located in South Africa, the world's biggest manganese-producing country, which is a significant player in that country and has operations in Australia: South32.

The company, while not publicly releasing a sustainability report, provides information on a number of its activities through its website, which explains how the company contributes to the SDGs ⁽⁹¹⁾ and the company's approach to community, health, safety and the environment, as well as forced labour ⁽⁹²⁾. However, very few measurable targets are presented; for instance, partial information is provided on certain social aspects, such as gender balance (at company level, so for all locations). Environmental and water risk are critical in the South African context according to the hotspot analysis presented in Chapter 2 and, while the company addresses

⁽⁹⁰⁾ Information reported on the Glencore website (<https://www.glencore.com/what-we-do/metals-and-minerals/cobalt>, accessed in March 2020). It is not specified which cobalt product(s) it refers to (cobalt hydroxide, metal or both).

⁽⁹¹⁾ <https://www.south32.net/who-we-are/sustainability-approach/sustainable-development-goals>.

⁽⁹²⁾ https://www.south32.net/docs/default-source/sustainability-reporting/fy2019-sustainability-reporting/hsec-management-approaches-2019.pdf?sfvrsn=ae3490f9_2.

water-related aspects in a dedicated report; this does not provide information specifically about manganese but instead focuses on the company's aluminium, alumina and coal operations.

The company also reports on social and governance indicators that are relevant to South African investors and regulators, such as the representation of black people in its South African workforce.

3.3. Main findings of the chapter

The analysis of company sustainability reports shows that there are high levels of discrepancy in the information disclosed at the company level. In most cases, the level of data disaggregation is very low and data are disclosed at the level of company or material produced (which means considering the overall performance of many operations running in various countries in the world). This can also create numerous data gaps, at least in communication materials. This discrepancy can be traced to the use of different data-reporting standards.

Among them, the EU's non-binding guidelines for non-financial reporting stress the importance of providing information that allows the assessment of impacts, and that has to be complemented by contextual information and points of reference, which are often neglected in sustainability reports.

Yet, as highlighted in the review, information is rarely contextualised to take into account the local project conditions, and at the same time it is rarely reported at the project level. This complicates the assessment of potential impacts. It is thus necessary to assess company-level data when taking the local operational context into consideration either through a tool such as the hotspot analysis or through dedicated site visits.

Moreover, while independent auditing is recommended by the aforementioned EU guidelines and by the vast majority of practitioners, it is implemented only by 4 out of the 14 companies in the selected sample. This third-party assurance of self-reported information is paramount to ensure that sustainability claims are not just whitewashing operations but disclose the true nature of the operations' impacts, and that the data disclosed are meaningful and allow a proper impact assessment.

A stricter policy on sustainability reporting, in particular concerning information on aspects critical in the country where the materials are produced, would make it possible to have more consistent and transparent information that could be used for impact assessment as well as in the context of sustainable finance. This would also make it possible to incentivise and support companies operating responsibly in critical social contexts and creating positive social impacts.

The analysis performed here could be done for other materials and products in a systematic procedure.

While this chapter focused on sustainability reporting, the next one deals with responsible sourcing. We present the main schemes and initiatives of interest to the battery sectors and especially for cobalt, which emerged as the most critical material from a social point of view in the previous chapters.

4. Responsible and sustainable supply of battery materials: review of the main initiatives and standards

The term 'responsible sourcing' has emerged in recent years in relation to conflict minerals (3TG). Media and NGOs reported on the role of these minerals in financing the armed actors taking part in the conflicts of the eastern DRC (after the formal end of the Second Congo War) and responsible for large-scale human rights abuses. However, much earlier, similar concerns in the diamonds sector led to the deployment of the Kimberley Process ⁽³³⁾ in 2000.

As shown in the previous chapter, sustainability assessing and reporting, using a variety of standards and frameworks, has also become a more common practice at the corporate level. One of these methodologies is S-LCA, which was developed in an academic context, and provides a framework of social impact categories that can be applied to any supply chain, product, service, etc.

Concerning the battery supply chain, nowadays, downstream industries are increasingly looking at ensuring a responsible supply of raw materials for their products, and especially for cobalt, pushed by a combination of perceived forthcoming regulatory demands, business-to-business demands and concern for any loss of brand value.

To date, these actors have relied principally on the implementation of due diligence practices aligned with the OECD Guidance. The guidance offers them a framework to undertake the due diligence required to evaluate whether or not their cobalt supply is free of problem cobalt sources, which a non-negligible number of downstream industries understand as being any cobalt with an ASM origin. Industry associations have supported the development of tools to facilitate cobalt due diligence, made efforts towards the validation of cobalt-processing refineries and developed frameworks for cobalt supply chain reporting and/or disclosure.

Further initiatives and projects promote transparency efforts or aim at the validation of cobalt-processing refineries by developing frameworks for more transparent reporting or disclosure of the company's supply chains.

A few downstream actors have also chosen to engage directly with the sector in order to take part in the transformation of the cobalt ASM sector.

In this chapter, we review and briefly describe the main initiatives and standards on responsible and sustainable supply of minerals (and in particular of cobalt). The review is partially based on the work published in a report of the Horizon 2020 project Strategic Dialogue on Sustainable Raw Materials for Europe (Strade) ⁽³⁴⁾, but it also covers cobalt-related initiatives. It does not aim to be comprehensive, especially concerning the sustainability frameworks, but aims to provide an analysis of the risk categories included in the different frameworks, and to identify the elements defining the concept of sustainable supply as distinct from responsible sourcing.

4.1. Responsible sourcing frameworks and guidance

4.1.1. OECD due diligence guidance for responsible mineral supply chains

The OECD Guidance is a government-backed multistakeholder set of recommendations on responsible supply chain management that has become the underlying standard of a significant number of mineral certification schemes and audits, as well as of a number of companies' corporate policies regarding mineral sourcing from CAHRAs. To date the OECD Guidance is arguably the most influential and widely recognised standard for responsible mineral sourcing; critically it is the guidance underpinning the EU Conflict Minerals Regulation ⁽³⁵⁾. The OECD Guidance is in its third edition, and now encompasses all minerals and CAHRAs.

The OECD Guidance provides a set of minimum standards and guidelines for companies to ensure that they do not finance conflict or human rights abuses through their mineral sourcing. It is a flexible five-step

⁽³³⁾ <https://www.kimberleyprocess.com>.

⁽³⁴⁾ Esiava (2018).

⁽³⁵⁾ Regulation 2017/821 of the European Parliament and of the Council of 17 May 2017 laying down supply chain due diligence obligations for Union importers of tin, tantalum and tungsten, their ores, and gold originating from conflict-affected and high-risk areas.

framework that can be adapted to the needs of any company. The OECD Guidance focuses on issues of human rights, provision of security, forced and child labour ⁽³⁶⁾, legality of operations and payment of taxes.

The risks to be assessed in the minerals supply chain due diligence are:

1. serious abuses associated with the extraction, transport or trade of minerals,
2. torture, cruel, inhuman and degrading treatment,
3. forced or compulsory labour,
4. the worst forms of child labour,
5. other gross human rights violations and abuses such as widespread sexual violence,
6. war crimes or other serious violations of international humanitarian law, crimes against humanity or genocide,
7. direct or indirect support to non-state armed groups,
8. public or private security forces,
9. bribery and fraudulent misrepresentation of the origin of minerals,
10. money laundering,
11. issues related to the payment of taxes, fees and royalties due to governments.

4.1.2. International Finance Corporation's performance standards on environmental and social sustainability

The IFC PS are the part of the IFC's sustainability framework directed towards its clients. The IFC PS provide guidance on how to identify risks and impacts, and are designed to help avoid, mitigate and manage risks and impacts as a way of doing business sustainably. Their application is a requisite for IFC clients throughout the life of an IFC investment, and is imposed in order to manage environmental and social risks and impacts, and enhance development opportunities.

The IFC PS play an important role in regard to financing from donors or banks, as the Equator Principles³⁷ are based on them. The Equator Principles are applied to World Bank-financed projects, to publicly supported projects of OECD Member countries, and by all international private and public banks signatories to the Equator Principles.

In addition to the role they play with financiers, the IFC PS are, arguably, generally recognised as the most commonly benchmark for large-scale mining (LSM) risk characterisation and mitigation (complementary to the OECD Guidance).

This framework includes eight PS:

1. *assessment and management of environmental and social risks and impacts,*
2. *labour and working conditions,*
3. *resource efficiency and pollution prevention,*
4. *community health, safety and security,*
5. *land acquisition and involuntary resettlement,*
6. *biodiversity conservation and sustainable management of living natural resources,*
7. *indigenous peoples,*
8. *cultural heritage assessment and management of environmental and social risks and impacts.*

Each standard includes a certain number of aspects to be checked. The detailed list of objectives under each performance standard can be found in Annex 3.

⁽³⁶⁾ Further clarification for on how companies prevent, identify and mitigate risks of works forms of child labour based on the OECD Minerals Guidance is available at OECD (2017), Practical actions for companies to identify and address the worst forms of child labour in mineral supply chains.

⁽³⁷⁾ The Equator Principles (EPs) is a risk management framework, adopted by financial institutions, for determining, assessing and managing environmental and social risk in projects and is primarily intended to provide a minimum standard for due diligence and monitoring to support responsible risk decision-making.

4.1.3. China Chamber of Commerce of Metals, Minerals & Chemicals Importers and Exporters' Guidance

The China Chamber of Commerce of Metals, Minerals & Chemicals Importers and Exporters' (CCCCMC's) due diligence guidelines for responsible mineral supply chains (CCCCMC Guidance) also provide a set of minimum standards and guidelines to support companies' efforts to identify, prevent and mitigate the risks of directly or indirectly contributing to conflict or human rights abuses. Primarily based on the OECD Guidance as well as the UN Guiding Principles on Business and Human Rights, the CCCC Guidance also includes a clearer focus on issues related to indigenous rights, pollution and biodiversity conservation, among others. These risks, which are not considered core OECD Guidance risks, are referred to as type 2 risks.

Type 1 denotes risks of contributing to conflict and serious human rights abuses associated with extracting, trading, processing and exporting of resources from CAHRAs. **Type 2** risks are associated with serious misconduct in environmental, social and ethical issues.

The detailed list of risks is in Annex 3.

While flexible in its minerals and applications, the CCCC Guidance is currently focused on the 3TG and cobalt supply chains. Supported by the Chinese Ministry of Foreign Affairs, its ambition is to become the go-to standard for Chinese companies operating abroad and is therefore important to consider when preparing data collection templates.

4.1.4. Social life-cycle assessment

S-LCA⁽⁹⁸⁾ is an impact assessment technique used to capture the social impacts of goods and services at each step of their life cycles. This approach makes it possible to avoid shifting burdens between geographical areas or supply chain steps when evaluating impacts.

In the context of S-LCA, social impacts are defined as the consequences on human populations of any public or private action that alter the ways in which people live, work, play, relate to one another, organise themselves so as to meet their needs and generally cope as members of societies⁽⁹⁹⁾. Social impacts are therefore consequences of positive or negative pressures on social areas of protection (i.e. well-being of stakeholders). As a cause-effect chain is not well defined and a proper impact assessment method has not been developed yet, often the term 'social risk' is adopted. Social risk refers to the potential for one or more parties to be exposed to negative social conditions that, in turn, undermine social sustainability⁽¹⁰⁰⁾. Positive social impacts hidden in product supply chains are also taken into account in the S-LCA methodology, even though their theoretical definition and implementation in the methodology are still under debate.

Regarding this specific methodology, recognised internationally standards do not exist yet, but guidelines have been produced in the document 'Guidelines for social life cycle assessment of products' by the UNEP/SETAC Life Cycle Initiative⁽¹⁰¹⁾. That document provides a reference set of stakeholders and impact categories to consider in an S-LCA study (Table 13).

⁽⁹⁸⁾ UNEP/SETAC Life Cycle Initiative (2009), Guidelines for social life cycle assessment of products.

⁽⁹⁹⁾ Interorganizational Committee on Guidelines and Principles (ICGP) (1995), 'Guidelines and principles for social impact assessment', *Environmental Impact Assessment Review*, Vol. 15, No 1, pp. 11–43.

⁽¹⁰⁰⁾ Pelletier et al. (2018).

⁽¹⁰¹⁾ UNEP/SETAC Life Cycle Initiative (2009).

Table 13 Social LCA framework of impact subcategories and related stakeholder categories

Stakeholder categories	Subcategories
Workers	Freedom of association and collective bargaining
	Child labour
	Fair salary
	Working hours
	Forced labour
	Equal opportunities/discrimination
	Health and safety
	Social benefits/social security
Consumers	Health and safety
	Feedback mechanism
	Consumer privacy
	Transparency
	End-of-life responsibility
Local community	Access to material resources
	Access to immaterial resources
	Delocalisation and migration
	Cultural heritage
	Safe and healthy living conditions
	Respect of indigenous rights
	Community engagement
	Local employment
	Secure living conditions
Society	Public commitments to sustainability issues
	Contribution to economic development
	Prevention and mitigation of armed conflicts
	Technology development
	Corruption
Value chain actors (not including consumers)	Fair competition
	Promoting social responsibility
	Supplier relationships
	Respect of intellectual property rights

Source: UNEP/SETAC Life Cycle Initiative (2009)

4.2. Responsible sourcing initiatives focusing on cobalt

As highlighted in previous chapters, from a responsible sourcing point of view, cobalt can be considered the material presenting the highest risk among battery materials. Many reports by NGOs and international organisations have stressed the social risks linked to cobalt extraction in the DRC, for instance the Amnesty International report published in 2016⁽¹⁰²⁾ and others⁽¹⁰³⁾. Given the strategic importance of batteries for achieving the decarbonisation of the economy⁽¹⁰⁴⁾, several responsible sourcing initiatives and strategies have been announced regarding this material.

The promoters of these initiatives are companies in the cobalt value chain, industry organisations (e.g. industry associations or chambers of commerce), NGOs, private actors in the field of responsible sourcing and certification of raw materials, and also government programmes.

In this section we describe the main initiatives on responsible sourcing of cobalt, describing objectives, focus (the supply chain step that is addressed), general features and risks/issues of concern that are under scrutiny.

⁽¹⁰²⁾ Amnesty International (2016).

⁽¹⁰³⁾ E.g. SOMO (2016).

⁽¹⁰⁴⁾ See, for example, Commission communication – A clean planet for all: A European strategic long-term vision for a prosperous, modern, competitive and climate neutral economy (COM(2018) 773 final).

4.2.1. Cobalt Industry Responsible Assessment Framework

The Cobalt Industry Responsible Assessment Framework (CIRAF) is an industry scheme proposed by the Cobalt Institute, a non-profit trade association composed of cobalt producers, users, recyclers and traders. The framework, launched in January 2019, consists of a list of risk categories and risk priority areas to be assessed by companies buying or producing cobalt when performing due diligence. The CIRAF project seeks to:

1. identify material risks within the cobalt sector for CIRAF participants as well as their customers;
2. provide a good-practice-based framework that will provide guidance to CIRAF participants on how to respond to core risks and report on existing responses with the degree of flexibility appropriate to their operations;
3. ensure the framework is credible, well managed and accepted by stakeholders ⁽¹⁰⁵⁾

CIRAF is not a certification scheme or an audit programme. CIRAF participants must identify which risk categories and risks apply to their operations based on a materiality assessment. As a baseline requirement, participants must obtain third-party assurance of their policies and due diligence management systems for human rights.

Table 14 shows the list of aspects included in CIRAF.

Table 14 Risk categories and priority areas suggested in the CIRAF framework

Risk category	Priority risk area
Environment	Air/water/soil/environmental impacts
	Biodiversity impacts
OHS	OHS and working conditions
Human rights	Conflicts and financial crime (*)
	Human rights impacts (aligned with Annex II model policy in OECD Guidance)
	Worst forms of child labour (*)
Community engagement	ASM
	Livelihoods
	Resettlement

OHS, occupational health and safety.

(*) Included in the OECD Guidance, to an extent.

4.2.2. Umicore sustainable procurement framework for Cobalt

Umicore is a global material technology and recycling group. It owns two cobalt refineries in Belgium and Finland and has one minority joint venture in China. It buys its raw refined materials (e.g. cobalt hydroxide) directly from mine sites, including from DRC mines. The group has developed its own sustainable procurement framework, which applies to all its cobalt purchases. The application of the framework aims to minimise the risk of any possible connection between the cobalt in its supply chain and human rights issues or unethical business practices.

The framework ⁽¹⁰⁶⁾ is based on the OECD Guidance and was audited by a third party. The Umicore management due diligence system includes four steps (Figure 6).

1. Supply chain traceability, whereby the company identifies and registers the origin of cobalt-containing raw materials, using logistical and commercial documentation.
2. Supplier research, including a first assessment of potential new suppliers (including collection of information on the ground, through plant visits).

⁽¹⁰⁵⁾ Cobalt Institute and CIRAF (2019).

⁽¹⁰⁶⁾ Umicore (2019).

3. Risk assessment, whereby all suppliers are evaluated for their practices (Table 15Figure 6). Unacceptable practices (e.g. torture, child labour, corruption) are categorised as red flags and lead to the elimination of that supplier. Artisanal mining and hand-picking fall under this category and are therefore excluded by the Umicore supply chain. A materiality test is then applied, meaning that suppliers contributing less than 1% of the total cobalt supply of the company are excluded from the following steps of the assessment. Mine visits are then performed, twice per year in the case of the DRC. The orange flag check includes the assessment of aspects that can be remediated by the supplier (including artisanal mining as a secondary source, which has to be remediated in a reasonable time frame, or lack of minimum required legal permits and certificates). The approval or exclusion of orange-flagged companies is decided by an approval committee. In the last phase of the risk assessment, Umicore assigns a risk level to the supplier, based on its sustainable procurement and ethical business practices. Companies with a low/medium to high risk score are further assessed through questionnaires.
4. Risk mitigation, the last phase of the process, which includes the identification of remediation actions on the identified issues.

Figure 6 Steps in the Umicore due diligence process



In line with the fourth step of the OECD Guidance, Umicore is committed to having its due diligence practices audited by independent third parties. The framework is audited by a third party and Umicore is reporting on its due diligence practices for cobalt in its annual report (e.g. 'Due diligence compliance report cobalt procurement 2019' ⁽¹⁰⁷⁾).

⁽¹⁰⁷⁾ <https://www.UMICORE.com/en/cases/sustainable-procurement-framework-for-cobalt/compliance-report>

Table 15 List of criteria for the Umicore supplier assessment

Red flag criteria	Orange flag criteria
Any form of torture, cruel, inhuman or degrading treatment or punishment	Hand-picking and/or artisanal mining (as secondary source)
Any form of forced or compulsory labour	Supplier does not have the minimum required legal permits and certificates
Any form of child labour	Supplier does not have procedures in place to minimise environmental impact
Any form of bribery or corruption related to cobalt operations	Supplier does not have procedures in place to ensure a healthy and safe working environment
Hand-picking and/or artisanal mining (as primary source)	
Supplier is not willing to accept the principles stated in the Umicore Charter or does not have similar policies in place	

Note: Red-flagged suppliers are excluded from the supply chain, orange-flagged suppliers have some time to take corrective actions before being reassessed.

4.2.3. Responsible Cobalt Initiative of the CCCMC

The Responsible Cobalt Initiative (¹⁰⁸) was launched in November 2016 by the CCCMC, with the support of the OECD. Many companies in the electronic industry are involved. The objectives are to:

- 'Have downstream and upstream companies recognise and align their supply chain policies with the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas and the Chinese Due Diligence Guidelines for Responsible Mineral Supply Chains in order to increase transparency in the cobalt supply chain and improve supply chain governance.'
- 'Promote cooperation with the Government of the Democratic Republic of the Congo, civil society, and affected local communities to take and/or support actions that address the risks and challenges in the cobalt supply chain.'
- 'Develop a common communication strategy to communicate progress and results effectively to impacted communities, miners, and the public; to harmonise working objectives and plans with other stakeholders.'

No more information is publicly available on this initiative.

4.2.4. Responsible Minerals Initiative cobalt due diligence standard and reporting template

The Responsible Minerals Initiative (RMI) was created in 2008 by members of the Responsible Business Alliance and the Global e-Sustainability Initiative, and has grown into one of the most utilised and respected resources for companies from a range of industries addressing responsible mineral-sourcing issues in their supply chains. The RMI offers a variety of tools and services to assist companies in creating sustainable supply chains (¹⁰⁹).

1. The **Cobalt Reporting Template (CRT)** serves to identify choke points and collect due diligence information in the cobalt supply chain. It was formally launched in December 2018. The RMI reviewed and integrated feedback from the pilot phase into the current version of the CRT. The CRT was designed for downstream companies to gather and disclose information about their supply chains. RMI members collaboratively developed this tool to create efficiencies and simplify the supply-chain-surveying process. Downstream companies include those companies from the end user up to but not including the smelter.

⁽¹⁰⁸⁾ <http://www.respect.international/responsible-cobalt-initiative-rco/>.

⁽¹⁰⁹⁾ <http://www.responsiblemineralsinitiative.org/emerging-risks/cobalt/>.

2. The **Pilot Cobalt Refiner Due Diligence Standard** was developed in collaboration by CCCMC, the Responsible Cobalt Initiative and the RMI. The risks to be assessed under this standard are described in Table 16, and they include the CCCMC Guidance or the OECD Guidance, as well as additional risks.
3. Other tools not specific to cobalt include the Risk Readiness Assessment, a voluntary self-assessment and self-reporting tool for mineral and metal producers and processors to communicate their environmental, social and governance practices and performance.

Table 16 List of risks included in the RMI standard

CCCMC Guidance: Annex Model Supply Chain Policy	OECD Guidance, Annex II Model Policy
Serious human rights abuses associated with the extraction, transport or trade of minerals: - any forms of torture, cruel, inhuman and degrading treatment, - any forms of forced or compulsory labour, - the worst forms of child labour, - other gross human rights violations and abuses such as widespread sexual violence, - war crimes or other serious violations of international humanitarian law, crimes against humanity or genocide. Direct or indirect support to non-state armed groups and public or private security forces. Corruption, money laundering and payments to governments.	Serious abuses associated with the extraction, transport or trade of minerals: - any forms of torture, cruel, inhuman and degrading treatment, - any forms of forced or compulsory labour, - the worst forms of child labour, - other gross human rights violations and abuses such as widespread sexual violence, - war crimes or other serious violations of international humanitarian law, crimes against humanity or genocide. Direct or indirect support to non-state armed groups. Direct or indirect support to public or private security forces. Bribery and fraudulent misrepresentation of the origin of minerals. Money laundering. Non-payment of taxes, fees and royalties to governments.
Additional risks: Occupational health and safety conditions that are not adequate to maintain the miners' direct employees' and indirect employees' physical and mental health.	

4.2.5. Eurasian Resources Group Clean Cobalt Framework

The Eurasian Resources Group (ERG) produces cobalt in the DRC and expects to increase its cobalt production through the Metakol roan tailings reclamation project in the Kolwezi area. This project aims to extract cobalt and copper from two tailing deposits ⁽¹¹⁰⁾.

Through the Clean Cobalt Framework the company wants to communicate its commitment to stakeholders and costumers to source responsibly produced materials. In particular, the company wants to ensure that its cobalt production is compliant with the OECD Guidance and that other important human rights and sustainability issues are managed in line with the UN Guiding Principles on Business and Human Rights.

The framework is based on the OECD Guidance and addresses other aspects:

⁽¹¹⁰⁾ ERG (2019).

child labour, with the age limit for employment set at 18,

traceability of cobalt in the stages of origination, processing and transport, through the provision of a chain of custody management system,

exclusion of ASM materials from the supply chain,

environment restoration (due to the nature of the project, which is a tailings reclamation operation),

collaboration in the promotion of sustainable community development.

4.2.6. Projects on cobalt artisanal mining

Various stakeholders have launched initiatives on responsible cobalt sourcing, which aim to improve the conditions of workers in artisanal cobalt mining sites in the DRC. To our knowledge, three initiatives are currently in place. Two of them had been running for close to 1 year at the time of this report's field data collection phase, and therefore were chosen for in-depth analysis, described in Chapter 4.1.

Table 17 summarises these initiatives and their main characteristics.

Table 17 Characteristics of initiatives on the ground

Name	Promoters and implementers	Date of launch	Characteristics
Better Mining (*)	RCS Global Group (audit and consulting group); Coopérative Minière Kupanga (Comiku); Congo Dongfang International Mining (CDM).	June 2018 (pilot phase) January 2019	Implemented in the Kasulo artisanal mining area, it is a site-monitoring solution that generates monthly incidents reports and corrective action plans for its implementer
Mutoshi Pilot Project (*)	Partnership between the Trafigura Group (a commodities trading and logistics company), Chemaf (a mining company), Comiakol (an ASM cooperative) and Pact (an international NGO)	April 2018	Implemented in the Mutoshi concession, it aims to improve safe working conditions through site monitoring and reporting information on incidents; technical knowledge of ASM and of downstream demands; community outreach; and raising hazard awareness and safety management capacity among ASM miners
Cobalt for Development	Industries (BMW Group, BASF SE, Samsung SDI and Samsung Electronics); German federal agency for cooperation and development (GIZ GmbH)	October 2019	The scope is to improve artisanal mining working conditions, as well as living conditions for surrounding communities

(*) These initiatives are described in detail in Chapter 5.

4.3. Main findings of the chapter

Several responsible sourcing initiatives exist for cobalt, the material presenting the highest risk among the battery materials (see Chapter 2). These initiatives are promoted by various stakeholders (industry, international organisations) and most of them refer to the OECD Guidance, even though none of them have undergone a formal OECD Alignment Assessment ⁽¹¹⁾. The OECD standard focuses on specific issues for the mineral supply chains extracted in CAHRAs (indeed, the guidance underpins the EU Conflict Minerals Regulation), for instance the misrepresentation of the origin of minerals and the use of security forces on mining sites. The IFC PS and the S-LCA framework have a more general scope, as they include aspects

⁽¹¹⁾ OECD (2018).

typically addressed in sustainability assessment ⁽¹¹²⁾ and can be applied to any economic activity. The CCCMC standard, while being specific to mineral supply chains, encompasses the OECD risk areas and some of the IFC sustainability criteria, such as indigenous peoples' and local communities' rights, as well as environmental management and biodiversity. The Umicore and Metalkol frameworks focus on specific risks included in the OECD Guidance and also consider the supply from artisanal mining a source of risk. The RMI standard reflects the OECD list of risks, and adds the working conditions. Four initiatives are implemented in the upstream phase and three of them (Better Mining, Mutoshi and Cobalt for Development) engage with the artisanal mining sector and work on the ground in order to improve working conditions in the DRC. The impacts of two of them (those implemented for at least 1 year) are discussed in the following chapter. Figure 7 shows the positioning of the initiatives discussed above within the value chain.

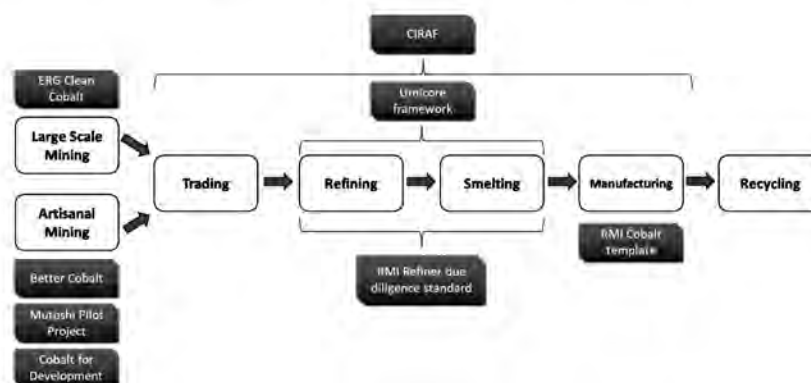


Figure 7 Positions of the actors implementing responsible sourcing initiatives in the material value chain

⁽¹¹²⁾ The IFC PS include both social and environmental aspects, whereas 5-LCA is a separate methodology and environmental aspects are mainly captured by the life-cycle assessment.

5. Field investigation on two responsible sourcing initiatives operating in artisanal mining of cobalt in the Democratic Republic of the Congo

5.1. The Congolese 2C ASM sector

Understanding the impact of responsible cobalt from the DRC ASM sector cannot be done without understanding the relevant characteristics of the sector. To do so, this section briefly outlines its defining relevant characteristics; for further details and nuance, the reader is directed to the recent studies made by the BGR ⁽¹¹³⁾ and the OECD ⁽¹¹⁴⁾.

Estimates and findings presented in published reports are by nature conservative, as publicly available reports only present findings that can be backed by indisputable evidence. In the field, reality is often richer and more nuanced. For example, the presence of politically exposed persons (PEPs) in organisations is seldom demonstrable and thus not reported, but in the field 'everyone knows' and, importantly, all actors behave accordingly, making these unprovable facts a hard reality. Furthermore, difficulties in accessing sites, not least due to the presence of uncooperative armed forces or companies ⁽¹¹⁵⁾, are likely to produce a bias towards better managed, and thus more accessible, sites in data collection exercises.

Thanks to the geological make-up of the region, both cobalt and copper (2C) can be extracted not only from the same deposits but often also from the same ores. Their supply chains can also overlap for most of their journey and therefore the 2C sector is often considered as a whole during the analysis of one of its components. Thus, while this analysis looks specifically at the cobalt ASM sector, information on cobalt LSM as well as on copper ASM and LSM will be provided when relevant to the understanding of the sector.

The DRC has become a focal point of discussions on the sustainability and impact of batteries, because of both its pre-eminence in the global supply of cobalt and its governance conditions. The country's provinces of Haut-Katanga and Lualaba currently account for 57 % of the global cobalt mine production ⁽¹¹⁶⁾ and hold just under half of the world's known reserves ⁽¹¹⁷⁾; the country's cobalt ASM sector accounts for 15–40 % ⁽¹¹⁸⁾ of this production according to various estimates, with most hovering around the 20–25 % mark. This makes the DRC cobalt ASM sector the second world producer, equalling or surpassing the combined production of Russia and Australia (the world's second and third largest cobalt-producing countries) ⁽¹¹⁹⁾.

Specific terminology

Within this chapter, the following distinctions are made:

Creuseurs refers to ASM diggers. **ASM miners** refers to all categories of workers directly involved in mineral production on an ASM site (*creuseurs*, washers, transporters).

System refers to the purpose-designed management and/or technological tools that aim to support the responsible sourcing of cobalt. **Initiative** refers to concrete responsible cobalt-sourcing programmes currently deployed on the ground, which include a system as a component.

Site refers to the dedicated ASM area (including the extraction, washing and temporary storage subareas). **Title** refers to the entirety of the mining title, of which the site might only be a part.

Pilot refers to the implementation of an initiative on a site if the initiative has been tailored to the specifics of a site, then the term encapsulates those changes.

Informal refers to all ASM activities taking place either outside an established ASM mining zone (*zone d'exploitation artisanale*, ZEA) or outside the framework provided by agreements between ASM miners and the title holder. While technically such mines are illegal under Congolese law, characterising them strictly as such has proven to be highly counterproductive from a research and policy perspective.

⁽¹¹³⁾ BGR (2019).

⁽¹¹⁴⁾ OECD (2019).

⁽¹¹⁵⁾ For example, BGR (2019) reports not having been able to access 13 of the 79 ASM sites it had located. In 5 cases this access to the sites was refused by Congolese armed forces, while in 8 cases access was denied by companies or cooperatives.

⁽¹¹⁶⁾ Based on U.S. Geological Survey (2018).

⁽¹¹⁷⁾ Based on U.S. Geological Survey (2019).

⁽¹¹⁸⁾ Sources: OECD (2019), BGR (2019), CSO representatives consulted; some of these sources are based on non-public Ministry of Mines estimates. Estimates congruent with the consultant's own estimates.

⁽¹¹⁹⁾ Based on U.S. Geological Survey (2018).

DRC cobalt ASM is thus globally significant not only in size but also in impact. During recent years ASM has been an incredibly dynamic supplier, able to ramp up production in a heartbeat compared with the LSM sector and its longer-term planning and heavier investment requirements ⁽¹²⁰⁾. Effectively, DRC ASM cobalt miners have become the swing producers of global cobalt supply chains, smoothing the global supply of the metal ⁽¹²¹⁾. This same dynamism has recently led a number of ASM cobalt miners to shift their focus towards copper in the face of lower cobalt prices, lowering the expected ASM production of cobalt in 2019.

Despite being of ASM origin, this material exits the country through raw refiners and exporters that mix a variety of feeds into their raw refining process prior to export (see Section 5.2.4 for further details). Moreover, the inherent dynamism of the 2C ASM sector complicates any attempts to quantify precisely the contribution of the DRC ASM sector to global cobalt supply chains.

When it comes to requirements for the responsible sourcing of minerals, the DRC has non-negligible experience with the issue of conflict minerals and their association with the ongoing conflict and violence outbreaks in the country's eastern provinces. While this issue centred on 3TG and on the conflict in the east of the country, the underlying issues of limited state capacity, high levels of corruption, grinding poverty and absence of alternative livelihoods also characterise the provinces where 2C extraction takes place. Human rights abuses linked to the exploitation of cobalt have risen to public attention in 2016 following a report by Amnesty International ⁽¹²²⁾, but have been reported on since 2011 ⁽¹²³⁾ or even 2007 ⁽¹²⁴⁾, at a time when the sector employed significantly fewer ASM miners.

5.1.1. Governance of the artisanal and small-scale cobalt- and copper-mining sector

Mining, and more specifically cobalt and copper extraction and processing, dominate the Haut-Katanga and Lualaba economies and are paramount to the lives of these provinces. Without the incomes generated from mining, these regions' inhabitants could not import the foodstuffs they require from neighbouring Zambia, as the region is not self-sufficient. While the majority of the sector's production and royalties come from LSM, ASM employs the bulk of the sector's miners, an estimated 150 000–200 000 ⁽¹²⁵⁾. Individual ASM sites sometimes employ upwards of 10 000 *creuseurs* (artisanal miners). The low-entry-barrier livelihood opportunities offered by the 2C ASM sector have recently become all the more vital in the region, as they help to absorb a substantial part of the internally displaced persons generated by the humanitarian crises taking place in the neighbouring Kasai province since 2016 ⁽¹²⁶⁾.

Despite this vital role, the sector suffers from a number of challenges that either blunt its role as an engine for local development or have negatively affected the human rights of local communities. Saemape (*Service d'Appui à l'Exploitation Minière Artisanale et à Petite Échelle*) is an agency that was created to remediate the shortcomings of the ASM sector and support its development. As the authority competent to oversee the 2C ASM sector, it is present throughout the provinces, and nationally in the DRC.

5.1.2. Location of ASM activities

According to Congolese regulations all ASM mining should take place in dedicated mining titles known as ZEAs. Yet only 4 % of ASM sites are on ZEAs, according to the BGR ⁽¹²⁷⁾. The rest are located on LSM titles, in particular on titles belonging to Générale des Carrières et des Mines (Gécamines), the dominant state-owned enterprise (SOE) of the DRC's Katangese copper belt (which amount to a little more than half of the total working ASM sites). Under Congolese law, these sites are informal if not illegal, unless there are specific arrangements in place with the title holders. Their sheer number makes them not only the most common form of ASM in the provinces but also a legitimate social phenomenon for most of the region's population. As a result, Saemape agents are regularly present on more than half of these sites, suggesting that the existence of such sites is so widespread that, for local regulatory purposes, they are the *de facto* norm ⁽¹²⁸⁾.

According to representatives of civil society organisations (CSOs), miners and state agencies consulted, the limited appetite of ASM miners for ZEAs can be attributed to a few underlying causes:

⁽¹²⁰⁾ BGR (2019).

⁽¹²¹⁾ Reuters (2019).

⁽¹²²⁾ Amnesty International (2016).

⁽¹²³⁾ Oka-Institut (2011).

⁽¹²⁴⁾ Swedwatch (2007).

⁽¹²⁵⁾ BGR (2019).

⁽¹²⁶⁾ BGR (2019).

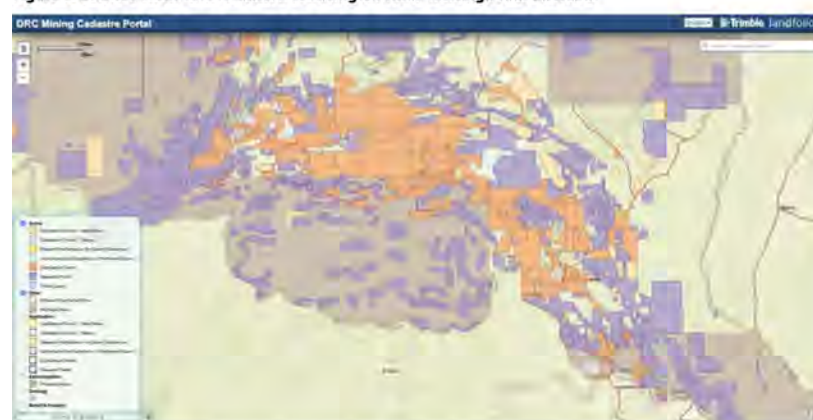
⁽¹²⁷⁾ BGR (2019).

⁽¹²⁸⁾ OECD (2019).

First, as can be seen in Figure 8, the majority of the land under and around the major cities of Lualaba and Haut-Katanga as well as around the regions' main communication axes is already titled to LSM operators, predominantly Gécamines. As can also be seen in the figure, some of these titles are well into the hundreds of square kilometres, and include villages, fields and major roads, making the monitoring of informal activities on site effectively impossible. Given this, and in the absence of marked interest from LSM operators in relinquishing part of their titles, there is virtually no space to create ZEAs that are (i) located on known deposits that are economically viable for ASM miners and their modes of extraction and (ii) close enough to a city and its amenities to be considered suitable for ASM miners, and with sufficiently developed infrastructure.

The current configuration is also exacerbated by poor enforcement of the Mining code, which requires applicants of exploration and exploitation licence to demonstrate commencement of work in order to renew their permits, and the limit of 50 for the number of permits held.

Figure 8 Extract from DRC cadastre focusing on Haut-Katanga and Lualaba



Note: Orange, exploitation permits; purple, exploration permits; brown, restricted areas.

Second, there is no investment in ZEAs and these are little more than plots of land when given to ASM miners. Making these ZEAs viable for ASM miners would require substantial investment in order to establish whether or not a mineral deposit commercially viable for ASM is present, remove the overburden to safely access the deposit, and connect the site to the road, electricity network and/or water sources.

As a result more than 90 % of 2C ASM activities take place either on LSM titles or in urban areas sitting atop economically viable deposits ⁽¹²⁹⁾. Both situations create a host of problems.

Not only do urban ASM sites facilitate the occurrence of child labour, owing to the lack of adequate separation between living space and mining area, but the same lack of separation greatly contributes to poor public health and creates numerous accident risks for local communities (falls into pits, localised geological instability resulting in building collapses, etc.).

While multiple ASM/LSM configurations can, and do, exist (as detailed by the OECD ⁽¹³⁰⁾), in a number of cases ASM miners have been or are still considered to be stealing the minerals from the concession and/or to be detrimental to the operational integrity and security of the title. In those cases, LSM operators rely on security services to stop the incursions, and ASM miners can on occasions react violently to efforts to evict them from their pits ⁽¹³¹⁾. Only a single armed force in the DRC is authorised to be stationed on mining sites, the Mining Police (*Police des Mines et Hydrocarbures*, PMH). Despite its name, the PMH does not receive any specific training on mining-site security or ASM community management. On various recent occasions, the PMH has been singled out as having committed repeated human rights violations while undertaking its duties. This

⁽¹²⁹⁾ BGR (2019).

⁽¹³⁰⁾ OECD (2019).

⁽¹³¹⁾ OECD (2019).

force is also noted as being corruptible, especially on sites with intense activity, where a day of bribes can net an agent USD 250, compared with the monthly salary of USD 300 to USD 500 (¹³²).

5.1.3. Monitoring and oversight

Lack of oversight and monitoring of ASM operations located outside ZEAs is a result not only of the lack of state agents but also of limited skills and/or interest among posted agents. While Saemape agents are present on 53 % of mines, occupational health and safety (OHS) sensitisation and monitoring occur in only 28 % of sites (¹³³). This echoes claims from numerous *creuseurs* (¹³⁴) that Saemape agents on certain sites do little in regard to accident prevention and OHS monitoring and instead focus on adjudicating disputes between ASM miners and extracting payment for their presence, services and/or non-intervention. According to Enough, Saemape staff received a monthly salary of approximately USD 55 in early 2018; however, the report notes, 'it's dazzling that they own USA-made jeeps and luxurious villas in town. All that is done at the miners' expense.' (¹³⁵) Failure to comply with the payment demands of Saemape agents can lead to intervention by armed forces (¹³⁶).

5.1.4. Participation of politically exposed persons

Adding complexity to the governance of the sector is its connection to political elites. While it is likely that the true extent of the phenomenon will remain unknown, it is no secret that former President Kabila's family had, and according to numerous stakeholders on the ground still has, substantial interests in the 2C ASM sector, which include the direct control of a number of ASM sites (¹³⁷). Similarly, other established political figures continue to benefit from the sector and its lack of transparency, either through ownership of companies providing services to LSM companies (¹³⁸) or through involvement in ASM cooperatives (¹³⁹). These players have no interest in facilitating the underlying objectives of the international demand for responsible and transparent cobalt supply. They have instead begun to integrate themselves into the responsible cobalt narrative to their advantage, while replicating the process that has led to the concentration of the tin, tantalum and tungsten sector into the hands of a handful of actors after the emergence of extra-territorial demands for conflict-free minerals triggered by US Conflict Minerals legislation (¹⁴⁰). The emergence of the Touche Pas à Mon Cobalt (Don't Touch My Cobalt) campaign can be seen through this prism, although the slogan has now been adopted by those demanding better conditions for workers in the sector (¹⁴¹).

5.1.5. Role and influence of cooperatives

Against this backdrop, the new Congolese Mining Code of 2018 (¹⁴²) now requires all ASM miners to be affiliated to a cooperative, a demand consistent with the fact that ZEAs are assigned only to cooperatives. In practice, this has exacerbated some of the sector's issues.

While called cooperatives, these organisations apply few of the principles that define cooperatives (¹⁴³). This is particularly notable when it comes to the democratic control of cooperatives by their members, which is completely absent in our experience (¹⁴⁴), with only very few members allowed to vote and/or participate in decision-making. Often PEPs are representatives of cooperatives; 'C'est la coopérative de [PEP]' (it's [PEP]'s cooperative) is a common answer when broaching the subject with either miners or CSOs. Furthermore, as cooperatives are assigned to ZEAs through ministerial decrees, there is a risk that political factors and personal favours weigh heavily in that process, especially as companies that are willing to engage with ASM

(¹³²) OECD (2019).

(¹³³) BGR (2019).

(¹³⁴) Comments received by the consultant during prior field visits to 2C sites in Haut-Katanga and Lualaba in 2016 and 2017.

(¹³⁵) Enough (2018), p. 19.

(¹³⁶) Enough (2018).

(¹³⁷) Congo Research Group (2017); Enough (2018).

(¹³⁸) Enough (2018).

(¹³⁹) OECD (2019).

(¹⁴⁰) For further details on this process see Diemiel (2018).

(¹⁴¹) Enough (2018).

(¹⁴²) *Loi no 18/001 du 09 mars 2018 modifiant et complétant la Loi no 007/2002 du 11 juillet 2002 portant Code minier*.

(¹⁴³) See International Co-operative Alliance (n.d.) for a summary list of these principles.

(¹⁴⁴) Based on a review of about 15 mining cooperatives' status in the DRC in the provinces of Haut-Katanga, Lualaba, Haut-Lomami, Maniema and South Kivu, as well as interviews with miners in Haut-Katanga, Lualaba and Maniema.

miners are required to do so through a cooperative, and are usually required to pay a fee to the cooperative representative for 'cooperative management activities' ⁽¹⁴⁵⁾.

Second, according to BGR (2019), on two thirds of the sites where cooperatives are present, payment of fees or levies to the cooperatives is mandatory. This can range from a flat monetary fee for each bag of material to about 50 % of the production in the most extreme cases. Payment of the fees and 'membership' in the cooperative typically do not grant rights or benefits to the miners. Even their right to representation through the cooperative is generally trumped in favour of the representation of the interests of the voting members of the cooperative. To paraphrase a cooperative representative during a site visit, miners elect (through an unidentified mechanism) a representative who can put forward their grievances and demands during consultations with the cooperative's management, although the management has no obligation to answer these demands. Thus, cooperatives, instead of representing the interest of ASM operators, are often structures extracting payments from miners while providing them with scant or no benefits ⁽¹⁴⁶⁾.

While it is possible in theory for ASM miners to organise themselves, form a cooperative and be assigned to a ZEA, in practice this is not plausible. To do so would not only require that they possess the required legal knowledge and organisational skills to do so, but would also require a representative to travel and stay in Kinshasa to register the cooperative. Typically, ASM miners do not have access to these types of resources. Further work would also be required for the cooperative to be assigned to the desired ZEA, in competition with politically connected cooperatives. Despite these hurdles, the security of these decrees is paramount, as without them cooperatives or *creuseur* committees can be displaced from the area in which they work.

5.1.6. Human rights risks in the artisanal and small-scale cobalt- and copper-mining sector

Unlike the eastern DRC and despite some activity from a few **armed groups** ⁽¹⁴⁷⁾, there is no evidence that any armed group is taking part in the illegal taxation or control of 2C mining and trade ⁽¹⁴⁸⁾.

On the other hand, the **illegal presence of Congolese armed forces on artisanal sites** is an ongoing concern. Under Congolese law it is illegal for any armed force that is not the PMH to be found on a mine site. This includes the Congolese Army (*Forces Armées de la RDC*, FARDC), the Republican Guard (*Garde Républicaine*, GR) ⁽¹⁴⁹⁾, other branches of the police or any other armed forces. It should be noted that both the FARDC and the GR have repeatedly been flagged as institutions committing significant human rights abuses in their operations.

Whether intelligence services such as the ANR (*Agence Nationale de Renseignement*), FARDC's *Demiap* (*Détection Militaire des Activités Anti-Patrie*), or the police's Bureau 2 have a place on mine sites is somewhat less clear cut. The ANR even has a limited role in the issuance of some paperwork on sites ⁽¹⁵⁰⁾.

As noted by BGR, access to sites is sometimes denied by armed forces, in particular the GR or the National Police, and in the experience of the consultant the ANR ⁽¹⁵¹⁾. Despite these access difficulties, the outlook produced by BGR is telling: a little fewer than half of the sites (41 % of sites) exhibit the presence of members of the armed forces that are barred from mining sites, while the presence of intelligence agencies is even more common (47 % of sites), and given the nature of these services this statistic is likely to be a low estimate. Similarly, research by the University of California at Berkeley's Center for Effective Global Action found out that the PMH was only present in half of the sites assessed, while other services of the National Police were present in 30 % of sites ⁽¹⁵²⁾.

In addition to members of the armed forces, private security providers can also be found on certain LSM sites. Uptake of best practices in the provision of security by either armed forces or private security, such as the

⁽¹⁴⁵⁾ OECD (2019).

⁽¹⁴⁶⁾ See for example the case of *Exploitants Miniers Artisanaux du Katanga en Coopérative*, which has been mentioned by Global Witness (2006), CASM (2007), World Bank (2008), Pact (2010) and Amnesty International (2014) as behaving in a predatory fashion towards its members.

⁽¹⁴⁷⁾ Including Mai-Mai groups (Bakata Katanga and Apa na Pale) as well as several Twa and Luba armed groups engaged in communal violence.

⁽¹⁴⁸⁾ OECD (2019).

⁽¹⁴⁹⁾ The GR, an elite security force controlled by the Presidency 'and not integrated into the national army [...] is better trained, equipped, and paid than the FARDC, and its control runs outside the army chain and command.' It is also seen as more loyal to the government than the army is, thereby serving as buffer against coups or professionally minded officers withdrawing support from the regime' (Enough, 2018, page 17).

⁽¹⁵⁰⁾ Specifically, the loading and unloading report (OECD, 2019).

⁽¹⁵¹⁾ BGR (2019).

⁽¹⁵²⁾ Center for Effective Global Action (2017).

Voluntary Principles on Security and Human Rights (VPs) or the International Code of Conduct for Security Providers (ICoC), is limited to the providers working with a few of the largest LSM operators. This is also true of the PMH, whose members receive no mining- or ASM-specific training or training on the VPs and are typically simply relocated from standard police units ⁽¹⁵³⁾.

A number of **serious human right violations** are linked to the presence of these different forces. As Enough (2018) ⁽¹⁵⁴⁾ submits, 'there are also indications Republican Guard forces are violently or otherwise forcefully repressing disputes at mine sites' ⁽¹⁵⁵⁾. The recent posting on Twitter by an opposition politician of a video showcasing the whipping of a presumed *creuseur* in the locality of Kambove ⁽¹⁵⁶⁾ seems to further corroborate these claims. According to Amnesty International (2016), children have also reported being beaten by security guards when trespassing on sites.

The recent presence of the FARDC, deployed to control an ASM invasion on LSM mining titles in mid-2019 ⁽¹⁵⁷⁾, has also led to severe human rights abuses, including the death of *creuseurs* or local community members according to local CSOs ⁽¹⁵⁸⁾ and reports from media sources ⁽¹⁵⁹⁾. Historically the interventions of Congolese Armed Forces have often been problematic ⁽¹⁶⁰⁾. It should also be noted that General John Numbi, the inspector-general of the Congolese armed forces and in charge of the 2019 operation, has previously been targeted by US sanctions in relation to the political violence that accompanied the last presidential election cycle ⁽¹⁶¹⁾.

High levels of poverty and lack of other livelihood options mean that migrant workers with few options provide an ample and steady supply of labourers to the 2C ASM sector and cases of **forced labour** do not seem to take place in the sector. Nevertheless, the extremely unequal relationships between miners on the one hand and buyers and financiers on the other, while not constituting forced labour, are far from desirable. Similarly, *creuseurs* regularly complain about the (mis)calculation of mineral content in the ore they sell. In itself, it does not qualify as an indication of forced labour through withheld wages and/or unclear/unjustified deductions, despite being a key concern more generally.

The **worst forms of child labour** are a feature of the 2C ASM sector. BGR (2019) estimates that children (understood as individuals under 18 years old) are present on 29 % of sites and as a whole the 2C sector probably employs a little fewer than 5 000 children ⁽¹⁶²⁾. While a few children go into the pits, the vast majority of them work on surface activities, such as hand-picking, washing, sorting and transporting, in particular when younger than 15 years old ⁽¹⁶³⁾.

Children who are not involved with mining work can be found on mining sites either selling food and drinks or because their mothers bring them on site in order to supervise them in the absence of school or daycare options or because the site is located in an urban setting ⁽¹⁶⁴⁾.

Mining activities and their potential impacts on children and young teenagers are problematic without a doubt. At the same time, it should be understood that most of the children who turn to this activity do so for lack of other opportunities, especially as the tasks they engage in typically receive less compensation than those of adults. Some of these children also head their own families, as a result of either teenage pregnancies or the need to take care of their siblings. These are already among the most vulnerable children in the DRC and can be negatively affected by bans on child labour that do not offer livelihood alternatives. Lack of free education

⁽¹⁵³⁾ OECD (2019).

⁽¹⁵⁴⁾ Enough (2018), p. 18.

⁽¹⁵⁵⁾ During 2C ASM site visits in 2016, ASM miners in both an ASM site in Kolwezi and an ASM site in Kambove mentioned to the consultant the use of beatings, whippings, temporary incarceration and theft of production by either the GR or the FARDC units found at the mine sites at the time, comments backed up by local CSOs. The consultant could not further document these allegations.

⁽¹⁵⁶⁾ The video, which shows the beating/whipping and public humiliation of a bare-chested individual in front of mining trucks by a non-uniformed armed man, was still available online via the politician's account on 14 October 2019 (<https://twitter.com/MuyamboKyassa/status/1134090088282021890>). A copy of the video has been kept on file in case of online deletion.

⁽¹⁵⁷⁾ Bloomberg (2019).

⁽¹⁵⁸⁾ ONG Espoir (2019a,b).

⁽¹⁵⁹⁾ RFI (2019).

⁽¹⁶⁰⁾ Bread for All et al. (2014).

⁽¹⁶¹⁾ *Guardian* (2016).

⁽¹⁶²⁾ BGR (2019); Center for Effective Global Action (2017).

⁽¹⁶³⁾ Center for Effective Global Action (2017).

⁽¹⁶⁴⁾ Center for Effective Global Action (2017).

⁽¹⁶⁵⁾ is the other push factor behind child labour in the 2C sector and, while the Congolese Constitution grants free schooling to all Congolese children, education still often comes at an unaffordable cost for parents, as they must purchase school supplies and sometimes pay a fee to teachers.

The 2C ASM sector could not exist in its current form without substantial levels of **corruption**, as the overwhelming majority of the sector's production comes from outside ZEAs and is thus by definition informal if not illegal. Virtually all the material travelling to ASM trading hubs, such as the Musompo market, and sold there comes from sources that are not legal, as at the time of the field visit only two ZEAs were in production ⁽¹⁶⁶⁾. BGR further reports that barriers are found at the entrance to ASM sites or on their access routes in 38 % of sites, in which case it is necessary for the transporter to pay a levy to the state agent present. As a rule, these payments do not generate any form of receipt and are not enshrined by law. Accordingly, corruption takes place not only during the extraction of material but also during transport and trading.

A number of documents are issued by Congolese authorities with the objective of establishing a certain level of traceability. However, as the vast majority of ASM operators work on LSM sites, it can be necessary for them to obtain a document specifying the origin of the minerals as being from a ZEA ⁽¹⁶⁷⁾. In this case, it will be necessary to offer a payment to the actors issuing the documentation. This leads to the **misdeclaration of origin of minerals**. Yet, often, the origin of minerals is not a concern of the buyers or of the other stakeholders present along the supply chain, who simply do not ask about the origin of the minerals or are content with receiving the vaguest of answers. The origin of minerals becomes an issue when traceability is requested because of external demands, such as midstream or downstream requirements.

As ASM miners operate mostly informally, the **payment of taxes** to authorities from ASM operators is very limited. According to BGR (2019), 60 % of sites pay no taxes, whether legal or extra-legal. At the level of 2C traders, a number of schemes take advantage of equipment shortcomings (absence of weighbridges or mineral-testing capacity) that affect the capacity of government agencies to illegally minimise their tax exposure ⁽¹⁶⁸⁾.

According to the Extractive Industry Transparency Initiative's (EITI's) draft 2017 scoping report, neither Haut-Katanga nor Lualaba reported any payment of ASM-specific taxes. This includes payments related to the issuance of the *carte de creuseur* (digger's card), arguably the easiest form of ASM taxation to implement. Most other provinces, including those where ASM plays a much smaller role, declare the payment of ASM-specific taxes ⁽¹⁶⁹⁾.

Cartes de creuseur

Creuseurs are mandated by the DRC mining code to obtain this individual identification. At the time of the field visit these cards had not been issued in either Haut-Katanga or Lualaba. According to an interviewed Saemape official, this is mostly because of pragmatic considerations: if diggers paid to receive these cards, they would then request access to viable ZEAs, which the officials cannot grant, and the likely result would be disturbances to the current social peace.

As ASM activity is generated by community members, the 2C ASM sector does not generate substantial levels of displacement and resettlement. The notable exception is the Kasulo site, although the cause of the displacement and resettlement was not the ASM activity itself but rather the provincial government's formalisation efforts (see Section 5.5.9).

OHS is abysmal on ASM sites. To access the mineral veins, *creuseurs* dig underground tunnels that sometimes stretch



Picture 1 Dangerous pits with 25-m-deep galleries on loose tailings

⁽¹⁶⁵⁾ The Congolese constitution (art 43) states that primary education is free and mandatory. However, parents are often not able to afford the costs (e.g. uniforms, school consumables, sometimes fees to the teachers) and opportunity cost of school.

⁽¹⁶⁶⁾ BGR (2019).

⁽¹⁶⁷⁾ OECD (2019).

⁽¹⁶⁸⁾ OECD (2019).

⁽¹⁶⁹⁾ EITI (2019).

deeper than 50 m. Owing to the haphazard reinforcement of galleries and lack of coordination between neighbouring pits, gallery collapses are far from being unheard of. Over the 6-month period preceding fieldwork a number of accidents happened in and around Kolwezi, probably claiming the lives of around 100 *creuseurs*⁽¹⁷⁰⁾; in 2018 'a total of 63 fatal accidents and 101 accidents resulting in injuries were reported' ⁽¹⁷¹⁾.

In addition to these immediate risks, ASM miners are also exposed to potentially lethal long-term impacts, mostly in the form of pneumoconiosis caused by dust inhalation⁽¹⁷²⁾ and also potentially due to the exposure to the radioactive elements that can be found in cobalt ore⁽¹⁷³⁾. ASM miners are also exposed to the long-term detrimental health effects of heavy manual labour, such as (incapacitating) back pain, a problematic old age prospect considering the lack of social safety net or pensions.

Personal protective equipment (PPE) is also exceedingly rare on sites. Most miners work with a simple shirt on their back and are often barefoot, which they say gives them better purchase when climbing down into the pits.

ASM miners should receive training and support from both Saemape and cooperatives in order to work more safely and follow the established practices. In practice, according to observations and BGR (2019, p. 20), 'workers are neither sensitised to occupational health and safety and hygiene to a sufficiently consistent degree, nor is appropriate protective equipment provided (and therefore) risks are apparent in poor mine



Picture 2 *Creuseur* without PPE

design, lack of personal protective equipment, lack of training and accident records [...]. The high number of accidents (occupational health and safety) reflects not only this shortcoming, but also the generally inadequate supervision and safety-related monitoring of mines.'

It is indubitable that the 2C ASM sector generates its share of **environmental and public health impacts** in the region. However, it is not possible to conclusively attribute the diffuse sources of pollution (such as airborne dust, nitrogen oxide or greenhouse gas emissions caused by additional traffic) and their impacts on public health to a single site. Pinpointing the origin of the pollution of rivers and streams is somewhat more feasible.



Picture 3 Cobalt ore washing

The horizontal and dynamic nature of ASM sites, along with the lack of training and support from both Saemape and cooperatives mentioned in previous sections, has resulted in the total absence of any form of environmental management plan or measures on most ASM sites. Rivers are particularly affected, as they are used to wash minerals. The process, in addition to the increased siltation, contaminates these rivers not only with copper and cobalt elements but also with the heavy metals and/or radioactive elements, such as uranium, associated with certain 2C mineralisations. The public health impact of radioactive elements emitted from the mining and beneficiation processes in particular is worrying and barely understood⁽¹⁷⁴⁾.

⁽¹⁷⁰⁾ More specifically, 13 people died at KOV, a site on Kamoto Copper Company's title in March (Radio Okapi, 2019a), and again in June 50 to 70 *creuseurs* died at that site (*La Libre*, 2019a,b). Four *creuseurs*, including three underage miners, died in a cave-in in the Biwaia site in September 2019 (Radio Okapi, 2019b). Just a week before the start of this project's fieldwork, in October 2019, seven *creuseurs* died on the Kamulombe site and four were still missing according to Saemape sources consulted.

⁽¹⁷¹⁾ BGR (2019), p. 40.

⁽¹⁷²⁾ Kabamba et al. (2016).

⁽¹⁷³⁾ Nkulu et al. (2009).

⁽¹⁷⁴⁾ Nkulu et al. (2009).

Despite tribal affiliations playing a central role in Katangese politics, only the Twa (one of the ethnicities composing the African Pygmies) could be understood as an **indigenous people** in line with IFC performance standard No 7 ⁽¹⁷⁵⁾. The Twa are notably absent from the Katangese copper belt.

Despite the recent massive internal migratory influx from the Kasais, stakeholders consulted have not mentioned significant or even visible **discrimination** issues. The DRC's President's familial links to Kasai seem to have somewhat helped the social standing of these internally displaced persons, according to comments from miners.

Roles in the ASM sector follow strict **gender** lines and very few women take mining activities that are not related to the less strenuous activities of washing and sorting ⁽¹⁷⁶⁾. These activities are typically paid less than the extraction of minerals, as they are not only less strenuous and risky but also subcontracted by the *creuseurs*. This is in part because of customary beliefs, according to which the presence of a woman in a pit will sterilise the pit. That belief also penalises women traders, as they are not able to physically check that they receive the entirety of the production of the pits they finance ⁽¹⁷⁷⁾.

A small number of women can also work as merchants in the mining sites, which is a more remunerative activity compared to minerals washing, handpicking, and the sale of foodstuffs and sundries on site.

According to CSO staff consulted, Katangese society is overall more gender conservative and rigid than the country's eastern provinces, further stratifying the existing gender dynamics and keeping women in the back seat (especially as gender perceptions are so strongly entrenched in the 2C ASM sector). This is visible in the coupling of the issues of the worst forms of child labour and the presence of pregnant women on mining sites.

The role of women in artisanal mining has raised a growing scholarly interest, and many studies on this topic explore gender aspects in relation to, e.g. migration flows ⁽¹⁷⁸⁾, conflicts ⁽¹⁷⁹⁾ power relations ⁽¹⁸⁰⁾, etc. Some studies describe risks of abuses for women in the artisanal mining sites, such as sexual and gender based violence ⁽¹⁸¹⁾. Others argue that the ASM sector offers important livelihood opportunities for women, and that the women's role in the sector should be strengthened ⁽¹⁸²⁾.

5.2. Artisanal and small-scale cobalt- and copper-mining value chains

To contextualise the sector further and better understand the potential impacts of responsible sourcing initiatives, it is necessary to understand how the 2C ASM sector supply chain works (see Figure 11 for a visual summary).

⁽¹⁷⁵⁾ Widely considered the reference laying down the defining characteristics of an indigenous group by most major stakeholders in the extractive sector.

⁽¹⁷⁶⁾ BGR (2019).

⁽¹⁷⁷⁾ OECD (2019).

⁽¹⁷⁸⁾ Maclin et al. (2017).

⁽¹⁷⁹⁾ Hayes and Perks (2012).

⁽¹⁸⁰⁾ Bashwira and Cuvelier (2019).

⁽¹⁸¹⁾ E.g. Rustad et al. (2016).

⁽¹⁸²⁾ Bashwira et al. (2014).

5.2.1. Mining

The basic work unit is the *creuseur* (digger) team. As virtually all ASM takes place in underground tunnels, these teams are usually attached to a specific pit. Their work is supervised and coordinated by the *chef d'équipe* (team leader), who coordinates the work of the *creuseurs* and is the point of contact of the team with authorities and other stakeholders. Part of the team goes underground to extract material while the other part of the team stays above ground to hoist the material up, dispose of sterile during pit excavations and watch over the extracted material. Teams dig through the overburden until they reach a mineral vein, which they will then follow regardless of depth. At some point pumps might have to be brought in to pump air into and/or water out of the galleries. As work on the site is uncoordinated and unplanned, a pit's underground galleries can merge with others. This not only creates conflict between the teams (conflicts that are adjudicated either by the cooperative(s) or by the Saemape agents on site), but also further destabilises the tunnels.

Creuseurs live hand to mouth and generally do not have any spare income available to live on while they dig through the overburden or to hire pumps. Pre-financiers, called *sponsors*, offset this lack of resources by covering the expenses of the *creuseurs* until they are able to sell their production. Typically, they will do so in exchange for 30–50 % of the production. The extracted material is transported within the sites either on the backs of miners or on the bikes of transporters.

If required, this material is then concentrated through washing and sorting. Surface activities are undertaken principally by women and the younger workers. Washing, a back-breaking manual activity, is done either in rivers or more rarely in ponds dug out for this purpose, where sieves are used to remove non-2C-bearing earth. Visual sorting of minerals can also take place, either after or before the washing depending on the type of minerals found on site.

On certain sites, hand-picking activities take place. In this case, miners scour piles of discarded material (overburden, tailings or mixed materials) in order to find rocks with sufficient 2C content. Because of the selectivity of the process, washing of hand-picked material is rarely undertaken. Furthermore, because of the more limited quantities produced, hand-picked material is generally sold on site. Being a less strenuous but also less productive form of mineral extraction, washing, sorting and hand-picking activities are often undertaken by women and the

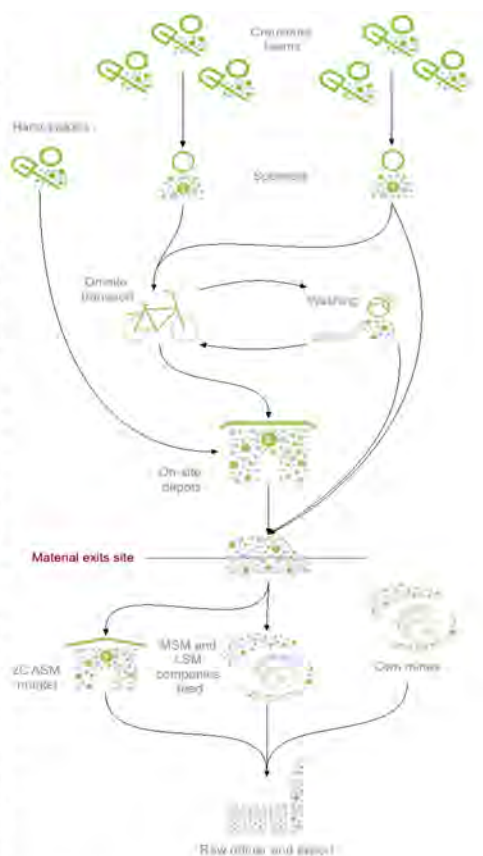


Figure 9 2C ASM supply chain



Picture 4 2C ore washers

younger workers.

Generally, neither *creuseurs* nor washers or transporters make a good living despite undertaking high-risk, high-exposure and high-impact work. BGR (2019) summarises the conditions on ASM sites succinctly ⁽¹⁸³⁾: 'The working conditions of most miners were found to be unacceptable. Apart from the fact that they are in informal employment, the majority of the miners surveyed (40 %) earn less than the national minimum wage of about \$5 per day. If one takes into account the almost universal complaints registered by the field teams regard unfair pricing practices and generally low purchase prices on the part of the intermediaries and depots, as well as the sometimes high tax demands of cooperatives and tax extortion on road barriers, it is easy to identify the causes of such grievances. The fact that this poorly paid work usually takes more than eight hours a day without adequate safety precautions and protective equipment underscores this assessment' ⁽¹⁸⁴⁾.

5.2.2. Trading and export

Once the material is extracted from the pit, and if necessary washed, it will be transported to buying centres within or next to the site, to specific clients or to market hubs such as the Musompo or Kisanfu market. The Kisanfu market was recently destroyed by the FARDC in a crackdown on illegal mining within the nearby Tenke Fungurume Mining concession ⁽¹⁸⁵⁾. These markets can be either loose or dense agglomerations of buying houses (*dépôts*).

Transport often uses bikes within the sites and mechanised vehicles (motorbikes, personal cars, vans, small flatbed trucks) to reach the buyers or markets located outside the sites.

Typically, at the point of purchase only the weight, ore content, and sometimes level of radioactivity of the product are tested. The origin of the material is not a consideration for buyers, unless one of their buyers requires this information. Testing of 2C content is done using portable X-ray fluorescence instruments, locally referred to as *Metorex*.

Creuseurs regularly complain of the price they are offered at these points of sale. They often complain not so much about the prices themselves but rather about the perceived cheating during the weighing and testing of the mineral content ⁽¹⁸⁶⁾. This cheating is perceived as being much greater on sites where a buyer or a group of buyers acts as a monopsony. It is not uncommon to hear miners say that a certain shop 'offre une meilleure teneur' (offers a better measured content).

Exporters of 2Cs, operators that have raw refining capacity, can source their material from a number of sources ⁽¹⁸⁷⁾. Some of them negatively affect traceability of the materials, and in certain cases raw refiners can end up buying material extracted from their own titles. These sources can include:

1. Own mining operations, which can be located either on a title they own or on an SOE title they operate on within the framework of a contract.
2. ASM operators delivering material directly from ASM sites.
3. ASM markets, either directly from sending agents or through intermediaries.
4. Other mining operators that either do not have their own refining capacity or focus on copper. These operators can also buy material from ASM operators or ASM markets.
5. Tailings of material sourced for its copper content, from any of the aforementioned sources, and already processed for copper extraction.



Picture 5 A street in Musompo market

⁽¹⁸³⁾ BGR (2019, p. 42) Note that prices are much higher in Kolwezi and the income needed to get a household through the day (housing, food, schooling, etc.) can be approximately USD 10-15 according to local CSOs.

⁽¹⁸⁴⁾ BGR (2019, p. 42).

⁽¹⁸⁵⁾ ONG Espoir (2019a).

⁽¹⁸⁶⁾ These allegations cannot be verified within the scope of the current project.

⁽¹⁸⁷⁾ OECD (2019).

The fact that most ASM production is exported, despite the fact that no ASM operator has the capacity to refine raw cobalt-bearing material into an exportable commodity, demonstrates that the entirety of ASM production is integrated into industrial channels one way or another ⁽¹⁸⁸⁾. As Enough (2018) notes: 'Some LSM companies in cobalt mining areas are well known by miners for their practices of buying artisanal minerals and exporting them under an industrial label. Civil society activists in Kolwezi noted that many of these companies hardly warrant the word "mining company." They're mostly running ASM export businesses that they export as industrially-mined minerals. By either allowing artisanal miners to dig on their industrial concessions and then logging the minerals as part of their own production, or else purchasing minerals from artisanal miners elsewhere and incorporating them into their own supply, some LSM companies are able to mask the true origins of their minerals.' ⁽¹⁸⁹⁾.

5.3. Existing systems

This section presents the key characteristics of the two selected systems concerned with the production or supply of responsible ASM cobalt: Better Mining and the Mutoshi Cobalt Pilot. As mentioned in the previous chapter, these are the only initiatives that had been implemented for at least 1 year at the time of the study, and had thus had enough time to generate some level of impact. The scopes and methods of these initiatives vary markedly and their definition of 'responsible' can also change, although they are based on the OECD Guidance.

5.3.1. Better Mining and Kasulo site

Implemented in the Kasulo ZEA (ZEA 786) by the globally operating consulting and audit group RCS Global Group, Better Mining is a site-monitoring solution that generates monthly incident reports and corrective action plans (CAPs) for its implementer, Congo Dongfang International Mining (CDM). CDM is the Congolese subsidiary of Huayou Cobalt Co., Ltd.

The Kasulo ZEA is composed of two sites: Kasulo 1 and Kasulo 2. It is owned by the Provincial Government of Lualaba, which has granted CDM an exclusive right to buy the production from the ZEA. The cooperative present on site is the Coopérative Minière Kupanga (Comiku), which according to Saemape documents consulted is represented by a direct relative of the Governor of Lualaba.

Better Mining started its implementation in Kasulo with a 6-month pilot phase, which started in June 2018, before being fully implemented from January 2019 onwards. Unlike the Better Sourcing Program (also implemented by RCS Global Group), Better Mining as implemented in Kasulo is solely focused on information collection, CAP preparation and dissemination. It does not provide any form of traceability: the information it provides characterises the site level and not any material. The implementation of Better Mining is paid for entirely by the operators using it. In the Kasulo site CDM is thus wholly financing the deployment of the system.



Pictures 6 Views of Kasulo site



⁽¹⁸⁸⁾ An exception could be noted in the form of limited direct undeclared and unchecked exports of ore to Zambia under the protection of the GR. This form of smuggling was noted in 2016 by a number of Congolese CSO stakeholders and border guards. It is unknown, however, how extensive this trade was and how much of it continues to this day.

⁽¹⁸⁹⁾ Enough (2018), p. 12

The information collected focuses on incidents and risks as well as relevant contextual information (price of cobalt outside the site, for example). Risks and incidents are based on the Better Sourcing Program Standard v6 (2016), a standard that is based on the OECD Guidance ⁽¹⁹⁰⁾. This information collection is done through site-based trained Better Mining staff equipped with a dedicated app on their smartphones. Once the information is collected, it is analysed by the RCS Global Group staff, who then identify underlying systematic causes and issue the CAPs. Better Mining does not implement any of the corrective measures from the CAPs, but monitors the implementation of the CAPs. For high-risk incidents, the implementer receives an immediate alert in addition to the monthly incident report and CAPs.

The deployment of Better Mining at Kasulo is limited to monitoring; long-term planning and implementation of mitigation measures are the responsibility of the operator (CDM) and the state agency (Saemape). Better Mining in Kasulo can thus be considered the monitoring component of a wider initiative and has limited leverage with the implementer.

Prior to its transformation into a ZEA in August 2017, Kasulo was an urban neighbourhood where mining was taking place between houses, in gardens and even within homes. This complete overlap of mining and habitation zones resulted in high numbers of children on site and endemic child labour issues. It also represented a non-negligible accident risk to the local community due to the potential for falls into pits, and caused occasional building collapses. As part of the transformation process, the neighbourhood has been evacuated, all buildings destroyed and the area walled off. During the process a number of issues relating to relocation emerged (see Section 5.5.9). These issues predate the implementation of Better Mining.

Access to the site is now only possible through dedicated doors, which are under supervision at all times. While in theory access to the site is conditional on the presentation of a Comiku membership card, this demand has been downgraded to the need to present a document certifying that the individual is over 18 years old, as no membership cards have been distributed outside Comiku's management. According to Comiku there were at the time of the visit about 1 300 *creuseurs* working on site, all male (180 of them work on Kasulo 2 and 1 115 on Kasulo 1). This is a significant decrease from the presence of 5 000 to 14 000 miners on site prior to its transformation into a ZEA.



Picture 7 Washing basin in Kasulo

Part of the site has benefited from overburden removal (see Pictures 8, bottom), which has targeted the areas considered at highest risk based on Saemape structural integrity assessments. Thanks to this measure as well as more thorough site monitoring by Saemape, encouraged by the monitoring and released CAPs, there have been no fatalities on site in the year up to the site visit.

Three dedicated washing basins have also been dug out within Kasulo 2, where 20 washers, all female, operate. These basins are individually filled with water and, once silted and dry, the tailings are removed. This avoids the washing of ores directly in the Dilala river, which previously took place. The washing basins are then refilled.

Once extracted, the product is transported to the different *dépôts* present on site. Material from Kasulo 2 is washed prior to being sent to the *dépôts*. At the time of the visit there were seven such *dépôts*, each with its own testing area and personnel. These *dépôts* can only sell to CDM. CDM then fills its trucks, which head to the company's raw refining plant located in Lubumbashi.

⁽¹⁹⁰⁾ BSR (2016).

In a nutshell

CDM has been granted the exclusive right to purchase minerals from the Kasulo site by the Government of Lualaba, the title owner. It purchases minerals through traders present on site.

Paid by CDM, Better Mining monitors the site, documents incidents and analyses the information to find the root cause of the incidents. It also prepares incident reports for CDM as well as corresponding CAPs for implementation, and monitors the implementation of the CAPs. Better Mining does not train stakeholders, provide traceability or implement the suggested CAPs. CDM, Comiku and Saemape jointly implement the CAPs.

5.3.2. Mutoshi Cobalt Pilot

In contrast to Better Mining at Kasulo, the Mutoshi Cobalt Pilot (MCP) implemented by the international NGO Pact⁽¹⁹¹⁾ is implemented not on a ZEA but on an LSM title (PE 2604) owned by Gécamines and leased to the mining and processing company Chemaf, part of the Shalina Group. The pilot makes use of provisions in the Congolese mining code that allow permit holders to authorise ASM activities on parts of their concessions. However, the exact nature of the arrangement remains unknown, as these documents are not in the public sphere and the information is kept by Chemaf. The cooperative present on site is the Coopérative Minière Artisanale de Kolwezi (Comiakol).

Unlike Better Mining (a template solution then tailored to the specifics of both sites and implementers), the MCP has been developed specifically for the site and to operationalise the demands for responsible ASM sourcing made by the MCP material buyer to the MCP operator.

In 2018, the trading company Trafigura Group Pte Ltd entered a 3-year cobalt hydroxide off-take agreement with Chemaf⁽¹⁹²⁾. One of the conditions of the agreement was alignment with Trafigura's Corporate Responsibility Policy and its Responsible Sourcing and Supply Chain Expectations, as well as with the OECD Guidance.

As a result of this agreement Chemaf works with Comiakol, as a subcontractor working on the MCP, the ASM site. In parallel, Trafigura has contracted Pact to support the efforts of Chemaf in working responsibly with the ASM miners on the pilot. Saemape is integrated into these efforts and, while the PMH is present on the pilot site, its relationship is at the title level with Chemaf and not directly with the pilot.

⁽¹⁹¹⁾ <https://www.pactworld.org/>.

⁽¹⁹²⁾ Trafigura (n.d.).

Mutoshi and the Mutoshi Cobalt Pilot

While they share part of the same name and of the same location, a clear distinction should be drawn between Mutoshi and the MCP. The former is the name used by local stakeholders to refer to both a neighbourhood of Kolwezi and the adjacent titles on which Chemaf operates. These titles include a number of ASM sites that are not formalised and where issues of child labour, life-threatening OHS and the presence of armed forces have been reported by ASM miners and CSOs.

The MCP meanwhile is a small subset of the Mutoshi titles and is not related to the rest of the title in its operations (with the exception of the buying centre).

Note that the results of our analysis concern solely the pilot site of the MCP.



Pictures 8 Views of Mutoshi ASM site



Pact's role within the project is to support and facilitate the collaboration between Chemaf, Comiakol and the ASM miners. It does so by:

1. supporting site monitoring and reporting information on incidents to Chemaf;
2. supporting Chemaf and Comiakol with its technical knowledge of ASM and of downstream demands;
3. working jointly with Chemaf and Comiakol on adapted community outreach;
4. raising hazard awareness and safety management capacity among ASM miners, jointly with Chemaf and Comiakol.

The Chemaf title includes not only the pilot area, but also villages, farmland and a mineral-buying centre managed by Chemaf and located 11 km away from the pilot site, as well as informal ASM sites. Chemaf is also constructing a refining plant on the title. According to communities consulted, Chemaf is undertaking exploration in some areas of the title.

The pilot site is located on an area previously developed as an informal ASM site for a number of years and next to the neighbourhood of Mutoshi. Prior to the start of the project, the pilot area was a site pockmarked with deep tunnels, some of them more than 50 m deep. The pilot site is now divided into an extraction area, two washing areas, a temporary storage area and a tailings area (where the cobalt-containing overburden and silt from the washing basins are stored until completion of the local processing plant).

The entire pilot area, while not fenced off the rest of the site, is nevertheless inaccessible from the community. Miners who wish to enter the site must do so using designated gates, where their membership cards are verified, a requisite to enter the site, and miners entering are counted every day. An official listing of prices for cobalt at the buying centre is shown, in US dollars per tonne of material and for various mineral grades. In addition to their membership cards, miners have to be wearing PPE and closed shoes to enter the site. Overalls and hard hats are offered free of charge to the members; some members also use gloves or rubber boots depending on their tasks.

At the time of the visit, Comiakol counted 4 083 registered *creuseurs*, 142 registered washers, 364 male mineral buyers, 228 female mineral buyers and 98 *mobiles* (cooperative members in charge of overseeing the site).

Between 8 and 12 m of overburden has been cleared from the extraction area (see Pictures 9 and 10), making the deposit immediately accessible to *creuseurs*. *Creuseurs* have to limit the depth of their excavations to 6 m and proceed strictly vertically, as pits must not branch into tunnels. Compliance with these rules is monitored by a combination of Saemape agents and *mobiles*. Once a sufficient number of pits have reached their maximum depth, the site is once again levelled out with the use of machinery and the cycle starts anew. At the time of the visit, overburden removal was mentioned as having fallen behind schedule owing to cash-flow concerns at the Chemaf level. Those concerns also affected the capacity of the buying centre to pay miners on the spot, which led to a drop in the number of miners coming to the site.

Once the mineral is extracted from the open pit area it is transported on bikes either to washing pits or directly to the temporary storage area. Washing takes place in 14 dedicated washing basins. These are filled with water and left to dry once they are silted, before being re-excavated. Basin tailings are stored aside in an area that also receives the cobalt-containing overburden, where a few miners perform hand-picking. Material is then stored



Picture 9 Work on the MCP



Picture 10 Washing basin at MCP

until a team has enough material to send it to Chemaf's buying station using private cars and vans contracted by the traders. There the material is weighted and its cobalt and moisture content are determined. Teams are then paid accordingly and material is packed into big bags that at the time of the field visit went directly to Chemaf's Usoke processing plant in Lubumbashi, a plant that only treats ASM material ⁽¹⁹³⁾.

In a nutshell

Trafigura has an off-take agreement with Chemaf. Chemaf implements the MCP on a small part of its Mutoshi site. To do so it works with Comiakol and Saemape. All cobalt produced by the MCP is purchased by Chemaf and then Trafigura.

Paid by Trafigura, Pact provides technical support to the MCP by (i) supporting site monitoring and reporting information on incidents to Chemaf; (ii) sharing its technical knowledge of ASM and of downstream demands; (iii) community outreach; (iv) raising hazard awareness and safety management capacity among ASM miners. These actions are implemented jointly by Pact, Chemaf and Comiakol as well as Saemape.

5.4. Methodology used for the analysis of pilot projects

The analysis below is based on a comparison of the visited pilot projects with the general conditions of the 2C ASM sector in Lualaba and Haut-Katanga (as described in Sections 5.1 to 5.4). This approach has been chosen in the absence of an available baseline of the pilot sites prior to the implementation of the systems. Moreover, it was necessary to develop a robust rather than refined methodology that could weather out missing data and integrate the wide range of sometimes conflicting estimates given by different actors. Results from this approach are presented in Section 5.5.

The characterisations of pilot sites and of the 2C ASM sector are based on information collected through the information matrices on which this analysis is based. As most of this information is qualitative and suffers from significant loss of quality and meaning when turned into quantitative indicators, it has been kept in its qualitative form.

Information matrices have been chosen as a replacement for questionnaires, as a significant part of the supply chain remains non-formal (illegal, informal, outside applicable legal norms or with regulations applied selectively as a norm). Stakeholders therefore respond poorly to structured questionnaires, which are too thorough and too often make stakeholders confront their non-formality, which does not allow the establishing of the interpersonal trust necessary to obtain information on non-formal activities. These matrices are based on the OECD Guidance, the IFC PS and the CCCMC Guidance, as described in the previous chapter. The methodology used to develop the information matrices is presented in Annex 4.

Information collected for the filling of the information matrices has been collected through secondary sources (listed in Annex 4), phone interviews, in-person interviews, and direct observation in and around mine-sites. Interviews have been conducted over the phone and in person with a diverse range of stakeholders:

- subject matter experts not affiliated to a CSO (5),
- initiative implementers (3),
- community representatives (12),
- children ex-workers from neighbouring communities (15),
- representatives from CSOs (10),
- ASM miners from the pilot sites and ASM miners' representatives (6),
- government agencies' representatives (2).

In-country work was undertaken between 30 September and 8 October 2019 in Lubumbashi and Kolwezi.

⁽¹⁹³⁾ Trafigura (n.d.).

Section-specific colour coding

In this section, dedicated colour coding is used to summarise information under each heading. The summarised information describes the level of change observed on site compared with the rest of the sector, and the level of influence the system has on that situation.

Table 18 Colour coding used in the assessment

Situation in 2C ASM sector at large	
	No noted risks
	No noted risks, related issues remain
	Not applicable (absence of underlying factors)
	Systematic abuses
	Systematic and grave abuses
Situation on site compared with baseline	
	Major improvement
	Improvement
	No change
Influence of system on situation	
	Direct
	Through the initiative
	Unknown

Furthermore, visits on the two pilot sites have been conducted under the guidance of multiple representatives of the initiative implementers, the operators, the deployed Saemape agents and the assigned cooperatives (13 or 14 people in total depending on the pilot site). Because of the pervasive presence of officials, ASM miners were interviewed at a different time and in a neutral location.

This information gathering was complemented by a visit to a third ASM site, where no pilot was implemented. This site was chosen as representative of the general 2C ASM sector according to stakeholders consulted. This site will remain unnamed, as access to the site was conditional on anonymity.

5.5. Evidence from the sites

It is necessary to stress that neither Better Mining nor the Pact Mutoshi pilot operates in a vacuum or only by itself. Both approaches are part of broader initiatives implemented on site and coordinate their work with the mining operator, the miners, the cooperatives, the state agencies and, in the case of Mutoshi, the initiative's financier. This has significant implications when it comes to assessing the impacts of these systems individually and not as part of the broader initiatives they are a part of. In most cases, it is not possible to disentangle the working of the broader initiative from the influence a system may have had on these initiatives. This is because those systems have limited direct implementation capacity. Rather, they are instruments that implement or reinforce and when necessary reorient the managing systems of the operators so as to achieve a particular set of objectives, i.e. alignment with the demands of the OECD Guidance and applicable best practice. In other words, they indirectly affect the observed issues by playing their role in the initiatives they are a part of.

It should also be noted that both systems are implemented by LSM operators⁽¹⁹⁴⁾, which already have substantial management systems in place. There is therefore less room for these systems to have a more direct impact by prompting the adoption of management systems rather than reinforcing, correcting and reorienting existing management systems and procedures.

Coupled with the lack of a pre-implementation baseline, this makes assessing the impact of these systems extremely complex and fraught with errors. In order to avoid these pitfalls, the analysis is limited to highlighting, in addition to the level of change, whether the system could influence the situation on the pilot site if the other elements of the initiative were not present (**direct impact**) or the system's impact is wholly dependent on the other elements of the initiatives, which would not have the same level of impact, if any, without the presence of the system (**impact through the initiative**).

These elements are reflected in the colour coding of Table 19, and of the section headings below.

⁽¹⁹⁴⁾ CDM, in addition to its ASM sourcing, operates its own LSM assets.

Table 19 Results of pilots' assessment since implementation of the RS system. Summary table

Category	2C ASM sector	Kasulo	Mutoshi
Presence of armed groups	Not applicable		
Presence of armed forces			
Serious human rights violations			
Forced labour			
Worst forms of child labour		 	 
Corruption and bribery (at the level of the ASM miners)		 	 
Misdeclaration of origin of minerals		Contingent on operator's declarations	
Payment of taxes			
Displacement and resettlement			
Occupational health and safety			 
Environmental and public health impacts		 	 
Indigenous peoples	Not applicable		
Minorities and discrimination			
Gender			

In line with the methodology presented in Section 5.4, the sections presented below and summarised in Table 19 reflect the risks listed in the OECD Guidance, the IFC PS and the CCCMC Guidance.

At the risk of repeating ourselves, these results should be read while bearing in mind the scope of interventions of the systems.

Better Mining, for example, only makes recommendations and is not in charge of implementing changes or providing any sort of training to either miners or operator/cooperative/Saemape staff. It can only recommend the training and its focus. Furthermore, its contract is with the operator and not with the off-taker, which reduces leverage when established practices clash with best practices.

Pact, meanwhile, although it has more capacity to implement changes, operates on a pilot that is only a limited area of a much wider mining title. That title has an ongoing history of fraught community relations and tensions, over which the system has no impact. Furthermore, a number of management systems function at the site level, of which the ASM area is a subset. These include key elements such as selection and contracting of private security and long-term community relations planning. Hence it is important to highlight that the MCP should not be confused with the Mutoshi title.

5.5.1. Presence of armed groups

Sector baseline	Kasulo	Mutoshi
N/A		

Compared with the baseline, there is no change in regard to the presence of non-state armed groups on mining sites, along transport roads or at trading points. This risk can be considered minimal under the current circumstances.

5.5.2. Presence of armed forces

Sector baseline	Kasulo	Mutoshi
		

Compared with the baseline, the inappropriate presence of state armed forces is much lower. In neither of the sites was the presence of the FARDC, National Police, GR or any armed forces other than the PMH observed.

In Mutoshi, as in any ASM site in the region, the ANR is rumoured to have agents on the pilot site.

In Kasulo the *Division des Mines* shares its offices with the *renseignement* (intelligence services), as is written on a plaque by the entrance to the office. This was confirmed by local staff. It is understood, based on interviews with miners, that the intelligence services present on site include ANR, Demiap and Bureau 2. However, this could not be confirmed.

While the issue of the presence of intelligence agencies on ASM sites is less clear cut than that of armed forces, the presence of agencies noted for their negative human rights record is nevertheless cause for concern.

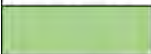
5.5.3. Serious human right violations

Sector baseline	Kasulo	Mutoshi
		

No serious human rights violation has been observed directly on the pilot sites. However, protests in the Kasulo neighbourhood adjacent to the site and triggered by the ASM activity on site ⁽¹⁹⁵⁾ turned violent and led to the intervention of armed forces not stationed on site. The intervention resulted in four fatalities, two of them not miners, according to CSO reporting ⁽¹⁹⁶⁾.

Both pilots ensure the absence of non-authorised miners in their operations through fencing/walling, thereby reducing the opportunities for confrontation between armed forces or private security staff present on site and ASM miners. At the same time, on neither of the sites were either security or PMH agents trained on the VPs or ICoC, according to the staff interviewed. In both cases the contract is not established at the pilot level and there is thus a lack of clarity on site about the rationale behind the selection of any particular firm or its human rights track record.

5.5.4. Forced labour

Sector baseline	Kasulo	Mutoshi
		

Compared with the baseline, there is no change in the presence of forced labour on sites, along transport roads or at trading points. This risk can be considered minimal under the current circumstances.

5.5.5. Worst forms of child labour

Sector baseline	Kasulo	Mutoshi
		

Compared with the baseline, no cases of child labour or of young adolescents working on sites have been either directly observed or reported by the consulted CSOs or miners.

Both pilot sites seem to rigorously enforce age control systems in order to avoid the presence of minors on sites, with success.

Issues of child labour (hand-picking) on Chemaf's title have been mentioned by local community children but are not connected to the pilot.

5.5.6. Corruption and bribery

Sector baseline	Kasulo	Mutoshi
		

Compared with the baseline, extortion or requiring miners to pay for services they are owed (such as the services of Saemape) is reported to be minimal or non-existent on these sites, according to miners consulted.

For both Kasulo and the MCP, the granting of mining titles was managed by the respective companies and not by the pilot. This issue is therefore not considered in this analysis.

⁽¹⁹⁵⁾ The exact cause of the protest could not be determined at the time of writing. According to Comiku and CDM staff in Kasulo, the protests were initiated by miners not working on site and protesting against entry requirements, while CSO representatives attribute it to dissatisfaction of Kasulo miners with prices and mineral contents (i.e. perceived incorrect determination of cobalt content) offered on site.

⁽¹⁹⁶⁾ ONG Espoir (2019b).

5.5.7. Misdeclaration of origin of minerals

Sector baseline	Kasulo	Mutoshi
	Contingent on operator's declaration	

The potential issue of misdeclaration of mineral origin is somewhat more complex.

In Kasulo, minerals from outside cannot enter the site without the willing participation of staff. The entire production of the walled-off area is legitimate, as it originates from within the ZEA. Neither CSOs nor miners have mentioned that any mineral production enters from outside the site. It should, however, be noted that CDM does buy minerals from other sites; in particular, its purchase of ASM copper material (which contains amounts of cobalt) is noted as casting a wide net. Therefore, any claims that CDM production is responsibly sourced would have to be treated with caution, as no assurance regarding the conditions of extraction of material that is not from Kasulo or a similarly monitored site could be given. Furthermore, as highlighted, Better Mining does not provide any traceability of materials.

Regarding the Chemaf buying centre located within the Mutoshi title, all stakeholders have mentioned that Chemaf's buying station buys ASM minerals regardless of their origin. In parallel to these claims a small flatbed truck fully loaded with minerals bags was seen entering the Chemaf title, in front of the ASM pilot site. The door was opened by on-site security with no signs of agitation and could move forward without any kind of checks.¹⁹⁷

ASM miners and community members consulted all declared that no material can exit the Chemaf title. According to them anyone caught trying to smuggle material out of the title will get his production confiscated and faces a likely beating. Note that these comments applied to production from the informal sites on the title and not the pilot site.

In a nutshell

Issues of misdeclaration of mineral origin are currently not an issue, as neither operator makes claims about the product it sells. Instead, claims are focused on the implementation of initiatives. Issues could potentially emerge if operators started making claims about the characteristics of the specific material they supply, and did so without fully guaranteeing that these claims could be associated with the specific material they were selling to their clients.

5.5.8. Payment of taxes

Sector baseline	Kasulo	Mutoshi

Payment of taxes is unknown.

Accessing tax information and the contracts that underpin specific tax arrangements (in the case of Kasulo the contract designating the CDM as the unique buyer of minerals in Kasulo, and in the case of Mutoshi the leasing contract between Chemaf and Gécamines) is extremely sensitive in the DRC context and was not possible.

However, these being formal operations, it is extremely likely, although not confirmed, that the pilots pay at least some taxes.

¹⁹⁷ The entrance of the truck could be photographed by the team

5.5.9. Displacement and resettlement

Sector baseline	Kasulo	Mutoshi
	→	→

Compared with the baseline, there is no change in the risk of displacement or resettlement, as both systems are implemented on existing sites. The site of Kasulo has experienced issues of displacement in the past but these issues predate the implementation of the Better Mining pilot ⁽¹⁹⁸⁾.

In Mutoshi, issues of resettlement on Chemaf's title have been mentioned by local community members but are not connected to the pilot.

5.5.10. Occupational health and safety

Sector baseline	Kasulo	Mutoshi
	🦟	👤👤

Compared with the baseline, the OHS conditions on both sites are significantly better, as neither had recorded any fatalities during the year before the visit, and the level of risks has decreased markedly according to both miners and CSOs consulted ⁽¹⁹⁹⁾. While it is too early to draw conclusions at this stage, this could probably be attributed either to the complete removal of overburden in the case of Mutoshi or to the combination of risk-based localised overburden removal with additional Saemape monitoring in the case of Kasulo.

It is also likely that the long-term impacts of washing activities (urinary tract infections and other gynaecological complications) will decrease or disappear, as precautionary measures (shallow washing ponds) have been implemented on both sites, eliminating the need for washers to stay semi-immersed in mineral-laden water for long periods of time.

However, a number of OHS risks remain.

In Kasulo a number of pits not in production are open and barely marked, which could lead to falls into the 10- to 20-m vertical shafts. The risk, however, is somewhat mitigated by the lack of presence on site at night and the decoupling of the mining area from the neighbourhood. Complete absence of PPE on site can also result in injuries.



Pictures 11 OHS risks observed in Kasulo

⁽¹⁹⁸⁾ It should be noted that the Kasulo resettlement process has been riddled with issues related to appropriate compensation of the people resettled, the compensation of farmers on whose land the resettlement took place or has to take place, and the capacity of households to give meaningful free prior informed consent. This expropriation concerned 544 parcels, whose owners were given 14 days to choose between a cash payment (both the amount and how it was calculated are unknown by CSO informants) and receiving new housing in a rural area 12 km outside Kolwezi with no school or hospital. Concomitantly 326 land owners have had to give up either a part or the totality of their farming land to state agencies to enable the resettlement of the Kasulo inhabitants (both the amount and how it was calculated are unknown by CSO informants). As of early 2018, very few housing units had been constructed and resettled people were complaining not only of the quality of accommodation received but also of their lack of understanding of the process or their rights (Solom, 2018), thereby vitiating claims that meaningful free prior informed consent was obtained from the communities. While this falls completely outside the purview of Better Mining, as the displacement and resettlement process took place prior to the deployment of the system, members of local CSOs nevertheless stress that in their opinion Better Mining should address this historic legacy. This perceived shortcoming affects their perception of the system.

⁽¹⁹⁹⁾ On a very encouraging note, on the day after the site visit the MPC held a celebration of 1 million hours worked without an incident serious enough to suspend work temporarily.

Furthermore, despite Saemape being much more robustly and effectively involved than usual and the fact that Congolese law limits the depth of underground pits and tunnels to 30 m, this limit is often flouted by miners and despite knowledge of it by SAEMAPE (as illustrated by SAEMAPE own pit diagrams, see Pictures 11), work continues unopposed.

On both sites there is a noted absence of mine-dust protection, despite the known long-term effects of dust on ASM miners⁽²⁰⁾. This risk is potentially higher in Mutoshi because of the nature of the deposit (hard rock) and the open pit design of the site, generating higher levels of dust. Long-term impacts of digging, transport and washing activities that can result in back pain and other forms of reduced mobility at an older age are also not addressed in either site. These can be a significant burden for miners in their later life, as no social safety net is in place.

Life-threatening DHS issues on Chema's title have been mentioned by local community representatives and CSOs, and observed by the team, but are not connected to the pilot.

5.5.11. Environmental and public health impacts

Sector baseline	Kasulo	Mutoshi
		

Compared with the baseline, environmental impacts are mitigated. Indeed, the main direct environmental impact of ASM sites, the pollution of river and streams due to the washing process, does not occur, thanks to the use of washing basins. As these basins are not connected to any stream or river, they do not generate any such pollution. Once silted and dried, the silt is either discarded or stored for processing as low-content ore.

Other environmental impacts, related to the generation of dust and of greenhouse gases due to transport, could not be assessed within the scope of the study and are also too complex to pin on a single source.

5.5.12. Indigenous peoples' rights

Sector baseline	Kasulo	Mutoshi
N/A		

Compared with the baseline, there is no change in impacts on and risks to indigenous communities. This risk can be considered minimal under the current circumstances.

5.5.13. Minorities and discrimination

Sector baseline	Kasulo	Mutoshi

Compared with the baseline, there is no change in regard to issues of discrimination. This risk can be considered minimal under the current circumstances.

5.5.14. Gender

Sector baseline	Kasulo	Mutoshi
		

⁽²⁰⁾ Kabamba et al. (2016).

Compared with the baseline, the situation in Kasulo is unchanged.

In Mutoshi, however, about 7–10 % of diggers are female, a visible departure from the strict gender separation of roles observed on most sites. This can be linked to the open-pit nature of the site, as CSOs and Saemape agents consulted have linked the work of women as diggers to the lack of underground work, of which women are not capable according to these sources.

5.5.15. Other considerations

The implementation of both Better Mining and the MCP seems to have produced positive changes to the conditions on site, but they also have created or exacerbated some issues of their own, according to CSOs and miners consulted. These issues are not reflected in the human rights risk indicators used in most due diligence or risk-mapping efforts, as these are not strictly covered by the reference standards.

It should be noted that the potential issues presented below for the most part stand outside the scope of the analysed systems, in part due to the latter's focus on the OECD Guidance. Moreover, given the lack of available channels to seek redress or influence on the sector, both CSOs and miners tend to make demands upon systems that may either be loosely connected to the scope of these systems or go over and beyond their scope.

While, once again, it is too early to draw anything but very preliminary insights, the governance context of the DRC means that such worries should nevertheless be carefully taken into account by actors engaging with responsible cobalt-sourcing initiatives.

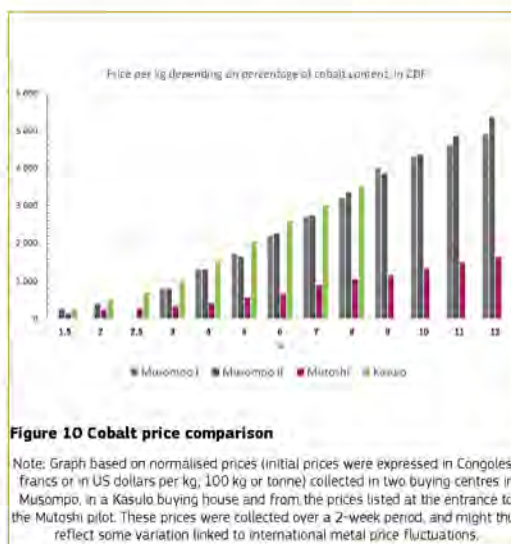
• Miners' income

Miners do not earn a salary and instead their income depends on their daily production. Its value is determined not only by the volume of ore they extract but also by its cobalt (or copper) content, as well as international prices. In certain buying stations, the moisture content of the ore is also taken into account.

With the exception of the Chemaf buying centre, located in the Chemaf title, prices are somewhat similar across all markets, as illustrated in Figure 10.

As noted earlier (see Section 5.2), miners regularly express their unhappiness with their earnings, although this is directed not as much at mineral prices as at the perception that they are cheated during mineral content determination and weighting. This led to recent protests at both sites⁽²⁰¹⁾, which in the case of Kasulo turned violent and led to four fatalities, as noted in Section 5.5.3. According to Comiku and CDM staff in Kasulo, the protests were initiated by miners who did not work on site and local miners were defending the site. The most accurate narrative could not be identified at this time.

As part of their operations, both sites limit mineral buyers on their sites and do not allow material to be sold outside, thus creating monopsonies. ASM miners perceive these as more prone to cheating, as they cannot have their material assessed on the open market and thus find a buyer offering them a measurement of mineral content that is closer to what they believe is correct. The accuracy of the mineral content determination could not be tested.



⁽²⁰¹⁾ Elavox (2019); ONG Espoir (2019b).

Scales have also been highlighted as another way to cheat miners, in particular when few competing buyers are present. Testing of these scales has shown a ± 2 -kg fluctuation, well short of the discrepancies of more than 15 kg sometimes reported.

While pay level is not part of the standards that are applied when performing human rights due diligence in the sector, it is undoubtedly a major determinant of the living conditions of miners. Furthermore, perceived injustices can lead to protests and the involvement of Congolese armed forces, which are not trained in the VPs and have often committed human right violations when confronting ASM miners ⁽²⁰²⁾.

In this respect, it is encouraging to note that Better Mining includes as part of its approach information on the prices found in Musompo market in its reporting to CDM.

- **Cooperatives**

Working with a cooperative is necessary both legally and organisationally but there are concerns surrounding the fact that cooperatives do not operate in line with cooperative principles. They are thus at best a form of organisation that is not accountable to its 'members' or governed by them, and can at worst be a form of organisational structure that extracts revenue from ASM miners without providing them with any benefit, save for the authorisation to work on a site. In that regard the assignation of cooperatives to specific sites through decrees is also a non-transparent procedure that raises a number of red flags, especially as the involvement of PEPs in cooperatives is the rule rather than the exception.

The cooperatives assigned to both sites are backed/owned by PEPs, according to CSOs consulted. While this cannot be substantiated in the case of Comiakol, consultation of a Saemape document on registered cooperatives shows that the representative of Comiku is a relative of the Governor of Lualaba. Furthermore, according to CSOs and miners consulted, the assignation of Comiku on Kasulo displaced an existing *comité de creuseurs* that was previously on site. Such committees are typically local 'cooperatives' that lack the resources to be formalised as such but might be more legitimate locally, as they are often started by miners who are directly involved in the site.

According to stakeholders consulted, Comiakol was also a *comité de creuseurs* before Pact supported it in its registration as a fully fledged cooperative.

- **Misleading claims of origin/impact**

There are concerns among CSOs consulted that the current efforts made and/or financed by private actors in the cobalt supply chain, while having a positive impact on the sites where they are implemented, might be used as a way to whitewash the entire production, sourcing or image of the implementer. This could happen either by association or through unclear or confusing communication about the characteristics of the operators' cobalt production or sourcing. This concern is more acute regarding actors that use a number of different ASM sources, which do not operate under the same standards as the sites where initiatives are piloted.

This is similar to the criticism of downstream users of the Better Gold Initiative (BGI), a number of whom made claims about the nature of their gold sourcing that were disproportionate to the size of their actual sourcing of BGI material. In other words, 'BGI has been singled out as allowing the Swiss gold smelting industry to enhance their image to an extent that is not in line with BGI's contribution to their production' ⁽²⁰³⁾.

- **Transparency**

Civil society representatives point out that there remain high obstacles to accessing information regarding the sites on which the pilots are implemented.

Indeed, barely any information is accessible without direct contact with project implementers, even when it is not commercially sensitive. That is a difficult hurdle for CSOs to clear. Similarly, site visits are very difficult to organise for these stakeholders, they report.

A number of documents that should have been made public in accordance with Congolese regulations and policies remain inaccessible. For example, and much to the dismay of local CSOs, the content of the agreement between CDM and the provincial authorities as it relates to the operation of Kasulo is not known, including the information relating to payments to authorities both for taxation purposes and for service

⁽²⁰²⁾ ONG Espoir (2019a,b).

⁽²⁰³⁾ Strade (2018).

delivery (presence of the PMH and of Saemape on site). The exact nature of the arrangement that allows Chemaf to work with ASM miners on its site is also unknown and, while the Congolese Mining Code contains legal clauses that allow it, local CSOs complain that they are not able to access that information.

- **Historical grievances**

That responsible sourcing systems do not seek redress for historical grievances on sites is seen as a shortcoming of the responsible sourcing efforts deployed by the systems, and affects local stakeholders' perceptions of the systems.

The case of the troublesome resettlement of Kasulo has been cited by a number of CSO representatives as an example of these unaddressed grievances.

5.6. Main findings of the chapter

As presented in Section 5.5, both Better Mining and the MCP have triggered or catalysed positive changes in their pilots.

As the summary tables show, systems are very dependent on the initiatives they are a part of. This is more obvious for Better Mining, as the system's scope is limited to reporting and creating CAPs, whereas the MCP's direct engagement with miners and the local community gives it some additional measure of direct impact on miners and communities. The more integrated a system becomes within an initiative, the better it can support impact. However, it then becomes more difficult to disentangle the impacts the system has by itself from those of the initiative.

An additional advantage of the MCP over Better Mining when it comes to implementing changes is that its client is the off-taker and not the operator. This means stronger leverage when ongoing practices must be aligned with international best practices (including the OECD Guidance), as the producer is contractually tied to the off-taker and its responsible sourcing demands.

The systems analysed operate in very complex environments and require to be analysed within the context of the relevant environment to be understood. Changes will take time to manifest, and tenacious issues will probably only be solved by repetitive iteration and gradual correction. For example, fostering something as simple as the use of PPE on site has taken months for the MCP.

Being commercially funded, neither system depends on continued disbursement of public money for continuing implementation, but instead they depend on cobalt prices remaining over a certain threshold. Downturns in the price of the metal will affect the profitability of the operations and may lead to either a downsizing or a freeze of the initiative or the systems' implementation.

Being integrated into commercial initiatives, the systems can suffer from the initiatives' need to be profitable, which can affect the prices initiatives offer to *creuseurs* and can lead to frictions not only with ASM miners but also with the CSOs representing them. (Perceived) misevaluation of mineral content is a particularly damning practice in the eyes of the miners and damages confidence substantially.

While the issue of price is, strictly speaking, outside the focus of these systems and rather falls under the initiatives that implement them, it has become apparent during the course of fieldwork that stakeholders, and CSOs in particular, seldom make a distinction between the two. Similarly, in the case of Mutoshi, the issues Chemaf may have with communities on its titles are easily transferred to the MCP in the discourse of local stakeholders. This lack of clear differentiation makes any potential issue of whitewashing of operations as a whole, through participation in responsible sourcing initiatives, all the more relevant to these stakeholders.

Reminder: systems, initiatives, sites, titles and pilots

System refers to the purpose-designed management and/or technological tools that aim to support the responsible sourcing of cobalt.

Initiative refers to concrete responsible cobalt-sourcing programmes currently deployed on the ground, which include a system as a component.

Site refers to the dedicated ASM area (including the extraction, washing and temporary storage subareas).

Title refers to the entirety of the mining title, of which the site might only be a part.

Pilot refers to the implementation of an initiative on a site. If the initiative has been tailored to the specifics of a site, then the term 'pilot' encapsulates those changes.

Historical grievances, such as those created by the Kasulo resettlement, can take up a lot of space in discourse. Failure to address them (even if redressing these grievances is completely outside the scope of the system or even the initiative) creates shortcomings, in the perception of certain categories of stakeholders, particularly CSOs and miners. This should not come as a surprise, as for these stakeholders, with very few avenues available to seek redress, the initiatives represent a possible solution and expectation are high, which can complicate operations. Open and transparent communication and expectation management are thus key to addressing these issues.

Association with a cooperative is a precondition to the implementation of any system integrating ASM production, but is fraught with potential issues as most of these have very close relationships with PEPs. Existing mining cooperatives in the DRC make use of a two-tiered system of membership that does not grant membership benefits to members that have not contributed to the capital of the cooperative. These “members” are usually the ones undertaking the manual labour on site and the most likely to migrate from on site to another in response to local (changes in security enforcement) or global (variation of copper and cobalt prices) shifts. It is unclear what the effects of creating a cooperative with a strict “one member, one vote” policy from the bottom up would be or how existing actors would respond to its creation.

The imposition of additional demands on 2C producers, and in particular ASM producers, risks further entrenching already established actors while at the same time stifling the development of small producers with few connections, as they are unlikely to be able to adapt to these new demands. These smaller actors are at a disadvantage, as they may have neither the understanding of international demands required to swiftly adapt nor the financial capacity or connections necessary to implement the required changes. This could further concentrate the control of the ASM sector among a few already well-placed players⁽²⁰⁴⁾, some of whom may be PEPs or be connected to them.

This roll-out of initiatives, while producing desirable outcomes, might also disincentivise Congolese authorities from intervening or investing in the sector, thus leading to the subcontracting of what are implicitly state functions, such as the monitoring and development of the ASM sector.

Critically, there appears to be a significant disconnect between what ASM miners perceive as better working conditions and the demands of international standards. ASM miners are focused on day-to-day survival, and for them issues such as pay and fair determination of mineral content take centre stage. Such elements are not taken into account by current approaches, as they are driven by downstream demands. It is thus necessary to expand the scope of these approaches to incorporate key demands from the upstream actors they are supposed to support. That could be implemented within the framework of the five-step approach of the OECD Guidance.

Finally, it should be noted that, while in the public perception many opportunities for responsible cobalt sourcing exist, in practice this is far from the case. Few systems are actively implemented on the ground, and half of the systems implemented exclude ASM by design. At the time of this report's preparation, only two systems were implemented on producing sites that work with ASM, so only two or three ASM sites were operating under responsible cobalt-sourcing initiatives, a fraction of the DRC's ASM sector. It is unlikely that the supply of responsibly produced cobalt that incorporates ASM could surge in the short term, even under the most auspicious scenarios of increased downstream demand for responsible cobalt. This is due not only to the nature of the sector and of its actors, but also to the limited pool of local skilled talent required to scale up the implementation of the evaluated systems.

⁽²⁰⁴⁾ For a description of how this process unfolded in the Katangese tin, tantalum and tungsten sector, see Diemelt (2018).

6. Conclusions

Given the strategic role of batteries for the fulfilment of the EU policy objectives, ensuring that materials used in batteries are produced and sourced in a responsible and sustainable way is paramount. This report has analysed this topic from different angles, focusing first on the potential social risks, using secondary data at country level (Chapter 2) and corporate level (Chapter 3), and then exploring initiatives developed to respond to such criticalities. This was done by reviewing the existing initiatives promoted at the various steps of the supply chain (Chapter 4) and then assessing two of them using primary data collected at mining sites (Chapter 5).

The **hotspot analysis** showed which materials and countries represent the highest risk and could be potential issues of concern in the future for the sustainable and responsible supply of materials for batteries. Media, international organisations, NGOs, etc. have associated cobalt with serious human rights abuses, corruption and the use of armed forces in the extraction sites. The analysis confirmed that this material has, by far, the highest risk among those researched when taking into account global indices on governance, conflicts, social risks, environmental performance and water risk. However, other criticalities emerged from the analysis and might come to public attention in the future, for instance nickel from the Philippines and natural graphite from Mozambique. Future problems could also arise from the extraction of graphite from Tanzania, lithium from Bolivia and nickel from Indonesia. Supply from emerging countries such as Brazil, China, Russia and South Africa could be a problem from a responsible sourcing perspective. The main areas of potential impacts are biodiversity and indigenous community rights in Brazil, water risk and environmental performance in South Africa, and decent working conditions in China. In Russia, the main concern relates to conflicts and governance indicators (probably related to the war in Crimea but not necessarily linked to the mining sector, which is, however, very poorly scrutinised by NGOs, international organisations, etc.). India might also present risks, even though this country is not very relevant to the supply of battery materials to the EU. Other non-EU countries, which did not emerge as hotspots, have medium to high risk levels in some categories only, for instance water risk in Australia, conflict risk in the USA (in two indicators out of three) and governance in Argentina. The screening allowed us to identify areas for further research and in-depth investigation. Given the nature of these data (country-based indicators), the level of accuracy of this analysis is low, and territorial heterogeneity is not captured by this analysis. Another limitation is that only the mining sector is in the scope of this analysis. The other phases of the supply chain (e.g. smelting/refining, manufacturing) should also be scrutinised in order to get the complete picture.

The **analysis of company disclosures** showed the amount and quality of information that comes from sustainability reporting and could be used to perform an S-LCA. The levels of disclosures are very heterogeneous between companies and only in a few cases are commodity-specific information, project-level disclosures and third-party assurance reports available. Most of the time, data are provided at the corporate or country level. The categories of impacts that are reported most often relate to health and safety at work, diversity and gender balance issues, and activities in local communities. Given the importance and spread of sustainability reporting, having more stringent guidance on how to self-report sustainability information and provide meaningful figures would allow a more robust social impact assessment, avoiding the risk of whitewashing.

The **review of initiatives and standards** provides an overview of the heterogeneous landscape of actions undertaken by different stakeholders to address responsible and sustainable sourcing. The analysis shows the different scopes and positioning in the supply chain of the initiatives. The areas of risk that are taken into account are also different. Most of the responsible sourcing initiatives are based on the OECD risk categories, and add other aspects to be taken into account (for instance, health and safety at work and impacts on local communities are often included). Some initiatives also include environmental aspects such as biodiversity impact, or use of resources, showing that responsible sourcing can be a flexible concept going far beyond the risks mentioned in the OECD Guidance. All the initiatives include child labour as a risk category to be scrutinised in a due diligence process. However, some initiatives refer to the 'worst forms of child labour' (as recommended by the OECD) while others refer to any form of child labour. Attitudes towards ASM can also be different. Two initiatives exclude ASM from their supply chain, as it is considered to be too risky, and aim to supply only from LSM.

The systems analysed as part of the **case study** (Kasulo and Mutoshi mining sites) have shown that they are effective at implementing the changes that they are designed to implement. This is especially obvious when it comes to life-threatening health and safety issues and child labour. While the results of the analysis are overall very encouraging, it is necessary to highlight that these systems have brought forward positive change only within their scope. This means that their impact is limited to the sites where they have been

implemented and do not necessarily spill over to the titles these sites are part of. Furthermore, their impacts are limited to the risk categories they are designed to work with, risk categories that are dictated by downstream expectations and do not necessarily correspond to the demands of the miners they are designed to protect. Issues of price calculation are particularly salient and are not captured by evaluations that rigidly follow downstream responsible sourcing demands. The S-LCA methodology offers a promising avenue to expand the scope of enquiry in a structured manner.

Another key point is that these systems in their current form do not guarantee traceability, and do not seek to do so. Therefore claims can only be made regarding the characteristics of the material produced by the pilots and not of the overall supply of the operators. And while the OECD guidance does not prescribe traceability as a strict requisite to attaining sufficient upstream supply chain transparency but also accepts other systems (such as chain of custody systems or mass balance approaches, depending on the risk profile of the supply chain), the reporting and communication of operators should fully disclose the nature and limitations of their chosen approach to supply chain transparency.

In line with this finding, local civil society organizations representatives have repeatedly voiced the worry that companies' participation in the pilots could be used to whitewash their reputation as a whole in a way that does not reflect the contribution of the pilot sites to the companies overall supply, thus sweeping under the carpet the issues found in the rest of the companies' operations.

Finally, the scalability of these pilots within a short time frame, in order to respond to any increase in the demand for responsibly sourced cobalt (triggered by future legislation, for example), is an unknown factor. At present it appears that the lack of availability of skilled and dedicated local professionals with integrity might become a bottleneck to the further deployment of responsible sourcing systems and/or initiatives. Other factors that, plausibly, could be considered as bottlenecks and should be better investigated regard the cost/competitiveness disadvantages with informal ASM; the lack of land made available to ASM; the lack of LSM or other operators with similar engineering expertise willing to engage in formalization projects.

Despite the challenges noted above, the analysed systems represent a very promising avenue to reconcile the rising global need for cobalt with the development, formalisation and professionalisation of a sector that provides unmatched livelihood opportunities to hundreds of thousands of the DRC's most vulnerable citizens, who would be affected significantly by any ASM ban that would have an impact on the price they could ask for their production and thus their day-to-day lives and those of the families that depend on them. Given the positive results of the initiatives and the vulnerability of commercial systems to commodity price cycles, further support through, e.g., public funding, would facilitate the development of similar initiatives.

6.1. Outlook and next steps

This study is a first step towards the understanding and quantification of the main risks in battery supply chains, and the assessment of the impact of current initiatives aimed at improving the situation of the artisanal mining sector in the DRC. In the DRC mining sector, severe impacts have been reported by several studies in the past, but how responsible sourcing initiatives are working on the ground, and their effectiveness in achieving improvements of social conditions, have not been addressed so far, to our knowledge. This study is intended to fill this research gap, investigating the initiatives that are at a sufficient stage of implementation. As more initiatives are going to be deployed, the investigation could be replicated to increase knowledge of this issue and build recommendations for improving the effectiveness of these initiatives and strengthening the due diligence efforts of downstream companies.

From the hotspot analysis performed in this study, other criticalities emerged in terms of potential social risks. Therefore, these results indicate areas where further primary data collection and impact assessment could be addressed. In particular, countries supplying many materials to the EU (Brazil, China, Russia and South Africa) are poorly investigated in terms of social conditions in the mining sector. The analysis performed here, moreover, could be extended to further steps of the supply chain.

The review of responsible sourcing initiatives performed in this study, and focused on cobalt, could be deepened in order to systematically analyse the risk and impact categories taken into account in each scheme and compare the different coverages. This would allow the identification of a set of risks/impacts to be assessed in order to ensure the ethical sourcing of materials for batteries. Such analysis would be very useful for future policy purposes, for example to support the preparation of potential due diligence requirements in the forthcoming regulation on sustainability requirements for batteries. Moreover, it would help in establishing a common definition of responsible sourcing, defining its distinctive characteristics and differences from the concept of sustainable supply.

The hotspot analysis and the screening of sustainability reports proposed in this report could be applied to other strategic sectors and applications that contain critical raw materials (renewable energies, digital application, etc.) in order to identify potential social risks in other supply chains. Moreover, this analysis could be replicated and extended to novel materials used in innovative battery technologies, in order to provide foresight of potential social risks linked to future battery technologies.

References

- Amnesty International (2014), Profits and Loss: Mining and human rights in Katanga. Available at: <https://www.amnestyusa.org/wp-content/uploads/2017/04/afr620012013en.pdf>
- Amnesty International (2016), This is what we die for: Human rights abuses in the Democratic Republic of the Congo power the global trade in cobalt. Available at: <https://www.amnesty.org/en/documents/afr62/3183/2016/en/>.
- Anderson, K. (1998), 'Are resource-abundant economies disadvantaged?', *Australian Journal of Agricultural and Resource Economics*, Vol. 42, No 1, pp. 1–23.
- Barthel, J., Fava, J., James, K., Hardwick, A. Khan, S. (2017), UN Hotspots Analysis: An overarching methodological framework and guidance for product and sector level application, UN Environment, Economy Division, Paris.
- Bashwira, M. R., Cuvelier, J., Hilhorst, D., & Van der Haar, G. (2014). Not only a man's world: women's involvement in artisanal mining in eastern DRC. *Resources Policy*, 40, 109–116.
- Bashwira, M. R., & Cuvelier, J. (2019). Women, mining and power in southeastern Democratic Republic of Congo: The case of Kisengo. *The Extractive Industries and Society*, 6(3), 960–967.
- BBC News (2019), 'Brazil's Vale ordered to pay compensation for dam disaster', <https://www.bbc.com/news/world-latin-america-48935651>.
- Benoit-Norris, C.; Cavan, D.A.; Norris, G. (2012), Identifying Social Impacts in Product Supply Chains: Overview and Application of the Social Hotspot Database. *Sustainability*, 4, 1946–1965.
- BGR (2019), Mapping of the artisanal copper–cobalt mining sector in the provinces of Haut-Katanga and Lualaba in the Democratic Republic of the Congo, available at: https://www.bgr.bund.de/EN/Themen/Min_rohstoffe/Downloads/studie_BGR_kupfer_kobalt_kongo_2019_en.html.
- BHP (n.d.), *Sustainability Report 2018*, <https://www.bhp.com/-/media/documents/investors/annual-reports/2018/bhpsustainabilityreport2018.pdf>.
- Blengini, G. A., Nuss, P., Dewulf, J., Nita, V., Peirò, L. T., Vidal-Legaz, B., Latunussa, C., Mancini, L., Blagoeva, D., Pennington, D., Pellegrini, M., Van Maercke, A., Solar, S., Grohol, M., Ciupagea, C. (2017), 'EU methodology for critical raw materials assessment: Policy needs and proposed solutions for incremental improvements', *Resources Policy*, Vol. 53. Pages 12–19, ISSN 0301–4207, <https://doi.org/10.1016/j.resourpol.2017.05.008>
- Bloomberg (2019), 'Congo army to remove illegal miners from Glencore Site', www.bloomberg.com/news/articles/2019-07-01/congo-to-send-troops-to-remove-illegal-miners-from-glencore-site.
- Bread for All, RAID, Swiss Catholic Lenten Fund (2014), PR or Progress? Glencore's corporate responsibility in the Democratic Republic of the Congo.
- BSR (2016), OECD conformance assessment summary Better Sourcing Program.
- CASM (2007), Artisanal mining in the DRC, key issues, challenges and opportunities.
- CCCMC (2015), Chinese due diligence guidelines for responsible mineral supply chains, available at <http://www.cccmc.org.cn/docs/2015-10/20151029133501092584.pdf>
- Center for Effective Global Action (2017), Artisanal mining, livelihoods, and child labor in the cobalt supply chain of the Democratic Republic of Congo.
- Church, C., Crawford, A. (2018), *Green Conflict Minerals: The fuels of conflict in the transition to a low-carbon economy*, IISD report, <https://www.iisd.org/sites/default/files/publications/green-conflict-minerals.pdf>.
- Ciroth, A., Eisfeldt, F. (2017), PSILCA – a Product Social Impact Life Cycle Assessment database, version 1.0: Documentation 1–99.
- Cobalt Institute, CIRAF (2019), 'Introducing the Cobalt Industry Responsible Assessment Framework (CIRAF)', https://www.cobaltinstitute.org/assets/files/News/CIRAF-External-Primer_08042019_ENG.pdf.
- Congo Research Group (2017), All the President's Wealth: The Kabila family business.

- Cronje, J. (2019), 'Gemfields settles R100m Mozambican claim, denies liability', Fin24, <https://m.fin24.com/Companies/Mining/gemfields-settles-r104m-mozambican-claim-denies-liability-20190129>.
- Delve (n.d.), 'Find data', <https://delvedatabase.org/data>.
- Diemel, J. (2018), 'Mining reform, governance and the state in the Democratic Republic of the Congo: The traces "conflict-mineral" policy left behind on natural resource governance in Katanga', PhD thesis, University of Rotterdam.
- Drive Sustainability, Responsible Minerals Initiative, The Dragonfly Initiative (2018), Material Change: A study of risks and opportunities for collective action in the materials supply chains of the automotive and electronic industries, available at: <https://www.thedragonflyinitiative.com/material-change-report/>
- Eisfeldt, F. (2017), PSILCA – a Product Social Impact Life Cycle Assessment database: Documentation.
- EITI (2019), *Projet de Rapport de Cadrage ITIE-RDC 2017*
- Elavox (2019), 'Kolwezi: Les creuseurs de la carrière Mutoshi manifestent contre la sous-évaluation de leurs produits', available at <http://www.elavox.info/kolwezi-les-creuseurs-de-la-carriere-mutoshi-manifestent-contre-la-sous-evaluation-de-leurs-produits/>
- Enough (2018), *Powering Down Corruption: Tackling transparency and human rights risks from Congo's cobalt mines to global supply chains*.
- ERG (2019), *The ERG Clean Cobalt Framework: Our commitment to responsible production*, https://www.ergafrica.com/wp-content/uploads/Compressed-Cobalt-Brochure_July2019.pdf.
- Eslava, N. (2018), Successful implementation of certification and due diligence schemes and the European Union's role: Deliverable of the EU project STRADE (Strategic Dialogue on Sustainable Raw Materials for Europe).
- European Commission (n.d.), 'Inform', <http://www.inform-index.org/>.
- European Commission (2017a), Commission communication – Guidelines on non-financial reporting (methodology for reporting non-financial information) (COM (2017) 4234).
- European Commission (2017b), 'The regulation explained', <https://ec.europa.eu/trade/policy/in-focus/conflict-minerals-regulation/regulation-explained/>.
- European Commission (2018a), Commission communication – Europe on the move: Sustainable mobility for Europe: Safe, connected and clean (COM (2018) 293 final).
- European Commission (2019a), Commission communication – The European Green Deal (COM (2019) 640).
- European Commission (2019b), Commission communication – On the implementation of the strategic action plan on batteries: Building a strategic battery value chain in Europe (COM (2019) 176 final).
- Eurostat (n.d.) Comext Database, available at: <http://ec.europa.eu/eurostat/ec.europa.eu/newxtweb/mainxtnet.do>
- Faber, B., Krausey, B., Sanchez De La Sierra, R. (2017), *Artisanal mining, livelihoods, and child labor in the cobalt supply chain of the Democratic Republic of Congo*.
- Fund for Peace (2019), *Fragile States Index annual report 2019*, <https://fragilestatesindex.org/wp-content/uploads/2019/03/9511904-fragilestatesindex.pdf>.
- Gassert, F., Luck, M., Landis, M., Reig, P., Shiao, T. (2014), 'Aqueduct Global Maps 2.1: Constructing decision-relevant global water risk indicators', working paper, World Resources Institute, Washington, DC, https://files.wri.org/s3fs-public/Aqueduct_Global_Maps_2.1-Constructing_Decision-Relevant_Global_Water_Risk_Indicators_final_0.pdf.
- Gleick, P., Iceland, C. (2018), *Water, Security, and Conflict*, World Resources Institute, Washington, DC, <https://wriorg.s3.amazonaws.com/s3fs-public/water-security-conflict.pdf>.
- Glencore (2018a), *Modern Slavery Statement 2018*, <https://www.glencore.com/dam/jcr/06fa4bf0-e9b7-4a11-b372-f60f6b633388/2018-modern-slavery-statement.pdf>.
- Glencore (2018b), *Databook and GRI References 2018*, <https://www.glencore.com/dam/jcr/edb85a8-789f-404f-aa1d-28f90dd93b0f/2018-Glencore-GRI-Databook-.pdf>.

- Glencore (2018c), 'Our Approach to Sustainability', <https://www.glencore.com/sustainability/our-approach>.
- Glencore (2018d), *2018 Human Rights Report*, <https://www.glencore.com/dam:jcr/f89bbde0-e32b-4695-b2af-9ff85a7c1950/2018-Glencore-Human-Rights-Report.pdf>.
- Glencore (2019), *Responsibly sourcing the commodities for everyday life: Sustainability report 2018*.
- Global Witness (1998), *A Rough Trade: A seminal Global Witness report on the role of diamonds in funding the Angolan civil war*.
- Global Witness (2006), *Digging in corruption, fraud, abuse and exploitation in Katanga's copper and cobalt mines*.
- Global Witness (2009), *Faced with a gun, what can you do?: War and the militarisation of mining in eastern Congo*, Global Witness, London, https://cdn.globalwitness.org/archive/files/pdfs/report_en_final_0.pdf.
- Global Witness (2014), *Glencore and the gatekeeper how the world's largest commodities trader made a friend of Congo's president \$67 million richer*, Global Witness, London, <https://cdn.globalwitness.org/archive/files/library/glencore%20and%20the%20gatekeeper%20may%202014.pdf>.
- Good Shepherd Sisters (2013), *GSS Research: Violence and abuse against women, girls and children in artisanal mining communities of the DRC*.
- Guardian (2016), 'US imposes sanctions on top DRC officials after election delay', www.theguardian.com/world/2016/sep/28/us-sanctions-drc-officials-democratic-republic-congo.
- Hayes, K., & Perks, R. (2012) *Women in the artisanal and small-scale mining sector of the Democratic Republic of the Congo: High-Value Natural Resources and Peacebuilding*. London: Earthscan, 529-44.
- Heidelberg Institute for International Conflict Research (2013), *Conflict Barometer 2012*.
- IndustriALL (2018), 'DRC: IndustriALL mission finds Glencore gravely mistreating workers at cobalt mines', <http://www.industriall-union.org/drc-industriall-mission-finds-glencore-gravely-mistreating-workers-at-cobalt-mines>.
- Institute for Economics & Peace (n.d.), *Global Peace Index 2019: Briefing*, <http://visionofhumanity.org/app/uploads/2019/06/GPI-2019-Briefingweb-2.pdf>.
- Institute for Economics & Peace (2019), *Global Peace Index 2019: Measuring peace in a complex world*, Institute for Economics & Peace, Sydney, available at <http://visionofhumanity.org/reports>.
- International Co-operative Alliance (n.d.), 'Cooperative identity, values & principles', www.ica.coop/en/cooperatives/cooperative-identity.
- International Finance Corporation (2012), *Performance standards on environmental and social sustainability*, https://www.ifc.org/wps/wcm/connect/24e6bfc3-5de3-444d-be9b-226188c95454/PS_English_2012_Full-Documents.pdf?MOD=AJPERES&CVID=jkV-X6h.
- Interorganizational Committee on Guidelines and Principles (ICGP) (1995), 'Guidelines and principles for social impact assessment', *Environmental Impact Assessment Review*, Vol. 15, No 1, pp. 11-43.
- Kabamba Ngombe, L., Ngatu Nlandu, R., Nyembo Mukena, C., Kabyla Ilunga, B., Wembonyama Okitotsho, S., Kakoma Sakatolo, J. B., Danuser, B., Luboya Numbi, O. (2016). Respiratory health of artisanal miner of Lwisha in Katanga/DR Congo. *Open Access Library Journal*, 3(e3233), 1-10.
- Kaufmann, D. Kraay, A. and Mastruzzi, M. (2010), 'The Worldwide Governance Indicators: Methodology and Analytical Issues'. World Bank Policy Research Working Paper No. 5430. Available at SSRN: <https://ssrn.com/abstract=1682130> [Accessed on June 2020].
- Kemp, D., Bond, C. J., Franks, D. M., & Cote, C. (2010). Mining, water and human rights: making the connection. *Journal of Cleaner Production*, 18(15), 1553-1562.
- La Libre* (2019a), 'RDC: Nouveau drame mortel dans les mines de Kolwezi (Vidéo)', <https://afrique.lalibre.be/38234/rdc-nouveau-drame-mortel-dans-les-mines-de-kolwezi-video/>.
- La Libre* (2019b), 'Kolwezi: Escalade de la violence. Les creuseurs annoncent "la guerre"', <https://afrique.lalibre.be/38596/kolwezi-escalade-de-la-violence-les-creuseurs-annoncent-la-guerre/>.

- Liedtke, C., Baedeker, C., Kolberg, S., Lettenmeier, M. (2010), 'Resource intensity in global food chains: The Hot Spot Analysis', *British Food Journal*, Vol. 112, No 10, pp. 1138–1159.
- Maclin, B. J., Kelly, J. T., Perks, R., Vinck, P., & Pham, P. (2017). Moving to the mines: Motivations of men and women for migration to artisanal and small-scale mining sites in Eastern Democratic Republic of the Congo. *Resources Policy*, 51, 115–122.
- Mancini, L., & Sala, S. (2018). Social impact assessment in the mining sector: Review and comparison of indicators frameworks. *Resources Policy*, 57, 98–111.
- Mancini, L., Eynard, U., Elsfeldt, F., Ciroth, A., Blengini, G., Pennington D. (2018), *Social assessment of raw materials supply chains: A life-cycle-based analysis*, EUR 29632 EN, Publications Office of the European Union, Luxembourg.
- Mancini, L., Vidal-Legaz, B., Vizzarri, M., Wittmer, D., Grassi, G., Pennington, D. W. (2019), *Mapping the role of raw materials in sustainable development goals*, Luxembourg, Publications Office of the European Union.
- Marin-Ferrer, M., Vernaccini, L. and Poljansek, K. (2017), *Index for Risk Management INFORM: Concept and Methodology Report — Version 2017*, EUR 28655 EN, doi:10.2760/094023
- Nkulu Banza, C. L. N., Nawrot, T. S., Haufroid, V., Decrée, S., De Putter, T., Smolders, E., Ilunga Kabyla, B., Numbi Luboya, O., Ndala Llunga, A., Mwanza Mutombo, A., Nemery, B. (2009). High human exposure to cobalt and other metals in Katanga, a mining area of the Democratic Republic of Congo. *Environmental research*, 109(6), 745–752.
- NRGI (2017) 2017 Resource Governance Index.
- OECD (2016), *OECD due diligence guidance for responsible supply chains of minerals from conflict-affected and high-risk areas*. Third edition, OECD Publishing, Paris.
- OECD (2017), *Practical actions for companies to identify and address the worst forms of child labour in mineral supply chains*. Available at: <http://mneguidelines.oecd.org/Practical-actions-for-worst-forms-of-child-labour-mining-sector.pdf>.
- OECD (2018), *Alignment Assessment of Industry Programmes with the OECD Minerals Guidance*, available at: <https://mneguidelines.oecd.org/Alignment-assessment-of-industry-programmes-with-the-OECD-minerals-guidance.pdf>.
- OECD (2019), *Interconnected Supply Chains: A comprehensive look at due diligence challenges and opportunities sourcing cobalt and copper from the Democratic Republic of the Congo*, available at: <https://mneguidelines.oecd.org/interconnected-supply-chains-a-comprehensive-look-at-due-diligence-challenges-and-opportunities-sourcing-cobalt-and-copper-from-the-drc.htm>.
- Öko-Institut (2011), *Social impacts of artisanal cobalt mining in Katanga, Democratic Republic of Congo*.
- ONG Espoir (2019a), *Soulèvement des creuseurs a Fungurume, des personnes blessées et perte en vie humaine par les forces de l'ordre*.
- ONG Espoir (2019b), *Des morts dans les événements de Kasulo à Kolwezi*.
- Orocobre (2018), *2018 Sustainability Report: Salar de Olaroz Lithium Facility*, <https://www.orocobre.com/wp/?mdocs-file=5506>.
- Pact (2010), *Promines Study Artisanal Mining in the DRC*.
- Pelletier, N., Ustaoglu, E., Benoit, C., Norris, G., Rosenbaum, E., Vasta, A., Sala, S. (2018), 'Social sustainability in trade and development policy', *International Journal of Life Cycle Assessment*, Vol 23, pp. 629–639, <https://doi.org/10.1007/s11367-016-1059-z>.
- PRè Sustainability (2016), *Handbook for product social impact assessment*, PRè, Amersfoort.
- Radio Okapi (2019a), 'Kolwezi: Découverte de 13 corps des creuseurs artisanaux des minerais coincés sous terre', www.radiookapi.net/2019/04/02/actualite/securite/kolwezi-decouverte-de-13-corps-des-creuseurs-artisanaux-des-minerais.
- Radio Okapi (2019b), 'Kolwezi: 3 enfants tués lors d'un éboulement dans une carrière minière', www.radiookapi.net/2016/09/14/actualite/societe/kolwezi-3-enfants-tues-lors-dun-eboulement-dans-une-carriere-miniere.

RCS Global (2017), *The battery revolution: Balancing progress with supply chain risks*, <https://www.rcsglobal.com/wp-content/uploads/rcs/pdfs/RCS-Global%20The-Battery-Revolution.pdf>.

Resource matters (2019) Ni vus ni connus. Risques de corruption peu ou pas gérés dans la chaîne d'approvisionnement du cobalt, <https://resourcematters.org/wp-content/uploads/2019/04/ResourceMatters-NiVusNiConnus-RisquesCobaltCorruption-Avr-2019.pdf>

Reuters (2019), 'Why the cobalt market needs Congo's "illegal" miners', www.reuters.com/article/us-congo-cobalt-at-home/why-the-cobalt-market-needs-congos-illegal-miners-andy-home-idUSKCN1U71VS.

RFI (2019), 'RDC: Les ONG alertent sur les agissements des militaires sur un site minier', www.rfi.fr/afrique/20190925-rdc-repression-militaire-kolwezi-mines.

Rohn, H., Lukas, M., Biengen, K., Ansorge, J., Liedtke, C. (2014), 'The hot spot analysis: Utilization as customized management tool towards sustainable value chains of companies in the food sector', *Agris On-line Papers in Economics and Informatics*, 6, pp. 133–143.

Roskill Information Service (2018), *Cobalt Market Outlook to 2028*, 12th Edition.

Rustad, S. A., Gudrun, Ø., Ragnhild, N. (2016) Artisanal mining, conflict, and sexual violence in Eastern DRC, *The Extractive Industries and Society* 3(2). 475–484.

Sachs, J. D., Warner, A. M. (2001), 'The curse of natural resources', *European Economic Review*, Vol. 45, No 4, pp. 827–838.

Solomi (La Synergie des Organisations de la Société Civile du Lualaba (Euvrant dans le Secteur des Ressources Naturelles) (2018), *La délocalisation des communautés locales: Quel impact sur les droits humains? Rapport d'enquête sur les délocalisations et le respect des droits humains*.

SOMO (2016), *Cobalt Blues: Environmental pollution and human rights violations in Katanga's copper and cobalt mines*.

SQM (2019), *2018 Sustainability Report*, <https://www.sqm.com/wp-content/uploads/2019/05/SQM-SUSTAINABILITY-REPORT-2018.pdf>.

Strade (2018), *Successful implementation of certification and due diligence schemes and the European Union's role*.

Swedwatch (2007), *Powering the Mobile World: Cobalt production for batteries in the DR Congo and Zambia*.

Temper, L., del Bene, D., Martinez-Alier, J. (2015), 'Mapping the frontiers and front lines of global environmental justice: The EJAtlas', *Journal of Political Ecology*, Vol. 22, No 1, <https://journals.ua.ir.arizona.edu/index.php/JPE/article/view/21108>.

Trafigura (n.d.), 'Responsible Sourcing', www.trafigura.com/responsibility/responsible-sourcing/.

Tsiropoulos, I., Tarvydas, D., Lebedeva, N. (2018), *Li-ion batteries for mobility and stationary storage applications: Scenarios for costs and market growth*, EUR 29440 EN, Publications Office of the European Union, Luxembourg, doi:10.2760/87175, JRC113360.

Tsurukawa, N., Prakash, S., Manhart, A. (2011), *Social impacts of artisanal cobalt mining in Katanga, Democratic Republic of Congo*, Öko-Institut eV, Freiburg.

Ullmann's Encyclopedia of Industrial Chemistry (2012), *Manganese and manganese alloys*

Ullmann, F. (1985). *Manganese and manganese alloys*. Encyclopedia of Industrial Chemistry, 16.

Umicore (2019), *Sustainable Procurement Framework for Cobalt*, <https://www.umicore.com/storage/main/sustainablecobaltsupplybrochurefinal.pdf>.

UN Comtrade Database (n.d.), available at: <https://comtrade.un.org/>.

UN Sustainable Development Goals: 17 Goals to Transform Our World. Available online: <http://www.un.org/sustainabledevelopment/>

UNEP/SETAC Life Cycle Initiative (2009), *Guidelines for social life cycle assessment of products*.

UNEP/SETAC Life Cycle Initiative (2013), *The methodological sheets for subcategories in social life cycle assessment (S-LCA)*.

- U.S. Congress (2010) Dodd-Frank Wall Street Reform and Consumer Protection Act. Section 1502 Conflict minerals.
- U.S. Geological Survey (2018), *Advance data release of the 2016 annual tables*, https://prd-wret.s3-us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/atoms/files/myb1-2016-cobal-adv_0.xlsx.
- U.S. Geological Survey (2019), *Mineral Commodity Summaries*, <https://www.usgs.gov/centers/nrmc/mineral-commodity-summaries>
- Vale (n.d.), *Continuing our sustainable way for the next decade*, <http://www.vale.com/indonesia/EN/aboutvale/sustainability/Pdfs/2018-Sustainability-Report-PT-Vale-Indonesia-Tbk.pdf>.
- van der Ploeg F. (2011), 'Natural Resources: Curse or blessing?', *Journal of Economic Literature*, Vol. 49, No 2, pp. 366–420, available at <http://www.jstor.org/stable/23071620>.
- von der Leyen, U. (2019), A Union that strives for more: My agenda for Europe – political guidelines for the next European Commission 2019–2024.
- WEF (2019), A vision for a sustainable battery value chain in 2030: Unlocking the full potential to power sustainable development and climate change mitigation, World Economic Forum, Cologny/Geneva.
- Wendling, Z. A., Emerson, J. W., de Sherbinin, A., Esty, D. C., et al. (2020). 2020 Environmental Performance Index. New Haven, CT: Yale Center for Environmental Law & Policy. epl.yale.edu
- World Bank (2008), Democratic Republic of Congo – Growth with governance in the mining sector.
- World Mining Data (2019), Commodity Trade Statistics Database, available at <https://www.world-mining-data.info/>
- World Resources Institute (2019) Water Risk Atlas (Aqueduct 3.0)

Abbreviations

ZC	cobalt and copper
3TG	tin, tungsten, tantalum and gold
ANR	Agence nationale de renseignement
ASM	artisanal and small-scale mining
BGI	Better Gold Initiative
BRICS	Brazil, Russia, India, China, South Africa
CAHRAs	conflict-affected and high-risk areas
CAP	corrective action plan
CCCMC	China Chamber of Commerce of Metals, Minerals & Chemicals Importers and Exporters
CCCMC Guidance	CCCMC due diligence guidelines for responsible mineral supply chains
CDM	Congo Dongfang International Mining
CIRAF	Cobalt Industry Responsible Assessment Framework
Comiakol	Coopérative Minière Artisanale de Kolwezi
Comiku	Coopérative Minière Kupanga
CSO	civil society organisation
Demiap	Direction Militaire des Activités Anti-Patrie
DRC	Democratic Republic of the Congo
EITI	Extractive Industry Transparency Initiative
EJ Atlas	Environmental Justice Atlas
EPI	Environmental Performance Index
ERG	Eurasian Resources Group
FARDC	DRC Army (Forces Armées de la RDC)
Gécamines	Générale des Carrières et des Mines
GPI	Global Peace Index
GR	Republican Guard (<i>Garde Républicaine</i>)
GRI	Global Reporting Initiative
ICoC	International Code of Conduct for Security Providers
IFC	International Finance Corporation
ILO	International Labour Organization
Inform	Index for Risk Management
KPCS	Kimberley Process Certification Scheme
LSM	large-scale mining
LTIFR	lost-time injury frequency rate
MCP	Mutoshi Cobalt Pilot
NGO	non-governmental organisation
OECD	Organisation for Economic Co-operation and Development
OECD Guidance	OECD due diligence guidance for responsible supply chains of minerals from conflict-affected and high-risk areas

OHS	occupational health and safety
PEP	politically exposed person
PMH	<i>Police des Mines et Hydrocarbures</i>
PPE	personal protective equipment
PS	Performance Standards on Environmental and Social Sustainability
PSILCA	Product Social Impact Life Cycle Assessment
RGI	Resource Governance Index
RMI	Responsible Minerals Initiative
S-LCA	social life-cycle assessment
Saemape	Service d'Appui à l'Exploitation Minière Artisanale et à Petite Échelle
SDG	Sustainable Development Goal
SOE	state-owned enterprise
SOMO	Centre for Research on Multinational Corporations
TRIFR	total recordable injury frequency rate
VPs	Voluntary Principles on Security and Human Rights
WGI	Worldwide Governance Indicator
WHS	World Heritage Site
WRI	Water Risk Index
ZEA	ASM mining title (zone d'exploitation artisanale)

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7. Annexes

7.1. Annex 1. Methodological notes on the hotspot analysis

Data sources and assumptions for the calculation of EU sourcing

In order to calculate the indicator 'EU sourcing' used in the hotspot analyses, material production of EU Member States and imports are taken into account. Trade statistics (usually Eurostat Comext and UN Comtrade) track the import and export of various materials and semi-finished products, which contain various amounts of materials. In Table 20 we report the data sources used to calculate EU sourcing, the related trade code and any assumptions made on the material content contained in the traded goods.

Table 20 Metadata related to material supply figures

Material	Sources	Trade codes and assumptions
Cobalt	Eurostat Comext database; Roskill Information Services, Cobalt: Market Outlook to 2018, 12th Edition; experts opinion	CN 2605 000 assuming 10 % cobalt content; CN 81052000 assuming 20 % cobalt if value EUR 10/t; 60 % cobalt if EUR 10–20/t
Lithium	World Mining Data (2012–2016)	CN 253090 assuming 46.5 % lithium content
Manganese	Commodity Trade Statistics Database; Ullmann's Encyclopedia of Industrial Chemistry (2012), Manganese and manganese alloys	2602 0000 manganese ores and concentrates, including ferruginous manganese ores and concentrates with a manganese content of 20 % calculated on the dry weight
Natural graphite	World Mining Data (2012–2016); Comext database	25041000 natural graphite in powder or in flakes; 25049000 natural graphite (excluding in powder or in flakes) assuming 95 % of carbon
Nickel	UN Commodity Trade Statistics Database	HS2604 nickel ores and concentrates, assuming 20 % nickel content

Child labour and fair salary risk assessment

Risk levels for two indicators used in the hotspot analysis, child labour and fair salary, have been retrieved from PSILCA. PSILCA is a repository of data for S-LCA developed by GreenDelta GmbH. It provides information on social aspects of products over their life cycles⁽²⁰⁹⁾. The risk levels for the categories child labour and fair salary have been retrieved from this database, adapting the PSILCA risk levels (five levels, from no risk to very high risk) into the four-level framework used in this hotspot analysis.

In the case of child labour, the data source is the World Bank, which provides data on children in employment, considering the ages 7–14. PSILCA provides six risk levels (from no risk to very high), which have been converted into the four-level scheme used in this analysis, as shown in Table 21.

Table 21 Risk assessment scheme used for the child labour category

Indicator	Unit	Indicator value (y: % of children in employment)	PSILCA risk level	Risk assessment used in this report
Children in employment	% of all children aged 7–14	0	No risk	Low risk
		$0 < y < 2.5$	Very low risk	
		$2.5 \leq y < 5$	Low risk	
		$5 \leq y < 10$	Medium risk	Medium risk
		$10 \leq y < 20$	High risk	High risk
		$20 \leq y$	Very high risk	Very high risk
		—	No data	—

⁽²⁰⁹⁾ Eisfeldt (2017)

In PSICLA, 'fair salary' is not a single indicator but is based on the combination of three indicators:

1. *living wage, per month,*
2. *minimum wage, per month,*
3. *sector average wage, per month*

The data sources for these indicators are WageIndicator (for the living and minimum wages) and ILOStat for the sector average wage. The risk level used for the category fair salary corresponds to the average of risk levels assigned to each indicator, according to the risk assessment scheme shown in Table 20.

Table 22 Risk assessment scheme for the fair salary category

Indicator	Unit	Indicator value (y: living wage)	PSILCA risk level	Risk assessment used in this report
Living wage, per month	USD	$y < 100$	Very low risk	Low risk
		$100 \leq y < 200$	Low risk	
		$200 \leq y < 500$	Medium risk	Medium risk
		$500 \leq y \leq 1\,000$	High risk	High risk
		$1\,000 \leq y$	Very high risk	Very high risk
Minimum wage, per month (x = living wage/minimum wage)	USD	$y > 300$ AND $x < 0.5$	Very low risk	Low risk
		$y > 300$ AND $0.5 \leq x < 0.9$	Low risk	
		$(y \leq 300$ AND $0.5 \leq x \leq 0.9)$ OR $(y > 300$ AND $0.9 \leq x < 0.3)$	Medium risk	Medium risk
		$(y \leq 300$ AND $0.9 \leq x \leq 1.3)$ OR $(y > 300$ AND $1.3 \leq x < 1.8)$	High risk	High risk
		$(y \leq 300$ AND $1.3 \leq x \leq 1.8)$ OR $(x \geq 1.8)$	Very high risk	Very high risk
Sector average wage, per month	USD	$2.5 \leq y$	Very low risk	Low risk
		$2 \leq y < 2.5$	Low risk	
		$1.5 \leq y < 2$	Medium risk	Medium risk
		$1 \leq y < 1.5$	High risk	High risk
		$0 < y < 1$	Very high risk	Very high risk

7.2. Annex 2. Company-based data used in Chapter 3

This annex presents the detailed information found in sustainability reports published by mining companies producing materials for batteries. The focus is on data related to social aspects.

Cobalt

Glencore

The main producer of cobalt is Glencore, one of the world's largest natural resource companies, which operates in the DRC. It is the world's largest cobalt-mining company, achieving total production of 27 400 tonnes in 2017 ⁽²⁰⁶⁾.

Glencore produces cobalt mainly as a by-product of copper mining in the DRC, but also as a by-product of nickel mining in Australia and Canada. It is also one of the largest recyclers and processors of cobalt-bearing materials, such as used batteries.

The company directly employs 83 679 people around the world, with a total of 158 000 including contractors.

The company publishes yearly sustainability reports. These reports present quantitative data on the main strategic priorities for the year of publication and 4 years before, in order to show the trend. Other data are available only for the year of publication and 1 or 2 years before. Table 23 shows the key performance indicators used by the company to monitor sustainability in the copper production sites, which also produce cobalt as a by-product. They include 19 sites around the world, including the Katanga site in the DRC. The same indicators are also measured for the other commodities produced by Glencore (e.g. coal, ferroalloys, nickel, zinc and oil) and at corporate level.

Table 23 Data reported by Glencore in the sustainability report 2018 related to copper production (selection)

Indicator	2018	2017	2016
Fatalities at managed operations	4	1	13
Lost time injury frequency rate (per million hours worked)	0.38	0.38	0.71
Total recordable injury frequency rate (per million hours worked)	2.87	2.34	2.89
New occupational disease cases	7	20	53
Water withdrawn (million m ³)	349	372	350
Total energy use (petajoules)	43	43	42
Community investment spend (million USD)	38.8	37.5	32.2
Number of employees and contractors	50 256	55 760	44 473
Percentage of female employees	8	8	8

The data reported above, while allowing for a temporal comparison and tracking of progresses, have some shortcomings in terms of understanding and assessment of impacts, for instance the following.

1. The severity of injuries and occupational diseases is not specified.
2. Data on water usage are not put into the context of data on local water stress, so they are barely usable to assess impacts.
3. The sources of energy used (e.g. proportion renewable) are not specified.
4. The investment in local communities is not further specified. Even though the report describes some financed activities for local communities in various countries where it operates, the proportion of investment for each activity is not disclosed.

⁽²⁰⁶⁾ Glencore (2019).

Additional insights are provided by Glencore through the 'scorecard', which examines key value flows that assets create for four principal stakeholder groups: employees, suppliers, communities and government (see Table 24).

Table 24 Glencore's scorecard with the key value flows that assets create for four principal stakeholder groups

Stakeholder group	Value flows	2018 results
Employees	Wages and benefits	96 % of workforce is local to the country where we operate
Suppliers and contractors	Procuring goods and services Skills and enterprise development	74 % of global procurement spend is with suppliers and contractors local to the countries where we operate More than 85 000 people benefited from enterprise development and economic diversification investments
Local communities	Community development Use of shared public use infrastructure Skills and enterprise development	USD 95 million spent on programmes supporting local community development, including about USD 17 million on enterprise development and economic diversification of local entrepreneurs Around 2.4 million people living near to assets have benefited from the community investment activities, including environmental initiatives, healthcare facilities, education programmes and enterprise development USD 5.3 million spent on infrastructure for water processing and distribution USD 3.9 million spent building or maintaining over 134 kilometres of roads
Local and national government	Taxes and royalties Shared public-use infrastructure	USD 5.7 billion paid to host governments in taxes and royalties In total nearly USD 20 million spent on public infrastructure such as water, sewage and power networks and roads USD 5.3 million spent on infrastructure for water processing and distribution USD 3.9 million spent building or maintaining over 134 kilometres of roads

Payments to governments

The company also discloses information on the annual payments to governments, including the information required by the EU Non-financial Reporting Directive, and details payments by country, project and recipient (Table 25). The amount paid to the DRC in 2018 was USD 1 063 million. The amount of payments, however, is not set in relation to earnings or other costs.

Table 25 Glencore payments to governments (top five), excluding value added tax

Country	Million USD
Australia	2 193
Democratic Republic of the Congo	1 063
Kazakhstan	438
South Africa	357
Canada	327

Note: Does not include total net refunds from governments on value added tax, goods and sales tax, and sales tax amounting to USD 1 559 million. Taxes and royalty payments for Equatorial Guinea amounting to USD 26 million are now included. Does not include income taxes paid in Colombia, Peru and Chile, relating to Glencore's proportionate ownership interest in joint ventures (Cerrejón, Antamina and Collahuasi), amounting to a total of USD 725 million.

Diversity is also part of the main corporate targets: during 2018, the company developed guiding principles to improve gender balance, encourage and support diversity, and prevent discrimination. Group-wide, 12 961 women, 15 % of the employees (2017: 12 037, 14 %) were employed.

Other data can be collected from the following reports published in 2018:

1. *Modern Slavery Statement 2018* ⁽²⁰⁷⁾,
2. *Databook and GRI References 2018* ⁽²⁰⁸⁾,
3. *'Our Approach to Sustainability'* ⁽²⁰⁹⁾,
4. *2018 Human Rights Report* ⁽²¹⁰⁾.

In its *Modern Slavery Statement 2018* Glencore reports its commitment to prevent modern slavery and human trafficking in its operation and supply chain. Data on the activities in progress in 2018 are listed and described, e.g. supply chain due diligence, human rights training and human rights incidents. The method of reporting them was updated as well as the data.

The supply chain due diligence throughout the entire business is built in accordance with the requirements of Glencore's code of conduct and is aligned with the UN Guiding Principles and OECD Guidance.

Information regarding the DRC

Particular attention is given to ASM, implementing activities to discourage the prevalent ASM of cobalt in the DRC. The company claims to develop due diligence processes to ensure ASM material does not enter in the supply chain.

In the DRC, the company also claims to have provided the local communities with the following activities in 2018:

school holiday camps for over 9 000 children, providing a meal each day and teaching them about children's rights, the importance of education and the risks associated with artisanal mining;

support to over 140 agricultural cooperatives for the development of small sustainable business (such as supplying vegetables to their Katanga mine site canteen and preparing meals for a local mining company);

1. a malaria prevention programme based on indoor residual spraying of local homes, raising awareness of malaria prevention strategies with employees and local communities, maintenance of the drainage systems in local communities and treating mosquito larvae;
2. actions to prevent HIV/AIDS, which include voluntary counselling and testing for both employees and local communities, education on HIV/AIDS (and tuberculosis) prevention and management, building awareness of mother-to-child transmission and an HIV/AIDS workplace awareness programme.

Concerning engagement in responsible sourcing initiatives, Glencore is a core taskforce member for the Cobalt Institute's development of CIRAF for the production of cobalt (see Section 4.2.1).

⁽²⁰⁷⁾ Glencore (2018a).

⁽²⁰⁸⁾ Glencore (2018b).

⁽²⁰⁹⁾ Glencore (2018c).

⁽²¹⁰⁾ Glencore (2018d).

In the sustainability report, the company declares that 'sanctions imposed on Dan Gertler, Katanga's deliberations with Gecamines over the required recapitalisation of its main operating subsidiary, the introduction of a new mining code and the appearance of excess levels of uranium in the cobalt hydroxide produced at Katanga.' (p. 6)

'sanctions imposed on Dan Gertler, Katanga's deliberations with Gecamines over the required recapitalisation of its main operating subsidiary, the introduction of a new mining code and the appearance of excess levels of uranium in the cobalt hydroxide produced at Katanga.'

On 22 February 2018, IndustriALL⁽²¹¹⁾, a global union federation, issued a public statement accusing Glencore of workers' rights abuses at Mutanda Mining and Kamoto Copper Company, its assets in the DRC. Allegations included assertions that the assets provide insufficient drinking water, low-quality food and limited healthcare for workers and their families, and that wages are low. When IndustriALL visited the DRC in February 2018 to meet with local unions at Glencore mines, the company denied access to its operations, and security forces attempted to break up a union meeting in a church and arrest the organisers.

Natural graphite

For graphite, we have considered the main producing company in each country where this material is produced: China Carbon Graphite Group (China), Graphite India Ltd (India) and South Star Mining Corp (Brazil). The level of awareness of sustainability aspects is lower than among the other material producers. In fact none of these three main producers has published a sustainability report.

Little information on social aspects can be found on Graphite India Ltd's website⁽²¹²⁾. It claims that 'all workmen are provided with nose masks, safety shoes, hand gloves, dress and helmets among other equipment. Regular safety audits are carried out and actions are taken. All the workmen who work at height are provided with belts and they work under supervision of engineer. Signboards indicate the necessity of safety devices and are displayed all over the plant. Fire extinguishers are installed/kept at vulnerable location. Regular training by qualified trainers are organized for fire fighting. The pressure vessel/storage tanks/life tackles are regularly checked for load bearing capacities.'

Quantitative data on targets and social aspects are not published.

Lithium

Argentina, Australia and Chile are the main lithium-producing countries. The South American Lithium Belt, a 500-miles-by-200-miles north-south strip centred on the junction of Argentina, Bolivia and Chile, contains more than 75 % of the world's lithium reserves.

This section takes into account some examples of companies producing lithium in Argentina, Australia and Chile: Talison Lithium Inc. in Australia, SQM and Albemarle Corporation in Chile, and Orocobre in Argentina.

Australia currently has eight companies listed on the Australian Securities Exchange with lithium deposits and was the world's leading producing country in 2019, according to World Mining Data.

Talison Lithium Inc

Talison Lithium Inc. is a world-leading lithium mineral producer. Its production from its Australian operation fulfils roughly a third of the world's lithium demand, and supplies 75 % of Chinese demand. Its Greenbushes lithium operation has been producing lithium for over 25 years. The mine is located 250 km south of Fremantle – a major container shipping port – and 90 km southeast of the Port of Bunbury, a major bulk handling port in Western Australia. The company website⁽²¹³⁾ includes pages on social sustainability, i.e. on 'Health and Safety' and on 'Community'. These pages describe the company values and some programmes provided to workers (e.g. training, counselling and advice on physical and mental well-being) and to the local community (support to the local school, event organisation, open days, etc.). However, no quantitative data on specific targets or performances are reported.

⁽²¹¹⁾ IndustriALL (2018).

⁽²¹²⁾ <https://www.graphiteindia.com/>

⁽²¹³⁾ <https://www.talisonlithium.com/sustainability-overview>.

SQM

Concerning Chilean companies, SQM ⁽²¹⁴⁾ produces lithium carbonate in the Salar del Carmen plant, close to Antofagasta, Chile, from solutions with high lithium concentrations extracted from the Salar de Atacama. It produces lithium hydroxide from lithium carbonate. The company published a sustainability report in 2019 (reporting for the year 2018 ⁽²¹⁵⁾), in line with the GRI standard. Similar reports have been published since 2011.

Jobs and working conditions

SQM provides an annual average of 11 721 jobs in Chile and around the world, including company personnel and contractors. The company has 5 214 direct workers, 4 937 of them based in Chile, while 277 are located abroad. The monthly average number of contractors was 6 507 in 2018. A total of 4 274 employees (87 %) work in the Tarapacá and Antofagasta regions, while 594 workers (12%) are based in the Metropolitan Region. Senior managers or executives are local employees who live in the regions where the main production centres and offices are located. Thus, 75 % of the executives come from and work in the Tarapacá and Antofagasta regions, while 100 % of the executives at the Santiago office are from the Metropolitan Region.

Concerning the type of contract, the company claims that 96 % of all employees (in Chile and abroad) have open-term contracts and 4 % are employed for a fixed term.

SQM direct workers receive a certain number of benefits. Some of them are mandatory under national law, while others are additional benefits provided by the company, such as the following:

1. national holiday and Christmas bonuses,
2. special bonuses for education, funeral assistance, marriage and births,
3. special leave for bereavement, marriage or moving and to have mammograms or prostate exams,
4. life insurance for each employee, which covers natural or accidental death and disability,
5. supplementary health insurance,
6. catastrophic health insurance,
7. dental insurance,
8. termination benefits in the event of employee resignation, with varying benefits based on position,
9. university scholarships for children of employees who demonstrate academic excellence,
10. university and graduate-level scholarships for outstanding employees.

According to the report, salaries are determined for each position based on several factors such as education, experience and job responsibilities. The salaries are reviewed yearly by considering these factors and comparable industries. No data are reported on salaries and it is not possible to compare them with a local living wage, but it seems that this topic receives much consideration.

The company has 20 unions representing 65 % of all employees, primarily at its main production centres including Antofagasta. Over 66 % employees in Chile are covered by a collective bargaining agreement.

Complaint channel

SQM developed a complaint channel available to all SQM employees around the world. If a worker wants to report an abuse, a corruption case can be reported through a website. The information given through the website is reviewed and handled by an ethics and compliance department before continuing through regular channels and procedures established in the internal investigation procedures.

The report specifies the types of complaint, 23 % being for violation of internal policies, 19 % harassment, 14 % corruption, etc. No complaints about discrimination or human rights abuses have been registered.

⁽²¹⁴⁾ <https://www.sqm.com/en/sostenibilidad/reporte-de-sostenibilidad/>.

⁽²¹⁵⁾ SQM (2019).

Occupational safety

The report describes progress on several social topics, including goals and few numerical targets in the health and safety area (Table 26).

Quantitative information is provided about types of contract (fixed term and open ended) per gender, training given for different employee categories and genders, accident type and lost-time injury frequency rate (LTIFR) for direct employees and contractors.

Table 26 SQM targets on occupational safety

Target 2018	Achievement	Target 2019
Zero accident goal Reference goal of attaining an LTIFR less than or equal to 1.22	Reduced LTIFR by 62%, from 1.28 in 2017 to 0.49 in 2018.	Reference goal: LTIFR less than or equal to 1 Reference goal: accident rate (LTIFR + NLTIR) of 4.24

Gender balance

Women represent 15.8 % of SQM employees in Chile, and initiatives to encourage women in its workforce were undertaken, for instance 'the participation in a working group in Santiago organized by the ministries of mining and women and gender equity, which culminated with the signing of the "Ten Commandments of the Mining Industry for Incorporating Women and Balancing Work, Family and Personal Life"' and 'the organization of campaigns to raise awareness among human resource staff regarding gender equity and workplace and sexual harassment'.

Community relations

The report dedicates a large section to the community relations and engagement, describing initiatives in training, scholarships, sports, etc. For instance, in 2018 a maths assistance programme interested more than 1 700 students. Commitments and achievements in the area of sustainable development are also described, but the amount invested in community relations and local development is not disclosed.

Albemarle Corporation

The Albemarle Corporation is a global specialty chemical supplier (bromine, catalysts, lithium derivatives, etc.), with headquarters in North Carolina (USA), operating in various countries in the world. It is an industry leader in lithium and lithium derivatives, one of the highest growth markets in the specialty chemicals industry.

It has a website dedicated to sustainability aspects and regularly publishes a sustainability report, since 2009 ⁽²¹⁶⁾. Unlike the reports published in 2009–2016, those published in the last 3 years (2017, 2018, 2019) are not compliant with the GRI standard ⁽²¹⁷⁾.

The company has three independent primary lithium resources in operation:

1. Salar de Atacama (Chile), where Albemarle has operated since the 1980s,
2. Silver Peak (Nevada, USA), where the company has operated in an additional brine-based plant since the 1960s,
3. Greenbushes, Western Australia, where lithium is extracted from spodumene resources.

The lithium sales registered in 2018 were USD 1.23 billion, representing 36.4 % of the whole corporate business.

Quantitative data on several topics are reported in the sustainability report, such as the lowest salary paid per location and compared with minimum wage. Only some of them are disaggregated by country and/or

⁽²¹⁶⁾ Available at <https://www.albemarle.com/sustainability/sustainability-reports/resources>

⁽²¹⁷⁾ <https://database.globalreporting.org/organizations/21527/>.

operation, while others are disaggregated by region (Latin America, Asia, Europe, etc.) or provided at corporation level.

For instance, data on injuries are disclosed at global level (Table 27), while data on training provided to employees are specified at plant level (

Table 28).

Table 27 Albemarle occupational health and safety indicators

Indicator	2018	2017	2016	2015	2014
Injury rate	0.54	0.56	0.53	0.57	0.33
Occupational diseases	0	0	0	0	0
Lost days	524	747	258	551	175
Work-related fatalities	0	0	0	0	0
Contractor rate	0.69	0.50	0.00	0.72	0.54

Table 28 Albemarle data on training

Location	Name	Average hours of training/year/employee
Salar de Atacama (Chile)	El Salar	24.6
Nevada	Silver Peak	20.0

Orocobre

Orocobre is a mineral resource company with its headquarters in Brisbane, Australia. It produces lithium carbonates in the Olaroz Lithium Facility, located in Jujuy Province in northern Argentina.

The company published a sustainability report in 2018, which is available on its website ⁽²¹⁸⁾. The report was developed in accordance with the GRI standard. The year 2018 was the second year of full commercial production and the second year of sustainability reporting for the company.

The report presents clear sustainability goals aligned with the UN SDG framework. They are measured with indicators for the years of production 2018 and 2017 (and 2016 in some cases).

Workforce composition and remuneration

Table 29 shows data on the composition of the workforce and its evolution in 2018 from the Orocobre sustainability report. The total number of employees had increased from 251 to 309, and the employees were mainly local (45 %), male (85 %) and in the 30 to 50 age group (62 %).

⁽²¹⁸⁾ Orocobre (2018).

Table 29 Data on workforce composition in Orocobre

Local employment	Share
Local	45 %
Provincial	28 %
National	25 %
International	2 %
Gender diversity	
Male	85 %
Female	15 %
Age diversity	
< 30	31 %
30 – 50	62 %
≥ 50	7%

Source: Orocobre (2018)

Occupational safety

Orocobre fosters a 'zero harm' approach when it comes to the safety of the employees and project contractors. The company claims to be strongly committed to reduce workplace risks and incidents, and consistently review its management and reporting systems. Example of data available are reported in Table 30.

Table 30 Orocobre data disclosures on health and safety

Health and safety indicators	2017	2018
Contractors		
LTIFR	3.5	1.7
TRIFR	3.5	3.5
Employees		
LTIFR	3.9	3.0
TRIFR	3.9	3.3

LTIFR, lost time injury frequency rate; TRIFR, total recordable injury frequency rate.

Moreover, an in-depth safety audit was conducted by DuPont in January 2018, which evaluated safety performance using the DuPont™ Bradley Curve™. This has provided a critical baseline and tool to objectively benchmark the journey to world-class safety performance.

Government payment

Other data disclosed concern the Argentinian government payment in royalties and taxes, as shown in Table 31.

Table 31 Orocobre payments to Argentinian government and other public authorities

Royalty and other government payments	USD (thousands)
Provincial royalty	1 641
Other provincial and municipal taxes	133
Other national taxes	850
Employment taxes paid by SDJ	1 487
Total paid by SDJ	4 111
Provincial withholding tax to local business	583
National withholding tax on salaries	550
National withholding tax to local business	5 265
Total withheld by SDJ	6 399

Local communities

The company claims to have aligned its community investment strategy to the UN SDGs and targets. The report presents some local economic development and capacity-building initiatives, such as the Community Microcredits Program, Education Plan and Artisan Development Project.

Manganese

South Africa is the world's largest producer of manganese and in 2018 its output of the metal remained almost the same as the previous year at 5.5 million tonnes. The country also holds the largest reserves of manganese, at 230 million tonnes.

South32

South32 is a major presence in the South African manganese space. South Africa Manganese, one of the company's four operations in South Africa, is made up of Metalloys and Hotazel Manganese Mines. Notably, the Hotazel mine is located in the manganese-rich Kalahari Basin, which holds 80% of the world's known manganese ore resources. About 3 000 people – both full-time employees as well as contractors – work on its South African manganese projects. The company also has mining and production sites in Australia.

Sustainability aspects are mentioned on the website. For instance, it is explained how the company contributes to the SDGs ⁽²¹⁹⁾. The company publishes on the website its sustainability approach concerning community, health, safety and environment, as well as its modern slavery statement for the years 2016 to 2018 ⁽²²⁰⁾. However, no quantitative targets are mentioned, with the exception of investment in community initiatives such as supporting the recovery from Cyclone Idai in Mozambique and response to floods in Townsville, Australia.

⁽²¹⁹⁾ <https://www.south32.net/who-we-are/sustainability-approach/sustainable-development-goals>.

⁽²²⁰⁾ https://www.south32.net/docs/default-source/sustainability-reporting/fy2019-sustainability-reporting/nsec-management-approaches-2019.pdf?sfvrsn=ae3490f9_2.

No sustainability report is available but the financial report shows some data on social aspects, such as the gender balance (at company level, so for all locations) and the representation of black people in the workforce in South Africa, for the years 2016, 2017 and 2018 (see Table 32).

Table 32 South32 disclosures on representation of women and black people (%)

Representation	2016	2017	2018
Women			
Workforce	16	16	17
Board	13	14	33
Lead team	17	17	29
Senior leadership	n.a.	31	32
Operational leadership	n.a.	18	18
Black people in workforce in South Africa			
Total employees	79	79	81
Management roles	45	42	45

Nickel

The main producer countries of nickel are Canada, Indonesia, the Philippines and Russia.

Nickel Mines Limited

Nickel Mines Limited is an Australian public company focused on becoming a globally significant, low-cost producer of nickel pig iron, a key ingredient in the production of stainless steel. Nickel Mines holds an 80 % economic interest in the Hengjaya Mineralindo Nickel Mine (Hengjaya Mine), a large-tonnage, high-grade saprolite deposit located in the Morowali Regency of Central Sulawesi, Indonesia. On the website, no mention is made of sustainability and no report is available.

Vale

Vale is the largest producer of iron ore and nickel in the world, with USD 5.5 billion of profit. It also produces manganese, ferroalloys, copper and other materials. It is present in 27 countries, on five continents; its headquarters are in Brazil. In 2017, Vale sold 288 200 tonnes of nickel, which represented 9.2 % of its total net revenue, which amounted to USD 34 billion⁽²²¹⁾. The company owns nickel mines in Brazil, Canada, Indonesia and New Caledonia, as well as wholly owned and joint-venture refineries in China, Japan, South Korea, Taiwan and the United Kingdom⁽²²²⁾. Vale has published sustainability reports in accordance with the GRI standard since 2017.

Vale's sustainability report 2018 contains information on all the aspects listed in the GRI standard, referring to the whole company and usually not disaggregated by material, country or plant.

Vale claims to have updated its sustainability goals for the coming years, in line with the SDGs. Concerning the social areas, priority is given to local income generation, basic health and education in Brazil, and targets for 2030 are set as in Table 33. The company claims that in 2018 it contributed USD 576.4 million in social-environmental expenditures and 34 % of this amount was paid on a voluntary basis.

⁽²²¹⁾ http://www.vale.com/PT/aboutvale/relatorio-de-sustentabilidade-2018/Documents/relatorio-sustentabilidade-2018/pdf/Sustainability_Report_Vale_2018.pdf.

⁽²²²⁾ <http://www.vale.com/en/business/mining/nickel/pages/default.aspx>.

Table 33 Vale's targets on social aspects

Aspect	New target (2030 deadline)
Income generation	Double the average income of 12 000 entrepreneurs
Basic health	Benefit 8 400 families with a supply of drinkable water and/or a dry compostable toilet, implying the reduction in incidence of waterborne diseases and infant mortality
Basic education	Enable full literacy for children up to 8 years of age in 23 municipalities

Other data disclosures include, for instance, the number of fatalities in the years 2016, 2017 and 2018 (Table 34), occupational injuries, social expenditure, anti-corruption training provided to employees in various countries (Table 35), impacts on local communities and resettlement.

Table 34 Vale's data on fatalities (GRI 403-2)

Year	Contractors	Employees
2016	3	2
2017	4	1
2018	1	1

Table 35 Employees trained in anti-corruption policies and procedures (GRI 205-2)

Country	Employees trained
Austria	2
Brazil	4 297
Canada	239
China	32
India	4
Indonesia	187
Japan	1
Malawi	33
Malaysia	176
Mozambique	511

New Caledonia	294
Oman	436
Paraguay	15
Singapore	52
Switzerland	65
United Arab Emirates	2
United Kingdom	3
Uruguay	1
Total	6 350

About one third of the 2018 Vale report is dedicated to the failure of Dam I of the Córrego do Feijão Mine (iron ore tailings) in Brumadinho in the state of Minas Gerais, which happened on 25 January 2019, as a result of which at least 248 people died ⁽²²³⁾. This part aims to report the actions and developments related to the failure of the dam as well as to describe the dam management process, incident prevention and emergency response.

PT Vale Indonesia Tbk is a company within the Vale group with a licence from the Government of Indonesia to explore, mine, process and produce nickel. It has published GRI-compliant sustainability reports since 2012 ⁽²²⁴⁾. The total sales volume of matte nickel in 2018 reached 75 631 tonnes. This accounts for around 4 % of total world nickel sales in 2018. Total employees in 2018 were 3 092 (of whom 243 were women). The report also includes quantitative information on social performances, in line with the GRI standard, for instance the number of workplace accidents disaggregated by area of production and gender in the years 2016, 2017 and 2018.

BHP Billiton

BHP Billiton is a global resources company, extracting and processing minerals, oil and gas. Copper and nickel are assets in Minerals Australia and Minerals Americas. Its headquarters are in Melbourne, Australia, and it has locations in 90 countries. Nickel production occurs in Western Australia, through the asset Nickel West.

BHP Billiton has 62 000 employees and its profits are about USD 8.9 billion. The company regularly publishes a sustainability report ⁽²²⁵⁾ in which it states its strategy with goals and targets, which are set in accordance with the SDGs (Table 36).

⁽²²³⁾ BBC News (2019).

⁽²²⁴⁾ Vale (n.d.).

⁽²²⁵⁾ BHP (n.d.).

Table 36 BHP indicators in the pillars People and Society

Indicators	Targets	Results 2018
Work-related fatalities	0	2
TRIFR	Year-on-year improvement of TRIFR per million hours worked	4.4
Occupational exposure reduction	50 % reduction in the number of workers potentially exposed to the most material exposures of silica and coal mine dust as compared to FY2017 baseline by FY2022	31 %
Significant community events (*)	0	0
Community investments	Not less than 1 % of pre-tax profits invested in community programmes that contribute to improved quality of life in host communities and support the achievement of the UN SDGs	USD 77.1 million
Indigenous peoples	By FY2022, implement Indigenous Peoples Strategy through the development of Regional Indigenous Peoples Plans	Regional Indigenous Peoples Plans have been developed across all geographically relevant assets

(*) A significant event, resulting from BHP-operated activities, is one with a severity rating of 4 or above, based on the company's internal severity-rating scale (tiered from 1 to 7 by increasing severity) and aligned to the Our Requirements for Risk Management standard.

The company claims to have a code of conduct setting the standard for integrity and respect, and mechanisms in place for anyone to raise a report if they feel the code has been breached. Employees and contractors can raise reports through line managers or human resources departments. Processes for the community to report potential breaches of the code are available at the asset level. Some 35 % of the reports received relate to harassments and bullying.

The company has an anti-corruption compliance programme, which is designed to meet the requirements of the US Foreign Corrupt Practices Act, the UK Bribery Act, the Australian Criminal Code and applicable laws of all places where it does business. Risk-based anti-corruption training was completed by 7 406 employees in 2018.

The company percentage of women employees grows annually and reached 1.9 % in 2018; the target is 3 %. Another target is related to flexible working (a key lead indicator for improving the representation of women), which reached 46 % (from 41 %).

The company has an employee inclusion group for BHP's lesbian, gay, bisexual, transgender and others (LGBT+) community and its allies, called Jasper.

The supply team leads a programme of work to build inclusion and diversity incentives into contracts in Australia.

About health and safety, the incidence of employee occupational illness is 4.18 per million hours worked (15 % decrease) and the incidence of contractor occupational illness is 1.92 per million hours worked (34 % increase).

In the report, it is stated that the Nickel West asset 'has not been fully integrated into the BHP Operating Model and has been granted exemptions from certain Our Requirements standards, including the requirements to conduct a human rights impact assessment every three years; have a quantified water balance model (unless required by a material risk); identify opportunities to reduce greenhouse gas (GHG) emissions outside of certain approved activities; and develop GHG public reduction targets. Statements in this Sustainability Report concerning these matters do not apply to Nickel West.'²²⁵

⁽²⁰⁰⁾ BHP Sustainability Report 2018, p. 6

7.3. Annex 3. Complete lists of risk categories addressed by initiatives and standards discussed in Chapter 4

International Finance Corporation's Performance Standards on Environmental and Social Sustainability ⁽²²⁷⁾

Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts

- Policy
- Identification of risks and impacts
- Management programs
- Organizational capacity and competency
- Emergency preparedness and response
- Stakeholder engagement
- Monitoring and review

Performance Standard 2: Labor and Working Conditions

- Working conditions and management of worker relationship
 - Human resources policies and procedures
 - Working conditions and terms of employment
 - Workers' organizations
 - Non-discrimination and equal opportunity
 - Retrenchment
 - Grievance mechanism
- Protecting the work force
 - Child labor
 - Forced labor
- Occupational health and safety
- Workers engaged by third parties
- Supply chain

Performance Standard 3: Resource Efficiency and Pollution Prevention

- Resource efficiency
 - Greenhouse gases
 - Water consumption
- Pollution prevention
 - Wastes
 - Hazardous materials management
 - Pesticide use and management

Performance Standard 4: Community Health, Safety, and Security

- Community health and safety
 - Infrastructure and equipment design and safety
 - Hazardous materials management and safety
 - Ecosystem services
 - Community exposure to disease
 - Emergency preparedness and response
- Security personnel

Performance Standard 5: Land Acquisition and Involuntary Resettlement

- General
 - Project design
 - Compensation and benefits for displaced persons
 - Community engagement
 - Grievance mechanism
 - Resettlement and livelihood restoration planning and implementation
- Displacement
 - Physical displacement

⁽²²⁷⁾ International Finance Corporation (2012).

Economic displacement

Private sector responsibilities under government-managed resettlement

Performance Standard 6: Biodiversity Conservation and Sustainable Management of Living Natural Resources

General

Protection and conservation of biodiversity

Modified habitat

Natural habitat

Critical habitat

Legally protected and internationally recognized areas

Invasive alien species

Management of ecosystem services

Sustainable management of living natural resources

Supply chain

Performance Standard 7: Indigenous Peoples

General

Avoidance of adverse impacts

Participation and consent

Circumstances requiring free, prior, and informed consent

Impacts on lands and natural resources subject to traditional ownership or under customary use

Relocation of indigenous peoples from lands and natural resources subject to traditional ownership or under customary use

Critical cultural heritage

Mitigation and development benefits

Private sector responsibilities where government is responsible for managing indigenous peoples issues

Performance Standard 8: Cultural Heritage

Protection of cultural heritage in project design and execution

Chance find procedures

Consultation

Community access

Removal of replicable cultural heritage

Removal of non-replicable cultural heritage

Critical cultural heritage

Project's use of cultural heritage

Chinese Due Diligence Guidelines for Responsible Minerals Supply Chains of the China

Chamber of Commerce of Metals, Minerals & Chemical Importers and Exporters⁽²²⁸⁾

Type 1 Risks. Risks of contributing to conflict and serious human rights abuses associated with extracting, trading, processing, and exporting of resources from conflict-affected and high-risk areas:

1. risks of committing, profiting from, assisting with, or facilitating, or sourcing from, or being linked to, any party committing, profiting from, assisting with or facilitating the following serious abuses:
 - (a) any forms of torture, cruel, inhuman and degrading treatment,
 - (b) any forms of forced or compulsory labour, which means work or a service that is exacted from any person under the menace of penalty and for which that person has not offered him- or herself voluntarily,
 - (c) the worst forms of child labour,
 - (d) other gross human rights violations and abuses such as, but not limited to, widespread sexual violence, or failing to ensure non-complicity in human rights violations, including profiting or seem to be profiting or condoning or seeming to condone human rights violations by others,
 - (e) war crimes or other serious violations of international humanitarian law, crimes against humanity or genocide;
2. risks of providing, or sourcing from, or being linked to, any party providing direct or indirect support to non-state armed groups:
 - (a) providing direct or indirect support to non-state armed groups through the extraction, transport, trade, processing or export of mineral resources, which includes, but is not limited to, procuring

⁽²²⁸⁾ CCCME (date).

mineral resources from, making payments to or otherwise providing logistical assistance or equipment to non-state armed groups or their affiliates who:

- illegally control resource extraction sites or otherwise control transportation routes, points where mineral resources are traded and upstream actors in the supply chain,
- illegally tax or extort money or mineral resources at points of access to resource extraction sites, along transportation routes or at points where mineral resources are traded,
- illegally tax or extort intermediaries, export companies or international traders;

3. risks relating to public or private security forces:

(a) risk of providing, sourcing from or being linked to any party providing direct or indirect support to public or private security forces who:

- illegally control mineral extraction sites, transportation routes and/or upstream actors in the supply chain,
- illegally tax or extort money or minerals at point of access to mineral extraction sites, along transportation routes or at points where mineral resources are traded,
- illegally tax or extort intermediaries, export companies or international traders, disrespect the rule of law and human rights, or neglect the security of workers, equipment and facilities, and the mineral extraction on site or on transportation routes from interference with legitimate extraction and trade,
- fail to ensure that security forces are engaged in accordance with internationally recognised standards or guidance documents with regard to private security forces, particularly the adoption of screening policies to ensure that individuals or units of security forces known to have been responsible for gross human rights abuses are not hired;

(b) risks of contributing to, or sourcing from, or being linked to, any party contributing to serious misconduct:

- directly or indirectly offering, giving, promising or demanding any bribes or any other undue advantages, and/or soliciting bribes to conceal or disguise the origin of mineral resources, to misrepresent taxes, fees and royalties paid to governments for the purposes of resource extraction, trade, processing, transport and export, or failing to follow relevant international standards and conventions for anti-corruption,
- engaging in money-laundering resulting from, or connected to, the extraction, trade, processing, transport or export of mineral resources derived from the illegal taxation or extortion of mineral resources at points of access to mineral extraction sites, along transportation routes or at points where mineral resources are traded by upstream suppliers,
- avoiding or misrepresenting taxes, fees and royalties or other payments to governments related to mineral resource extraction, trade and export from conflict-affected and high-risk areas, and failing to disclose such payments in accordance with the principles set forth under the Extractive Industry Transparency Initiative or related transparency initiatives.

Type 2 risks. Risks associated with serious misconduct in environmental, social and ethical issues:

1. Risks of contributing to, or sourcing from, or being linked to, any party contributing to serious misconduct.

2. Breaking Chinese or host country laws and regulations or industry minimum standards:

- (a) Employing children under the minimum working age as legally prescribed by the host country laws and regulations, or, if there is no relevant host country law or regulation, employing children below the minimum working age of 16 years.
- (b) Disrespecting the rights and interests of young workers (any workers over the legally prescribed minimum working age and under the age of 18).
- (c) Extracting or sourcing resources from land where the free, prior and informed consent of local communities and indigenous peoples has not been obtained, including those for which the extractor holds a legal title, lease, concession or licence.
- (d) *Extracting or sourcing resources from mining operations where the culture and heritage of local communities and indigenous peoples have not been respected and protected, or where traditional cultures of local peoples have been harmed.*
- (e) Extracting or sourcing resources where a legal title, lease, concession or licence has been illegally obtained or violates national laws, or where there are pre-existing legitimate claims to the land by local populations, including those that are under customary, traditional or collective land tenure systems, or where the population residing in the extraction area has been involuntarily resettled.
- (f) Adverse impacts and gross violation of international and national laws and regulations regarding ambient soil, air and water conditions, including manufacturing, trading and using chemicals and hazardous substances subject to international bans due to their high toxicity to living organisms,

- environmental persistence or potential for irreversible ecological impacts, and/or releasing arsenic and mercury emissions.
- (g) Failing to avoid, minimise or, if residual impacts remain, offset the environmental impact and ecological footprint throughout the mining life cycle by conducting thorough environmental impact assessments, minimising waste and emissions, ensuring mine closure and site rehabilitation, conserving resources and recycling, implementing environmental risk management, contributing to the conservation of biodiversity and seeking continual improvement of their environmental performance. Offsetting shall always be the last resort and applied only if all efforts for avoiding or minimising adverse impacts have been exhausted.
 - (h) Extracting or sourcing resources from World Heritage Sites (WHSs) or legally protected areas, mining within the buffer zones of WHSs or legally protected areas, or transporting mined resources through WHSs or legally protected areas, thereby providing a threat to the outstanding universal value for which these properties are protected.
 - (i) *Failing to report, in a regular and timely manner to stakeholders, on their material impacts and disclose their ethical, social, and environmental performance to their stakeholders in ways that are appropriate and meaningful to their needs. This includes a comprehensive view of their policies, risks and results with regard to ethical, environmental and social matters. It also includes proactively soliciting, respecting and responding to stakeholder feedback and expectations including those from NGOs and local communities.*
 - (j) Failing to take proactive steps to respect all other principles set forth in the Chinese Responsible Mining Guidelines that are not included under Type 1 risks or those risks listed above.

7.4. Annex 4. Detailed methodology of the case study presented in Chapter 5

Because of the nature of fieldwork in mixed artisanal and large-scale mining cobalt supply chains in the southern DRC (provinces of Haut Katanga and Lualaba), the field data collection was based on a combination of direct observation, document consultation and stakeholder interviews. However, as a significant part of the supply chain remains non-formal (illegal, informal, outside applicable legal norms or with regulations applied selectively as a norm), stakeholders respond poorly to structured questionnaires, which are too thorough and too often make stakeholders confront their non-formality, thus putting them in a situation of unease vis-à-vis the interviewer, a situation not conducive to establishing the trust and rapport necessary to obtain information on non-formal activities.

To overcome these shortcomings it was instead necessary to make use of open-ended interviews with a number of individuals representing the same categories of stakeholders. These open-ended interviews are in most cases only partial – i.e. they do not cover the entirety of the information to be collected – in order not to be too intrusive into individual's non-formal business. Nevertheless, partially overlapping interviews with multiple individuals representing the same category of stakeholders allow one to gather the required information and, at the same time, triangulate the information coming from various sources.

As there is no standard questionnaire it was necessary to devise an information matrix that highlights all the information to be collected at the different points in the supply chain. Once information had been gathered on all the items listed on the information matrix, using the aforementioned data collection methods, it was possible to fully characterise the situation on the ground.

The data to be collected on the field serve two purposes and are therefore based on two different information matrices:

1. an information matrix dedicated to the collection of the information required for the characterisation of the impacts of the implementation of responsible cobalt-sourcing initiatives in the DRC (Table 37),
2. an information matrix dedicated to the collection of the information required for an S-LCA (Table 38).

In order to enable comparisons and analysis, the characterisation was conducted at a Better Mining site and at a Mutoshi site, where responsible sourcing initiatives have been implemented, in addition to a baseline site representing the cobalt ASM sector in the DRC.

The resulting matrices are complementary and make it possible to gather all the information required by the relevant components of the project. The first matrix is aligned with globally accepted best practice in the form of standards (see next section), which are complementary in their focus, work well with the type of information demanded by S-LCA and are aligned with (but expand upon) the methodological categories used in the hotspot analysis.

Underlying standards and guidance

While a number of initiatives on responsible mineral production and sourcing exist, they are all based on a limited number of underlying guidance/standards that they seek to implement either in full or partially. These are the OECD Guidance and the IFC PS, described in Chapter 4.

As these standards are widely seen as benchmarks within the industry and among stakeholders connected to it, they frame the current responsible sourcing efforts globally and are thus used as the reference standards to develop the questionnaire.

Contextual information

In addition to the indicators necessary to characterise the impacts, both positive and negative, of operations, it is also necessary to collect descriptive information on the working of operations in order to provide the context needed to make more sense of the collected impact information, especially if such information is to be quantified from qualitative indicators. In this case, the contextual information is necessary not only to assign thresholds and benchmarks but also to explain and justify them during any review process.

This information is primarily concerned with operational and supply chain operation details around the mine sites, processing centres and transport, such as mining title ownership, steps in the process, gender breakdown of activities, level of mechanisation and early supply-chain organisation.

Selection of information to collect and indicators

The design of the information matrix followed a structured approach designed to incorporate feedback from subject area experts. It was composed of the following steps:

1. **Comparison of standards' demands.** All risks under the OECD Guidance and CCCMC Guidance and the objectives of the IFC PSs were extracted and compared. Any interconnection, complementarity or overlap was noted.
2. **Consolidation of standards' demands.** Based on the previous comparison, the different elements were consolidated in order to avoid any unnecessary overlap. Consideration was then given to the ASM context and the applicability of each element, particularly in the case of the IFC PSs; the demands of the standard targeting LSM are in certain cases not applicable to the capacity of ASM operations. The decision to include or exclude an element was justified.
3. **Development of first information matrix.** Based on the consolidated list, an initial list of information to collect was designed. This list includes preliminary indications of the information to collect.
4. **Feedback collection and integration.** Based on the feedback received from S-LCA experts, the list of information to collect was updated, and the type of information to collect for each element was added.

In order to keep the questionnaires separate yet ensure as much synergy as possible, S-LCA elements were integrated only when fully in line with the information list submitted for initial feedback collection (and thus based upon the OECD and CCCMC Guidance, and the IFC PSs); other elements were kept separate in a list of information to collect pertaining exclusively to the S-LCA data collection. For elements that would figure in both questionnaires, the *Indicators/Instructions* column was aligned whenever possible to match the indicators of the original S-LCA questionnaires received.

Complementing these information lists, a list of contextual information to collect was designed.

Information matrix finalisation

The finalised information matrix was then used to structure the field data collection and restitution. The information matrix was then used to characterise a Better Mining site and the Mutoshi site; a baseline site representing the cobalt ASM sector in the DRC was also developed in order to enable comparisons and analysis.

Tables 34 and 35 show the information matrix deriving from the responsible sourcing standards and from the remaining S-LCA aspects used to characterise the three mining sites.

Table 37 Information matrix based on responsible sourcing standards

STANDARD	Risk	Information to collect
OECD Guidance	Any forms of torture, cruel, inhuman and degrading treatment	Have any of the consulted stakeholders mentioned any forms of torture, cruel, inhuman and degrading treatment (this includes arbitrary detention, arbitrary confiscation of assets, beatings and whippings)? Locate the origin of the Twitter video; is this related to any of the sites?
	Any forms of forced or compulsory labour, which means work or service that is exacted from any person under the menace of penalty and for which said person has not offered him- or herself voluntarily	Have any of the consulted stakeholders mentioned any forms of forced labour? Are there suspicions of debt bondage? Are miners required to purchase the PPE or is it offered free of charge? Are IDs (not copies) kept on site? Are miners effectively stranded away from any populated centre? Are miners obliged to purchase goods from specific places?
	Regarding serious abuses associated with the extraction, transport or trade of minerals	Have any of the consulted stakeholders mentioned labourers under 18 years of age engaged in activities that are detrimental to their health and well-being? Are individuals visibly underage present on site? If so, what tasks are they carrying out?
	The worst forms of child labour	Are there mechanisms to prevent the presence of children on site (such as ID controls for sites that are managed)? If controls are present, are those systematically enforced? By whom?
	Other gross human rights violations and abuses such as widespread sexual violence	Are there local schools? Are they truly free?
OECD Guidance	War crimes or other serious violations of international humanitarian law, crimes against humanity or genocide	Have any of the consulted stakeholders mentioned any form of systematic human rights abuses linked to mining? This includes forced displacement and sexual violence
		Have any of the consulted stakeholders mentioned any such violations, in particular in relation to the political transition that is taking place and the lack of elections in 2016–2018?

Regarding direct or indirect support to non-state armed groups Any direct or indirect support to non-state armed groups through the extraction, transport, trade, handling or export of minerals. Direct or indirect support to non-state armed groups through the extraction, transport, trade, handling or export of minerals includes, but is not limited to, procuring minerals from, making payments to or otherwise providing logistical assistance or equipment to non-state armed groups or their affiliates who: (i) illegally control mine sites or otherwise control transportation routes, points where minerals are traded and upstream actors in the supply chain; (ii) illegally tax or extort money or minerals at points of access to mine sites, along transportation routes or at points where minerals are traded; and/or (iii) illegally tax or extort from intermediaries, export companies or international traders	Are there any non-state armed group in the area? If so have any of the consulted stakeholders mentioned direct or indirect payments (including in the form of protection payments and purchase of services)?
Regarding public or private security forces We agree to eliminate, in accordance with paragraph 10, direct or indirect support to public or private security forces who illegally control mine sites, transportation routes and upstream actors in the supply chain; illegally tax or extort money or minerals at point of access to mine sites, along transportation routes or at points where minerals are traded; or illegally tax or extort from intermediaries, export companies or international traders We recognise that the role of public or private security forces at the mine sites and/or surrounding areas and/or along transportation routes should be solely to maintain the rule of law, including safeguarding human rights, providing security to mine workers, equipment and facilities, and protecting the mine site or transportation routes from interference with legitimate extraction and trade Where we or any company in our supply chain contract public or private security forces, we commit to or we will require that such security forces will be engaged in accordance with the Voluntary Principles on Security and Human Rights. In particular, we will support efforts, or take steps, to adopt screening policies to ensure that individuals or units of security forces that are known to	Have any of the consulted stakeholders mentioned the direct control of mine sites, ASM miners' teams, cooperatives, transport companies or checkpoints by members of armed forces or private security groups? Have any of the consulted stakeholders mentioned ANY payments made to armed forces, including to 'perform services'? Are ANY other armed forces than the PMH present on site? If so, is their presence backed by a contract? Which armed forces are present at checkpoints or in markets? What is their role there? Are private security staff present on site? If so, are they armed? Do they have a contract? Are private security staff trained in the VPs or the ICoC and has due diligence been conducted during recruitment?

	have been responsible for gross human rights abuses will not be hired	
	We will support efforts, or take steps, to engage with central or local authorities, international organisations and civil society organisations to contribute to workable solutions on how transparency, proportionality and accountability in payments made to public security forces for the provision of security could be improved We will support efforts, or take steps, to engage with local authorities, international organisations and civil society organisations to avoid or minimise the exposure of vulnerable groups, in particular artisanal miners where minerals in the supply chain are extracted through artisanal or small-scale mining, to adverse impacts associated with the presence of security forces, public or private, on mine sites	If any payments are made to armed forces, what is the framework? Have the security forces received training on how to interact with at-risk constituents? Are grievance mechanisms available to stakeholders? Is a logbook of incidents available somewhere?
Regarding bribery and fraudulent misrepresentation of the origin of minerals	We will not offer, promise, give or demand any bribes, and will resist the solicitation of bribes to conceal or disguise the origin of minerals, to misrepresent taxes, fees and royalties paid to governments for the purposes of mineral extraction, trade, handling, transport and export	Have any of the consulted stakeholders mentioned the use of bribes during extraction, transport and trading of ores? If so, to whom and for what reason? Have any of the consulted stakeholders mentioned that minerals are mislabelled on purpose? Are there systems in place that could ensure that the origins of minerals are recorded truthfully?
	We will support efforts, or take steps, to contribute to the effective elimination of money laundering where we identify a reasonable risk of money laundering resulting from, or connected to, the extraction, trade, handling, transport or export of minerals derived from the illegal taxation or extortion of minerals at points of access to mine sites, along transportation routes or at points where minerals are traded by upstream suppliers We will ensure that all taxes, fees, and royalties related to mineral extraction, trade and export from conflict-affected and high-risk areas are paid to governments and, in accordance with the company's position in the supply chain, we commit to disclose such payments in accordance with the principles set forth under the EITI	Have any of the consulted stakeholders mentioned cases of money laundering? Do the investments into the mining, transport and trading operations come from legitimate actors and from clear formal business activities? Are the sources of funding subjected to Know Your Customer due diligence?
Regarding the payment of taxes, fees and royalties due to governments		Have any of the consulted stakeholders mentioned improper payment of taxes Do mining operations pay their cadastral taxes? Do traders possess the appropriate licences to operate?

IFC Performance Standards (additional items)		
Performance Standard 1: Assessment and Management of Environmental and Social Risks and Impacts	To adopt a mitigation hierarchy to anticipate and avoid, or where avoidance is not possible, minimise and, where residual impacts remain, compensate/offset for risks and impacts to workers, affected communities, and the environment.	Has the operator, or the operator purchasing from the operation, a risk evaluation and mitigation strategy?
	To ensure that grievances from affected communities and external communications from other stakeholders are responded to and managed appropriately.	Are there pending grievances from the community? Are there adapted grievance mechanisms?
	To promote and provide means for adequate engagement with affected communities throughout the project cycle on issues that could potentially affect them and to ensure that relevant environmental and social information is disclosed and disseminated	Are there adapted mechanisms to consult the community?
	To promote the fair treatment, non-discrimination and equal opportunity of workers	Have any of the consulted stakeholders mentioned discrimination as to who can work there? What is the gender assignment of roles?
Performance Standard 2: Labour and Working Conditions	To establish, maintain, and improve the worker–management relationship	Are there internal complaint mechanisms and other ways through which employees can communicate with management?
	To promote compliance with national employment and labour laws	Are there rules on the site on night mining? Depth of tunnels? Days of work per week? Freedom of association and collective bargaining? If yes, are those rules enforced systematically? By whom?
	To protect workers, including vulnerable categories of workers such as children, migrant workers, workers engaged by third parties and workers in the client's supply chain	What are the minorities present on site: ethnic, national, linguistic, gender, religious, migrant? What is the percentage of migrant labour?
	To promote safe and healthy working conditions, and the health of workers	Have any of the consulted stakeholders mentioned accidents on site? How many? Type and number of injuries? Number of deaths (any children)? Do the miners/workers wear dedicated PPE? What kind? Do the miners/workers wear shoes?

	Have any of the consulted stakeholders mentioned health impacts from work? Are there practices mitigating these impacts? If PPE is required, is it enforced systematically? By whom?
Performance Standard 3: Resource Efficiency and Pollution Prevention	Have any of the consulted stakeholders mentioned any impacts from pollution? What type of pollution? Can it be attributed to mining or refining activities beyond reasonable doubt? From the sites observed? Have any of the consulted stakeholders mentioned any impacts from competition for resources? Which resource: water, land, timber? Can it be attributed to mining or refining activities beyond reasonable doubt? From the sites observed? Are there mechanisms to prevent pollution and competition for resources? If yes, describe
Performance Standard 4: Community Health, Safety, and Security	Have any of the consulted stakeholders mentioned health impacts on the community? Can these be attributed to extraction and refining activities beyond reasonable doubt? From the sites observed?
Performance Standard 8: Cultural Heritage	Does the mining operation take place in the vicinity of an important cultural landmark for the miners? Does the mining operation take place in the vicinity of an important cultural landmark for the community? Does the mining operation limit the enjoyment of cultural rights (for example by blocking a path required to access the sites)?
CCCMC type 2 risks	
Type 2 risks NOT covered by OECD Guidance or IFC PS	5.2.1.6 Extracting or sourcing resources where a legal title, lease, concession or licence has been illegally obtained or violates national laws, or where there are pre-existing legitimate claims to the land by local populations, including those which are under customary, traditional or collective land tenure systems, or where the population residing in the extraction area has been involuntarily resettled (Related to Clause 2.4.3 of the Chinese Responsible Mining Guidelines)
	Does the operation have a mining title? Are there indications that this title was obtained illegally or conflicts with pre-existing claims, including local community claims for non-mining activities?

5.2.1.9 Extracting or sourcing resources from WHSs or legally protected areas, or mining within the buffer zones of WHSs or legally protected areas; or transporting of mined resources through WHSs or legally protected areas, thereby providing a threat to the outstanding universal value for which these properties are protected (Related to Clause 2.7.13 of the Chinese Responsible Mining Guidelines)	Does the operation (including its transport component) take place within a protected area?
5.2.1.10 Failing to report, in a regular and timely manner to stakeholders, on their material impacts and disclose their ethical, social and environmental performance to their stakeholders in ways that are appropriate and meaningful to their needs. This includes a comprehensive view of their policies, risks and results with regard to ethical, environmental and social matters. It also includes proactively soliciting, respecting and responding to stakeholder feedback and expectations including those from NGOs and local communities (Related to Clause 2.1.5 of the Chinese Responsible Mining Guidelines)	Does the operation or the operator buying ASM minerals from it disclose information on its ASM supply at a site-specific level in line with step 5 of the OECD Guidance? Does the operator buying ASM minerals from the operation disclose information on its ASM supply at a non-site-specific level in line with step 5 of the OECD Guidance?

Table 38 Information matrix based on S-LCA aspects not included in the table above (referring to stakeholder categories: local communities and workers)

		Performance indicator	Unit
Local community	Health and safety	Improvement of local infrastructure (e.g. telecommunications, road network, power and water supplies) due to mining activities	Yes/no <i>Please indicate type of improvement</i>
		Improvements in population's education/skills due to mining activities	Yes/no <i>Please indicate type of improvement</i>
		Improvement of local health services due to mining activities	Yes/no <i>Please indicate type of improvement</i>
		Programmes to enhance community health and safety	Number of programmes <i>Please indicate type of programme</i>
		Dependency on mine for sustaining local economy	Yes/no
	Local employment (and economy)	Local job creation/increased employment rate through company (direct job creation)	Number of additional jobs created/year
		Loss of industrial jobs typical of that area (e.g. agriculture or tourism) due to mining activity	Number of jobs lost/year
		Business and employment opportunities in other sectors (e.g. waste management) resulting from company's activity	Number of additional jobs created/year
		Activities to protect established industry sectors in this area	Number of activities/per year <i>Please indicate type of activity</i>
		Increase in exports and gross domestic product due to company activity	CDF/month or year
		Positive impacts on local community due to population growth and demographic change due to mining activity (e.g. gender balance)	Yes/no <i>Please indicate type of impact</i>
		Negative impacts on local community due to population growth and demographic change (e.g. migration influx)	Yes/no <i>Please indicate type of impact</i>
	Social benefits/losses	Family benefit – provision of programmes for the self-development of employees and their families (e.g. education programmes)	Number of programmes/year <i>Please indicate type of programme</i>
		Additional accidents due to mining traffic	Number of additional accidents/year <i>Please indicate type of accident</i>
		Inflation, rising cost of and reduced access to accommodation for population not related to mining company	Yes/no <i>Please indicate type of issue</i>
		Establishment and growth of informal settlements due to mining/company activity	Yes/no
	Cultural heritage and land rights	Loss of space used for recreational activities (e.g. sports)	km ² lost/year <i>Please indicate type of space</i>
		Presence of indigenous population in mining area	Yes/no
		Loss of space used by indigenous communities	km ² lost/year <i>Please indicate type of space</i>
		Agricultural and/or forest land bought by mining company for mining purpose	km ² of land/year
	Discrimination	Activities to protect existing communities in the mining area (especially indigenous communities)	Number of activities/per year <i>Please indicate type of activity per population group</i>

Workers	Forced migration/resettlement and land rights	People/groups of people forced to resettle without compensation	Number of people/year <i>Please indicate population group</i>
		Occupied land without ownership (e.g. taken from indigenous communities)	km ² of land occupied/year
	Poverty	Activities for poverty alleviation due to mining activity	Number of activities/per year <i>Please indicate type of activity</i>
	Health and social well-being	Average cases of mental health issues resulting from work	Number/year <i>Please indicate type of issue</i>
		Regular health checks for employees	Number/year and employee group <i>Please indicate employee group</i>
		Provision of free meals for employees	Number/month and employee group <i>Please indicate the kind of meal per employee group</i>
		Provision of sanitation facilities for employees	Yes/no
		Existence of a health and safety committee with participation of employees	Yes/no
	Wages	Living wage or prevailing wage	% of employees earning this wage <i>Please indicate amounts paid/month per employee group</i>
		Bonus paid	CDF/month or year <i>Please indicate to which employee group bonuses are paid</i>
		Overtime paid	Yes/no
		Remuneration/wages exceeding minimum wage	% of employees earning these wages <i>Please indicate amounts paid/month</i>
		Remuneration/wages undercutting minimum wage	% of employees earning these wages <i>Please indicate amounts paid/month</i>
		Pay gap between highest and lowest wage/salary paid	Ratio/year
		Equality of wages between men and women	Ratio/year and employee group <i>Please indicate employee group</i>
	Social benefits	Social benefits provided to employees (e.g. unemployment pay, health insurance, pension)	% of employees receiving social benefits <i>Please indicate type of benefits and employee group</i>
		Employee support – provision of memberships (e.g. gym) or living space (e.g. apartments)	% of employees receiving support <i>Please indicate type of support and employee group</i>
		Family benefit – provision of programmes for the self-development of employees and their families (e.g. education programmes)	Number of programmes <i>Please indicate type of programme</i>
	Working conditions	Contracted working hours per week	Average number of contracted hours/week and employee group <i>Please indicate employee group</i>
		Definition of core working time	Yes/no <i>Please indicate the hours for which a core working time is defined per employee group</i>

	Flexible working hours	% of employees having the option of flexible working time <i>Please indicate employee group</i>
	Permanent/temporary jobs	% of employees with permanent positions <i>Please indicate employee group</i>
	Stability of jobs	Average duration of employment <i>Please indicate employee group</i>
	Vacation days – number of regular vacation days	Average number of days/year and employee group <i>Please indicate employee group</i>
	Maternity protection	% of pregnant women in maternity protection <i>Only applicable to employees with direct family responsibilities</i>
	Parental or compassionate leave	% of employees on parental/compassionate leave <i>Only applicable to employees with direct family responsibilities</i>
	Nursery location available for employees' children	Number of places in nursery/number of employees <i>Only applicable to employees with direct family responsibilities</i>
	Average monitoring cycles performed by independent reviewer	Number/year <i>Please indicate type of monitoring person</i>
	Evidence of violation of laws and employment regulations	Cases/year and employee group <i>Please indicate employee group</i>
	Local people employed	% of local employees in the workforce <i>Please indicate employee group</i>
Discrimination	Actions taken to increase staff diversity and/or to promote equal opportunities	Number of actions/year <i>Please indicate type of action</i>
	Proportion of women in labour force	Ratio/year and employee group <i>Please indicate employee group</i>
	Proportion of women in high-responsibility roles	Ratio/year and employee group <i>Please indicate employee group</i>
Freedom of association and collective bargaining	Memberships in associations able to organise themselves and/or bargain collectively	% of employees having a membership
	Employees have the right to form associations	Yes/no
	Employees have the right to organise collective bargaining activities	Yes/no
	Employees have the right to strike	Yes/no
	Employer does not hinder or interfere but proactively informs employees about their right to organise themselves and bargain collectively	Yes/no
Training and education	Apprenticeships – finished and/or started	Number of apprenticeships/year and employee group <i>Please indicate type of apprenticeship and employee group</i>

Job satisfaction and engagement	Training of employees	Average hours of training/year and employee group <i>Please indicate type of training and employee group</i>
		% of employees receiving training/year and employee group <i>Please indicate type of training and employee group</i>
	Job satisfaction and engagement survey	Yes/no <i>Please indicate percentage of employees participating in the survey</i>

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**Natural History Museum letter to UK statutory Committee on Climate Change –
June 2019 – copy**

Posted by [philsharps](#)

3rd June 2019
Committee on Climate Change
7 Holbein Place,
London,
SW1W 8NR

Dear Committee Members,

Re: Reaching net zero emissions in the UK by 2050

In the Committee on Climate Change's May 2019 report¹ the key conclusion is '*that net-zero is necessary, feasible and cost-effective*'. The report is laudable but we attest is only likely to be feasible if considerations are made on the resource implication of what is needed to achieve that goal.

A key component of the net zero attainment is for '*all cars and vans to be electric by 2050*'. This further requires '*all sales to be pure battery electric by 2035 at the latest*'. In the report the need for vehicle charging facilities and infrastructure to support this change are acknowledged, but it entirely omits the challenge of the metal resources needed to produce the vehicles that will lead to this revolution.

There are currently 31.5 million cars on the UK roads. Between them they cover 252.5 billion miles per year². In 2017 electric and hybrid cars accounted for about 0.2% of the UK fleet, so that clearly needs to change rapidly for this to reach 100% by 2050. The stated challenge for all sales to be pure battery by 2035 is also a steep ask, given projections for vehicle sales, set to be around 2.5 million new vehicles per year.

Electric vehicles are resource hungry. Although the body and chassis are largely constructed from the same materials as internal combustion engine vehicles, the drive train and fuel (comprising stored electricity in the form of batteries) demand a new range of metals. An average battery electric vehicle with the next generation, low cobalt, NMC811 battery, will demand 6.6 kg cobalt and 8.4 kg of LCE (lithium carbonate equivalent)³. In addition, the electric drive chain contains between 1-2 kg of neo-magnets, containing around 0.2kg neodymium and 0.03kg dysprosium. Electric vehicles also need, on average, 90kg of copper for wiring to connect the battery and drive train. It should be noted that a conventional car currently contains between 9 and 25 kg copper along with minor cobalt in structural steel elements and minor rare earths for the electrical systems.

To replace all these UK-based vehicles today with electric vehicles (not including the LGV and HGV fleets), assuming they use the most resource-frugal next-generation NMC 811 batteries, it would take 207,900 tonnes cobalt, 264,600 tonnes of lithium carbonate (LCE), at least 7,200

tonnes of neodymium and dysprosium, in addition to 2,362,500 tonnes copper. This represents, just under two times the total annual world cobalt production, nearly the entire world production of neodymium, three quarters the world's lithium production and at least half of the world's copper production during 2018. Even ensuring the annual supply of electric vehicles only, from 2035 as pledged, will require the UK to annually import the equivalent of the entire annual cobalt needs of European industry.

If we are to extrapolate this analysis to the currently projected estimate of 2 billion cars worldwide¹, based on 2018 figures, annual production would have to increase for neodymium and dysprosium by 70%, copper output would need to more than double and cobalt output would need to increase at least three and a half times for the entire period from now until 2050 to satisfy the demand.

This choice of vehicle comes with an energy cost too. Energy costs for cobalt production are estimated at 7000-8000 kWh for every tonne of metal produced⁴ and for copper 9000 kWh/t⁵. The rare earth energy costs are at least 3350 kWh/t⁶, so for the target of all 31.5 million cars that requires 22.5 TWh of power to produce the new metals for the UK fleet, amounting to 6% of the UK's current annual electrical usage⁷. Extrapolated to 2 billion cars worldwide, the energy demand for extracting and processing the metals is almost 4 times the total annual UK electrical output.

Furthermore there are serious implications for the electrical power generation in the UK needed to recharge these vehicles. Using figures published for current EVs (Nissan Leaf, Renault Zoe), driving 252.5 billion miles uses at least 63 TWh of power. This will demand a 20% increase in UK generated electricity. If wind turbines are chosen for this extra capacity, each GW of added power capacity for new generation wind turbines uses 4700t copper, 200t neodymium and 13t dysprosium⁸. Data shows that wind farms in the UK operate at about 40% of their nominal capacity⁹, so for the 63 TWh needed annually to fuel the EV fleet, 18GW of new installed capacity is needed. Equating to 6000 wind turbines of 3MW capacity, these demand an additional 84,600t of copper, 3600t of neodymium and 234t of dysprosium. If we are to power all of the projected 2 billion cars at UK average usage, this requires the equivalent of a further years' worth of total global copper supply and 10 years' worth of global neodymium and dysprosium production to build the windfarms. The solar alternative to wind is also resource hungry; *all* the photovoltaic systems currently on the market are reliant on one or more raw materials classed as "critical" or "near critical" by the EU and/ or US Department of Energy¹⁰ (high purity silicon, indium, tellurium, gallium) because of their natural scarcity or their recovery as minor-by-products of other commodities. With a capacity factor of only ~10%¹¹, the UK would require ~72GW of photovoltaic input to fuel the EV fleet; over five times the current installed capacity. If CdTe-type photovoltaic power is used, that would consume over thirty years of current annual tellurium supply. Both these wind turbine and solar generation options for the added electrical power generation capacity have substantial demands for steel, aluminium, cement and glass which has been highlighted by previous authors¹².

It is clear that our move to a lower-CO₂ society and industry has a significant resource footprint, such that the availability (and price) of raw materials will likely be a major limiting factor. The UK's industrial and environmental strategies will depend not just on novel technologies for

energy generation, but on the discovery of new mineral resources, and more efficient extraction of a greater diversity and amount of elements and minerals from our mines. This has to be achieved while reducing the environmental impacts and energy consumption of those extractive industries. Researchers in the UK are engaged in research to do just this – the recent “Security of Supply” programme funded jointly by NERC, EPSRC, Newton and FAPESP (<https://www.bgs.ac.uk/SoSMinErals/?src=topNav>) focussed on improving our understanding of how particular scarce elements become concentrated in particular ore deposits, and how we can better extract them. Across the programme, our research has identified potential sources for cobalt, rare earths, tellurium and more; modelled the impacts of mining seabed resources; calculated the environmental and energy footprints of competing REE resources; piloted cobalt extraction through novel bio-processing; and developed new “deep eutectic” solvents capable of recovering a suite of metals with low energy inputs and water consumption.

This research represents the tip of the iceberg. Over the next few decades, global supply of raw materials must drastically change to accommodate not just the UK’s transformation to a low carbon economy, but the whole world’s. It is essential to have timely and sustainable supplies of raw materials in quantities greatly exceeding current global mining and processing capacity. There is space for us to look again at the our own local mineral endowment; Europe has great potential for many of these commodities but the current economics, socio-political framework and export of mining from the developed world have led the world’s mining industry to seek minerals in more permissive tracts; a move that has itself led to risks in the supply chain¹³. The UK itself has potential for some of the metals needed for these new vehicles, but currently we do not have a clear measure of that local potential. Society needs to understand that there is a raw material cost of going green and that both new research and investment is urgently needed for us to evaluate new ways to source these, potentially considering sources much closer to where the metals are to be used.

We would welcome the opportunity to discuss the contents of our letter with the committee and work with interested parties to build on the useful research started through the SoS MinErals programme and seek solutions for the resource supply challenge that a ‘Net Zero’ pledge raises.

Yours sincerely,

Professor Richard Herrington, *Head of Earth Sciences, The Natural History Museum, Cromwell Road, London SW7 5BD Email: r.herrington@nhm.ac.uk (corresponding author)*

Professor Adrian Boyce, *Professor of Applied Geology at The Scottish Universities Environmental Research Centre*

Paul Lusty, *Team Leader for Ore Deposits and Commodities at British Geological Survey*

Dr Bramley Murton, *Associate Head of Marine Geosciences at the National Oceanography Centre*

Dr Jonathan Naden, *Science Coordination Team Lead of NERC SoS MinErals Programme, British Geological Society*

Professor Stephen Roberts, *Professor of Geology, School of Ocean and Earth Science, University of Southampton*

Associate Professor Dan Smith, *Applied and Environmental Geology, University of Leicester*

Professor Frances Wall, *Professor of Applied Mineralogy at Camborne School of Mines, University of Exeter*

References:

1. Net Zero – The UK's contribution to stopping global warming, 2019, report, UK Parliamentary Committee on Climate Change, London, May 2019, 275pp
2. RAC Foundation <https://www.racfoundation.org>
3. McKinsey & Co Metals and Mining June 2018
Report <https://www.mckinsey.com/~/media/mckinsey/industries/metals%20and%20mining/our%20insights/lithium%20and%20cobalt%20a%20tale%20of%20two%20commodities/lithium-and-cobalt-a-tale-of-two-commodities.ashx>
4. Dai et al. 2018 https://greet.es.anl.gov/publication-update_cobalt
5. Energy Use in Copper Production, Rankin
2012 <https://publications.csiro.au/rpr/download?pid=csiro:EP12183&dsid=DS3>
6. Piero and Mendez (2013) 10.1007/s11837-013-0719-8
7. Energy consumption in the UK, 2015, UK Department of Energy & Climate Change
8. Ayman Elshkaki and T.E. Graedel, 2014, Dysprosium, the balance problem, and wind power technology, *Applied Energy*, 136, 548-559
9. Energy Numbers Info <http://energynumbers.info/uk-offshore-wind-capacity-factor>
10. Hayes & McCullough, Critical minerals: A review of elemental trends in comprehensive criticality studies, *Resources Policy*, V. 59, 2018
11. Hemingway, James (2013). "Estimating generation from Feed in Tariff installations" (pdf). *Energy Trends*. Department of Energy & Climate Change.
12. Vidal et al. (2013) <https://doi.org/10.1038/ngeo1993>
13. Herrington (2013) <https://doi.org/10.1038/ngeo1947>



March 16, 2021

The Honorable Joe Manchin
Chairman
Senate Committee on Energy and Natural
Resources
304 Dirksen Senate Office Building
Washington, DC 20510

The Honorable John Barrasso
Ranking Member
Senate Committee on Energy and Natural
Resources
304 Dirksen Senate Office Building
Washington, DC 20510

Dear Chairman Manchin and Ranking Member Barrasso:

On behalf of the 400 members of the National Stone, Sand, and Gravel Association, I am writing to support your work to review transportation technologies in today's hearing. NSSGA members will play a key role in delivering the materials that are critical to solving the challenges of our transportation system and we take great pride in our work to reduce emissions and promote sustainable business practices. I wanted to take this opportunity to highlight policies that we look forward to addressing with the Committee.

NSSGA represents aggregates producers and those who manufacture equipment and services that support the construction industry. Our members are essential to the work of this country, and we represent more than 90 percent of the crushed stone and 70 percent of the sand and gravel consumed annually in the United States. Our members employ more than 100,000 hard-working men and women and are responsible for the essential raw materials found in every home, building, road, bridge, and public works project.

Aggregates are Part of the Solution

Stone, sand, and gravel are an essential resource for developing any type of infrastructure and are key to producing renewable energy sources and sustainable public works. From new electric vehicle charging stations, to natural gas and hydrogen production and transportation, our members stand ready to supply the needed construction materials for these projects that will be needed to reduce emissions across the transportation industry.

In producing these needed materials NSSGA members take every effort to run their operations effectively to minimize waste, reduce air emissions, and to conserve water and are always working to improve energy efficiencies and developing alternative energy sources. The aggregates industry has undertaken many greenhouse gas mitigation efforts, such as investing heavily in fuel-efficient mobile equipment and improving operational efficiency. Further, our members are working to deploy new technologies that help further the goal of reducing environmental impacts like the utilization of recycled construction materials.

NSSGA members are leaders in taking aggressive action to protect our environment and enhance environmental stewardship. Companies across the industry routinely develop award-winning projects reclaiming land and unused areas that conserve critical habitats and promote biodiversity.

national stone, sand & gravel association
www.nssga.org | 800.451.7263

Transforming Business Practices

NSSGA members are not shying away from making new capital expenditures in machinery, equipment and developing renewable energy sources that will reduce emissions and improve our environment. We would encourage Congress to look at providing additional incentives to drive greater demand for these investments. We support the creation of tax credits to be provided to the purchase of low emissions vehicles to help further reduce fleet impacts on the environment. These types of incentives will not only help our members ability to upgrade their fleets but will drive greater demand for low carbon vehicles that bolsters American manufacturing.

Material Neutral Decisions

As the Committee looks at ways to promote the development of materials that improve our nation's built environment, we strongly urge that any federal solutions do not provide preference for one material over others. NSSGA has always supported Congress's longstanding work to promote research and development of building solutions that advances the performance, sustainability, and reliability of the materials. That is because NSSGA members value innovation and are always working to develop state-of-the-art technologies that improves our transportation networks.

As you work to advance new technologies and solutions, we would urge for careful consideration to not limit critical research dollars that promote one material over others through select marketing activities. Projects should be decided on by their merits and decisions should be left to engineers and those with technical expertise in designing and executing projects. This will ensure only the best solutions, that truly solve our infrastructure challenges, are delivered at the best expense of the taxpayers.

Sustainable Access to Construction Materials

We encourage the Committee to examine policies that ensure local sources of aggregates are available to supply construction projects. To build the 21st century energy and transportation infrastructure that will lead to reduced emissions we must have a sustainable supply of building materials.

Further, having access to locally sourced materials is a key factor in reducing costs of infrastructure projects and provides greater return to taxpayers. Further, decreasing the distance aggregates must travel to a project has shown to significantly reduce tail pipe emissions from haul trucks and improve road safety. Ensuring sustainable aggregates supply will support local economies with high paying jobs, reduce construction costs, and improve environmental outcomes.

Thank you for your consideration of NSSGA's views on these policies and we appreciate your leadership to address these important issues that impact the aggregates industry and our nation.

Sincerely,



Michael W. Johnson
President and CEO
National Stone, Sand and Gravel Association



Our Children's Trust
P.O. Box 5181
Eugene, OR 97405

March 25, 2021

Chairman Manchin and Ranking Member Barrasso, Full Senate Committee on Energy and Natural Resources

Re: Materials for March 16, 2021 Full Committee Hearing on Transportation Technologies

Dear Chairman Manchin and Ranking Member Barrasso,

On behalf of Our Children's Trust ("OCT"), a nonprofit law firm dedicated to securing the legal right to a stable climate system for youth and future generations, please find enclosed herewith materials for your consideration relevant to the Senate Committee on Energy and Natural Resources March 16, 2021 Full Committee Hearing on "Transportation Technologies." This submission will inspire you with the stories of courageous children and provide resources critical to developing science-based, technically and economically feasible solutions to the climate crisis.

Through youth-led constitutional legal actions, including *Juliana v. United States* ("*Juliana*") – the landmark federal constitutional climate case filed by twenty-one youth plaintiffs, including eleven Black, Brown and Indigenous youth – OCT supports youth seeking to hold their governments accountable for policies and actions that have caused, and continue to cause, the climate crisis. Through these actions, youth seek science-based remedies to reduce greenhouse gas emissions at rates necessary to protect their fundamental human rights.

It is OCT's understanding that the materials submitted for the March 16th hearing will inform the Committee's outlook how to best shape future climate policy and legislation pertaining to innovative transportation technologies with a focus on solutions that decrease emissions as we work in tandem with President Biden's actions to combat the climate crisis. Given our mission, OCT has a substantial interest in ensuring that any such legislation is consistent with what the best available science dictates is necessary to stabilize the climate system and protect the fundamental rights of youth and future generations.





We invite you to consult the materials enclosed herewith, which demonstrate that climate change is *already harming* the fundamental rights of young people in the United States and **legislation which ensures emissions reductions and sequestration of excess CO₂ is necessary for the protection of the fundamental rights of American children**. Please note in Exhibit C.1 below, the prescription to stabilize the atmosphere is a return to atmospheric CO₂ levels to 350 ppm by 2100, limiting global warming to less than 1 degree Celsius by 2100. This requires that net negative CO₂ emissions be achieved before mid-century

Specifically, enclosed as **Exhibit A** is a summary and status of the *Juliana* case, including some profiles of the diverse plaintiffs. Enclosed as **Exhibit B** you will find a document entitled "Government Climate and Energy Actions, Plans, and Policies Must Be Based on a Maximum Target of 350 ppm Atmospheric CO₂ and 1°C by 2100 to Protect Young People and Future Generations." This document details the scientific basis underlying, and prescription for, stabilization of the climate system as necessary to protect the fundamental human rights of youth and future generations relative to the climate crisis and explains that allowing warming of up to 1.5°C *is not safe*.

Enclosed as **Exhibit C** include reports published by the energy experts at Evolved Energy Research. **Exhibit C.1** is an executive summary entitled "350 PPM Pathways for the United States," which demonstrates multiple technologically and economically feasible pathways for transitioning to a 100 percent clean energy economy consistent with the science-based prescription for stabilizing the atmosphere and securing the fundamental rights of youth and future generations. The pathways reduce greenhouse gas emissions in the United States at a rate consistent with returning global concentrations of CO₂ in the atmosphere to 350 ppm by 2100, limiting global warming to less than 1.0 degree Celsius by 2100. This requires that net negative CO₂ emissions be achieved before mid-century. The report provides important policy guidance to achieve this steep and necessary level of emissions reductions in the United States.

This research demonstrates:

1. It is entirely possible to transition the U.S. off of fossil fuels at a pace consistent with returning global atmospheric CO₂ to 350 ppm by 2100.
2. Placing the U.S. energy system on a pathway to 350 ppm is affordable – temporarily increasing the total cost of the energy system in the United States by 2% or 3% of GDP, which does not account for the economic benefits of avoided climate change and other



energy-related environmental and public health impacts. This level of cost increase is small in comparison to recent (2005-2012) spikes in energy prices.

3. Eliminating fossil fuel dependence will also eliminate the potential for economic disruption caused by volatile fossil energy prices.
4. Any further delay in commencing the transition to a low-carbon energy system will result in dramatically increasing costs.
5. Rapidly falling prices for renewable energy technologies and conservative assumptions used in this research mean the transition off of fossil fuels may well cost less than the estimates found in this study.
6. There are multiple scenarios that achieve the scale and pace of reductions called for by the best available science. Even if one of the strategies is not pursued, for example, should the U.S. decide not to expand nuclear power or to restrict the use of biomass, the necessary emissions reductions can still be achieved.
7. Achieving this level of decarbonization creates an increase in demand for electricity, which justifies the need for this Committee to consider decarbonization policies across all sectors instead of policies that seek to decarbonize only one sector.
8. Achieving this level of decarbonization relies on investing in energy efficiency, electrifying everything that is practical to electrify, generating electricity from renewable sources, and some measure of carbon capture for utilization and/or storage.
9. **Electrifying and integrating energy systems across all sectors is essential and requires systemic planning at the national level.**
10. **The timeline for transitioning to low-carbon energy is aggressive but achievable:**
 - a. **In the 2020s: Begin large-scale electrification in transportation and buildings; Switch coal to fuel of last resort for electricity generation; Ramp up construction of renewable generation; Pilot new technologies that will need to be deployed at scale after 2030; Stop developing new infrastructure to transport fossil fuels.**



- b. In the 2030s: Maximum build-out of renewable generation; Nearly 100% of auto sales are electric vehicles; Begin large-scale production of bio-diesel and bio-based jet fuel; Build out of electrical energy storage for short-duration balancing.
- c. In the 2040s: Complete electrification of building heating equipment and vehicles; Deploy Direct Air Capture facilities and electrolytic hydrogen facilities to produce synthetic fuels; Use synthetic fuel production to balance and expand renewable generation.

Enclosed as **Exhibit C.2** is an executive summary entitled “350 PPM Pathways for Florida” that mirrors the national study’s target. **Updated national data is included in the full report as the U.S. model was upgraded to reflect the newer and even lower costs for renewable technologies.** The U.S. data from the Technical Supplement (starting on page 71) is also included under this Exhibit.

The remaining reports are from three expert witnesses in *Juliana*. Enclosed as **Exhibit D** is the expert report of Dr. Jim Williams, an international energy expert who serves as the Director of the Deep Decarbonization Pathways Project. This expert report includes policy recommendations to achieve rapid and deep decarbonization in the United States.

1. ***Sustained transformation.*** Deep decarbonization can be achieved technically and at an affordable cost, but requires a sustained commitment to infrastructure transformation over decades. Incremental improvements that do not facilitate complete transformation are likely to result in technology lock-in and emissions dead ends. Some examples of potential dead-ends include a pathway focused solely on energy efficiency in buildings that does not also include end-use electrification; a transition from coal to natural gas power generation without a further transition to zero carbon generation; or improvement in the fuel economy of gasoline internal combustion engine vehicles without widespread deployment of electric or fuel cell light duty vehicles. A sustained transformation requires stable policy and a predictable investment environment, and it also requires *planning*. Deferring responsibility to a carbon market, *ad hoc* decisions, and inconsistent incentives are not likely to produce a sustained or sufficiently rapid transition to full decarbonization.
2. ***Timely replacement.*** An 80% reduction in emissions x 2050 could be achieved in the U.S. without retiring existing equipment before the end of its economic lifetime, defined as the



time required to recoup initial capital investment including financing costs. However, because these lifetimes are long, there is only one natural replacement cycle before mid-century for some of the most important infrastructure, such as electric power plants, buildings, and industrial boilers. Failure to replace retiring infrastructure with efficient and low-carbon successors would lead either to failure to meet emissions goals or to potentially costly early retirement of the replacement equipment.

3. **Cross-sector coordination.** As deep decarbonization proceeds, interactions between mitigation measures in different sectors (for example, electricity and transportation) become dominant in determining overall emissions. Purely sectoral policies that do not recognize the importance of these interactions will produce suboptimal outcomes, yet there is currently little institutional coordination across sectors. Anticipatory development of shared institutional structures, both market and regulatory, will be required for efficient coordination of operations, planning, investment, and research.
4. **Integration of supply- and demand-side planning and procurement.** Related to the cross-sector coordination challenge is the supply-demand side challenge within the electricity sector. Maintaining reliability in an electricity system with high levels of wind and solar, or baseload nuclear, will require corresponding levels of flexible demand, such as EV charging and hydrogen production. Currently these are seen as outside the purview of electricity planning. To build a low-carbon system that matches supply and demand resources at the required spatial and time scales, however, will require integrated planning and procurement well beyond the scope of what is currently thought of as “integrated resource planning.”
5. **Suitable investment environment.** The annual investment requirement for low carbon and efficient technologies rises from under \$100 billion today to over \$1 trillion in a span of about 20 years. This is a large increase from the standpoint of energy sector capital investment, but not from the standpoint of the share of investment in U.S. GDP as a whole. Financial markets can supply this level of capital if investment needs are anticipated and a policy framework is constructed that limits risk and ensures adequate returns.
6. **The right kinds of competition.** Competition is potentially an important tool for driving innovation and reducing costs, but poorly informed policies can lead to unproductive competition. An example of this is current policies that have biofuels competing with gasoline; in the long run, this will be a poor use of scarce biomass resources, because gasoline internal combustion engine (ICE) vehicles have preferred substitutes such as



battery electric vehicles (BEVs) and fuel cell vehicles (FCVs), while the biomass will be needed for production of low carbon fuels used in applications that are difficult to electrify. Long-term pathways analysis will help policy makers and investors understand what types of competition have value. Federal policy will play an important role in driving market response.

7. *High rates of consumer adoption.* Achieving necessary rates of consumer adoption of equipment ranging from heat pumps to alternative vehicles will require a combination of incentives, financing, market strategies, and supporting infrastructure. This requires a high level of public-private cooperation among, for example, government agencies, auto manufacturers, and utilities in rapidly expanding alternative vehicle markets in tandem with the expansion of fueling or charging infrastructure, not unlike the public-private cooperation that originally created the fossil-fuel based energy system and infrastructure supporting ICEs.
8. *Cost reductions in key technologies.* Policy makers can drive cost reductions in key technologies by helping to create large markets. High production volumes drive technological learning, efficient manufacturing, and lower prices. This effect is already visible in battery storage and wind and solar PV generation. Large markets can be built through government procurement, technology standards, consumer incentives, coordinated research and demonstration, trade, and long-term policy certainty.
9. *Cost increases faced by consumers.* Businesses, utilities, and policy makers have a mutual interest in limiting the level and rate of consumer cost increases during a low-carbon transition. Coordinating energy efficiency improvements with decarbonization of energy supplies limits increases in total consumer bills even if per unit energy prices increase.
10. *Distributional effects.* A low-carbon transition policy can also minimize regressive cost impacts. Distributional effects across regions, sectors, and industries are largely a function of technology strategies, which can be tailored to mitigate these effects.

Enclosed as **Exhibit E** is the expert report of Mark Jacobson, Ph.D., Professor of Civil and Environmental Engineering at Stanford University. **Dr. Jacobson's expert report summarizes research, conclusions, and implications of studies he and his colleagues previously performed to develop 100% clean, renewable all-sector (electricity,**



transportation, heating/cooling, industry) roadmaps ("plans") for the 50 states and the United States as a whole. Jacobson states:

I conclude...that it is both technically and economically feasible to transition from a predominantly fossil fuel-based energy system to a 100% clean, renewable energy system for all energy sectors by 2050 with about 80% conversion by 2030.

Converting from fossil fuel energy to [wind, water, and solar technologies] would provide an estimated 3.9 million 40-year full-time construction jobs and about 2.0 million 40-year full-time operation jobs for the energy facilities alone.

These plans will result in each person in the U.S. in 2050 saving ~\$260 per year in energy costs (\$2013 dollars) and U.S. health and global climate costs per person decreasing by ~\$1,500 per year and ~\$8,300 per year, respectively.

Climate policy and legislation which ensure emissions reductions and sequestration of excess CO₂ consistent with what the best available science dictates is necessary for the protection of the fundamental rights of young people and future generations. The information in these Exhibits are additionally relevant to a forthcoming reintroduction of a Senate concurrent resolution, Children's Fundamental Rights and Climate Recovery ([S.Con.Res.47](#)), sponsored by Senator Merkley, supporting the *Juliana* youth plaintiffs. It recognizes the disproportionate effects of the climate crisis on children and their fundamental rights which demands renewed U.S. leadership and development of a national, science-based climate recovery plan. This resolution, originally introduced in September 2020, had the support of 63 cosponsors from both chambers.

Should you have any questions regarding the enclosed materials, please feel free to contact Liz Lee, OCT's government affairs staff attorney at liz@ourchildrenstrust.org.

Sincerely,

/s/ Julia Olson
Julia Olson
Executive Director
Our Children's Trust



Enclosures:

Exhibit A: *Juliana v. United States* Summary and Plaintiffs' Profiles

Exhibit B: Government Climate and Energy Actions, Plans, and Policies Must Be Based on a Maximum Target of 350 ppm Atmospheric CO₂ and 1°C by 2100 to Protect Young People and Future Generations

Exhibit C.1: 350 PPM Pathways for the United States (2019), Executive Summary, Evolved Energy Research

Exhibit C.2: 350 PPM Pathways for Florida (2020), Executive Summary and U.S. data from the Technical Supplement, Evolved Energy Research

Exhibit D: Expert Report of James H. Williams, Ph.D.

Exhibit E: Expert Report of Mark Jacobson, Ph.D.

Exhibit A:

Juliana v. United States Summary
and Plaintiffs' Profiles



Juliana v. United States

Young Americans Fight for Their Constitutional Rights and Climate Recovery

Background

Represented by attorneys at [Our Children's Trust](#), **21 young Americans filed their constitutional climate lawsuit, *Juliana v. United States*, against the executive branch of the U.S. government in 2015.** They assert that the government's affirmative actions causing climate change have violated their constitutional rights to life, liberty, property, and equal protection of the laws, and impaired essential public trust resources. They seek a declaration that the nation's energy system is unconstitutional. The youth are supported by a team of scientific experts who explain that atmospheric carbon dioxide levels must be reduced to 350 parts per million (ppm) by 2100, which would limit long-term warming to less than 1° Celsius, the safe target to stabilize the planet's climate system. Renowned energy experts published a 2019 [report](#) that demonstrates the technical and economic viability of the U.S. to meet this standard by 2100 and followed-up with a 2020 Florida [report](#) that includes updated U.S. data.

History

The U.S. District Court has repeatedly found that the youth plaintiffs have legitimate claims for trial. **In a ground-breaking decision in November 2016, the court found that the U.S. Constitution secures the fundamental right to a climate system capable of sustaining life;** that plaintiffs' injuries give them standing to bring their claims; and that the Court has authority to remedy the youth's injuries. Since that historic ruling, the defendants have relentlessly attempted to prevent *Juliana v U.S.* from going to trial. Four times in the Ninth Circuit Court of Appeals and twice in the U.S. Supreme Court, the courts ruled in favor of the youth.

On January 17, 2020, a divided panel of the Ninth Circuit Court of Appeals found for the plaintiffs in nearly every respect, but narrowly ruled that the courts cannot stop the executive branch of government from harming children with its policies that cause climate change. The plaintiffs filed a petition for rehearing on March 2, 2020, supported by ten *amicus curiae* briefs, including 24 members of Congress and constitutional law experts. On February 10, 2021, while a judge requested a vote, the Ninth Circuit denied the plaintiffs' request to rehear their lawsuit without explanation.

Looking Forward

To address the concerns of the Ninth Circuit, on March 9, 2021, plaintiffs requested to amend their complaint in the U.S. District Court seeking declaratory relief that the U.S. national energy system is unconstitutional in the hopes to go to trial. They can still seek review in the U.S. Supreme Court, if needed. **The Biden-Harris Administration and the Department of Justice now have a renewed opportunity to meet with the plaintiffs to discuss settling their claims,** and thereby protect their rights and the rights of children to come.

Support These Brave Plaintiffs

Please publicly support their right to have their constitutional claims upheld in a court of law. Support the congressional resolution recognizing children's fundamental rights and the need for a national, science-based climate recovery plan at ourchildrenstrust.org/congressional-resolution-2020 (Supported by 63 members of Congress when originally introduced in 2020.). Also, join future *amicus curiae* briefs in support of their constitutional rights and the judiciary exercising its Article III powers in their case. **Show our nation's children you care about their future, and the future of all generations to come.**

info@ourchildrenstrust.org | www.ourchildrenstrust.org



Juliana v. United States: Meet the Plaintiffs

Meet all 21 Juliana plaintiffs at ourchildrenstrust.org/federal-plaintiffs.
 Learn more about their stories in this [60 minutes segment](https://bit.ly/60minsjuliana) (bit.ly/60minsjuliana) and their
 visit to Congress in [this video](https://bit.ly/yearsprojectjuliana) (bit.ly/yearsprojectjuliana) from The YEARS Project

For over five years, these young plaintiffs, all of whom have been personally impacted by climate change, have been leading the game-changing litigation campaign to secure the legal right to a stable climate for young people, based on the best available science. In 2015, they filed their constitutional climate lawsuit against the U.S. government in the U.S. District Court for Oregon.



Kelsey Juliana, 24, Eugene, OR

Fighting climate change since she was 10, Kelsey has been increasingly exposed to hazardous wildfire smoke in her hometown. As a teenager, she participated in the Great March for Climate Action, marching 1,600 miles from Nebraska to D.C. Time Magazine recognized Kelsey as a Rising Star in its list of the Next 100 Most Influential People in the World.



Vic Barrett, 21, White Plains, NY

A Garifuna American, Vic has spoken about environmental justice issues and how his climate anxiety is increased because his identities — first generation, trans, indigenous, Latinx, Black, youth — make him uniquely vulnerable to the climate crisis. In 2019, he testified at a historic joint hearing of the House Foreign Affairs and Select Committee on the Climate Crisis alongside Greta Thunberg.



Jaime Butler, 20, Flagstaff, AZ

Jaime is of the Tangle People Clan, born of the Bitterwater Clan. She grew up in Cameron, Arizona on the Navajo Nation Reservation, but had to move due to water scarcity and failed attempts at dryland farming. Jaime knows firsthand the cultural and spiritual impacts of climate change as she and her tribe struggle to participate in their traditional ceremonies due to climate-related impacts.



Levi Draheim, 13, Satellite Beach, FL

Levi has lived most of his life on a barrier island in Florida, barely above sea level and literally washing away due to sea level rise and storms made worse by climate change. In 2019, Levi addressed a youth stakeholder's meeting with members of the Senate Democrats' Special Committee on the Climate Crisis at the United Nations Foundation. His baby sister is a source of motivation and inspiration.



Xiuhtezcatl Martinez, 20, Boulder, CO

Xiuhtezcatl is a renowned hip-hop artist and activist. He is also the former Youth Director and now Co-Chair of the executive board for Earth Guardians. He has experienced extreme weather events that have been exacerbated due to climate change, such as catastrophic flooding. Raised in the Aztec tradition, Xiuhtezcatl has spoken at the United Nations several times, including in English, Spanish, and his Native language, Nahuatl.

info@ourchildrenstrust.org | www.ourchildrenstrust.org

Exhibit B:

Government Climate and Energy Actions, Plans, and Policies
Must Be Based on a Maximum Target of 350 ppm
Atmospheric CO₂ and 1°C by 2100 to Protect Young People
and Future Generations



Government Climate and Energy Actions, Plans, and Policies Must Be Based on a Maximum Target of 350 ppm Atmospheric CO₂ and 1°C by 2100 to Protect Young People and Future Generations

INTRODUCTION

Human laws can adapt to nature's laws, but the laws of nature will not bend for human laws. Government climate and energy policies **must** be based on the best available climate science to protect our climate system and vital natural resources on which human survival and welfare depend, and to ensure that young people's and future generations' fundamental and inalienable human rights are protected.

Because carbon dioxide (CO₂) is the primary driver of climate destabilization and ocean warming and acidification, all government policies regarding CO₂ pollution and CO₂ sequestration should be aimed at reducing global CO₂ concentrations **below 350 parts per million (ppm) by 2100**. Global atmospheric CO₂ levels, as of 2019, are approximately 407 ppm and rising.¹ An emission reductions and sequestration pathway back to 350 ppm could limit peak warming to approximately 1.3°C this century and stabilize long-term heating at 1°C above pre-industrial temperatures.

As explained in more detail below, there are numerous scientific bases and lines of evidence supporting setting 350 ppm and 1°C by 2100 as the uppermost safe limit for atmospheric CO₂ concentrations and global warming. Beyond 2100, atmospheric CO₂ may need to return to below 300 ppm to prevent the complete melting of Earth's ice sheets and protect coastal cities from sea level rise. Fortunately, it is still not only technically and economically feasible to return to those levels, but transitioning to renewable energy sources will provide significant economic and public health benefits and improve quality-of-life.

WHY 350 PPM AND 1°C LONG-TERM WARMING?

Three lines of robust and conclusive scientific evidence, based on the paleo-climate record and real-world observations show that above an atmospheric CO₂ concentration of 350 ppm there is: 1) significant global energy imbalance; 2) massive ice sheet destabilization and sea level rise; and 3) ocean warming and acidification resulting in the bleaching death of coral reefs and other marine life.

¹ Ed Dlugokencky & Pieter Tans, NOAA/ESRL, www.esrl.noaa.gov/gmd/ccgg/trends/

1) Energy Balance

Earth's energy flow is out of balance. Because of a buildup of CO₂ in our atmosphere, due to human activities, primarily the burning of fossil fuels and deforestation,² more solar energy is retained in our atmosphere and less energy is released back into space.³ The energy imbalance of the Earth is roughly equivalent to 2500 Camp Creek⁴ fires **per day** burning around the world.⁵ Returning CO₂ concentrations to below 350 ppm would restore the energy balance of Earth by allowing as much heat to escape into space as Earth retains, an important historic balance that has kept our planet in the sweet spot for the past 10,000 years, supporting stable sea levels, enabling productive agriculture, and allowing humans and other species to thrive.⁶ The paleo-climate record shows that CO₂ levels, temperature, and sea level all move together (see Figure 1). Humans have caused CO₂ levels to shoot off the chart (circled in red), rising to levels unprecedented over the past 3 million years, and causing the energy imbalance.⁷

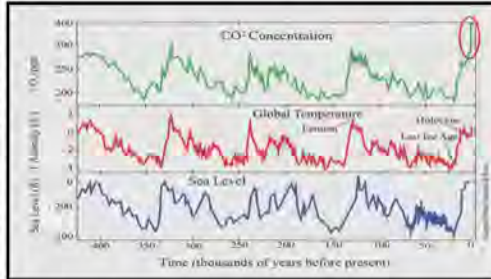


Figure 1- Evidence from the paleo-climate record showing the relationship between CO₂ concentration, global temperature, and sea level.

2) Ice Sheets and Sea Level Rise

The last time the ice sheets appeared stable in the modern era was in the 1980s when the atmospheric CO₂ concentration was below 350 ppm. The consequences of > 350 ppm and 1°C of warming are already visible, significant, and dangerous for humanity. With just 1°C of warming, glaciers in all regions of the world are shrinking, and the rate at which they are melting is accelerating.⁸ Large parts of the Greenland and Antarctic ice sheets, which required millennia to grow, are teetering on the edge

² Intergovernmental Panel on Climate Change, *Summary for Policymakers, Climate Change 2014: Impacts, Adaptation, and Vulnerability* 5 (2014).

³ James Hansen et al., *Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature*, PLOS ONE 8:12 (2013) [hereinafter *Assessing "Dangerous Climate Change"*].

⁴ The Camp Creek fire was the 2018 California fire, the deadliest and most destructive in the state's history, that burned over 150,000 acres (almost 240 square miles).

⁵ Steven W. Running, *Declaration in Support of Plaintiffs, Juliana v. United States*, No. 18-56082, Doc. 21-12 (9th Cir. Feb. 7, 2019).

⁶ James Hansen, *Storms of My Grandchildren* 166 (2009).

⁷ Willett et al., *Mid-Pleistocene transition in glacial cycles explained by declining CO₂ and regolith removal*, Science Advances (2019).

⁸ Zemp et al., *Global glacier mass changes and their contributions to sea-level rise from 1961–2016*, Nature (2019); B. Menounos, *Heterogeneous Changes in Western North American Glaciers Linked to Decadal Variability in Zonal Wind Strength*, Geophysical Research Letters (2018).

of irreversible disintegration, a point that if reached, would lock-in major ice sheet mass loss, sea level rise of many meters, and worldwide loss of coastal cities – a consequence that would be irreversible on any timescale relevant to humanity (see Figure 2).⁹ Greenland's ice sheet melt is currently occurring faster than anytime during the last three and a half centuries, with a 33% increase alone since the 20th century.¹⁰ The paleo-climate record shows the last time atmospheric CO₂ levels were over 400 ppm, the seas were **70 feet higher** than they are today and that heating consistent with CO₂ concentrations as low as 450 ppm may have been enough to melt almost all of Antarctica.¹¹ While many experts are predicting multi-meter sea level rise this century, even NOAA's modest estimate of 3-6 feet by 2100 would impact between 4 and 13 million Americans (see Figure 3).¹²



Figure 2: Antarctic melt water from the Nansen ice shelf.

Most climate models represent sea level rise as a gradual linear response to melting ice sheets, but the historic climate record shows something very different. In reality, seas do not rise slowly and predictably but rather in quick pulses as ice sheets destabilize.¹³ Scientists believe we have a chance to preserve the large ice sheets of Greenland and

Antarctica and most of our shorelines and ecosystems if we limit long-term warming by the end of the century to no more than 1°C above pre-industrial levels (short-term warming will inevitably exceed 1°C but must not exceed 1°C for more than a short amount of time).

⁹ Hansen, Assessing "Dangerous Climate Change," at 13; see also James Hansen et al., *Ice Melt, Sea Level Rise and Superstorms: Evidence from Paleoclimate Data, Climate Modeling, and Modern Observations that 2 °C Global Warming Could be Dangerous*, Atmos. Chem. & Phys. 16, 3761 (2016) [hereinafter *Ice Melt, Sea Level Rise and Superstorms*].

¹⁰ Trusel, L. D., et al., *Nonlinear rise in Greenland runoff in response to post-industrial Arctic warming*, Nature (2018).

¹¹ Dec. of Dr. James E. Hansen, *Juliana et al., v. United States et al.*, No. 6:15-cv-01517-TC, 14 (D. Or. Aug. 12, 2015); Intergovernmental Panel on Climate Change: 2007 Working Group I: The Physical Science Basis, Chapter 6.3.2, What Does the Record of the Mid-Pliocene Show?; Dowsett & Cronin, *High eustatic sea level during the middle Pliocene: Evidence from the southeastern U.S. Atlantic Coastal Plain*, Geology (1990); Shackleton et al., *Pliocene stable isotope stratigraphy of ODP Site 846*, Proceedings of the Ocean Drilling Program, Scientific Results (1995).

¹² NOAA, *Examining Sea Level Rise Exposure for Future Populations*, <https://coast.noaa.gov/digitalcoast/stories/population-risk>.

¹³ Wanless, H.R., et al., *Dynamics and Historical Evolution of the Mangrove/Marsh Fringe Belt of Southwest Florida, in Response to Sea-level History, Biogenic Processes, Storm Influences and Climate Fluctuations*, Semi-annual Research Report (June 1993 to February 1994); Hansen, *Ice Melt, Sea Level Rise and Superstorms*, at 3761; Hansen, Assessing "Dangerous Climate Change," at 20.



Figure 3: South Florida, including Miami, will face significant inundation with 6 feet of sea level rise.

3) Ocean Warming and Acidification

Our oceans have absorbed 93% of the excess heat in the atmosphere trapped by greenhouse gases (see Figure 4) as well as approximately 30% of CO₂ emitted into the atmosphere, causing ocean temperatures to surge and the ocean to become more acidic.¹⁴ Indeed, our oceans are warming much more rapidly than previously-thought.¹⁵ Many marine ecosystems, and particularly coral reef ecosystems, cannot tolerate the increased warming and acidity of ocean waters that result from increased CO₂ levels.¹⁶ At today's CO₂ concentration, around 407 ppm,¹⁷ critically important ocean ecosystems, such as coral reefs, are rapidly declining and will be irreversibly damaged from high ocean temperatures and repeated mass bleaching events if we do not quickly curtail emissions (see Figures 5 and 6).¹⁸ According to the Intergovernmental Panel on Climate Change, bleaching events are occurring more frequently than the IPCC previously projected and 70-90% of the world's coral

¹⁴ Hansen, Assessing "Dangerous Climate Change," at 1; *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press, 2013); Cheng et al., *How fast are the oceans warming?* 363 *Science* 128 (2019); National Oceanic and Atmospheric Administration, *What is Ocean Acidification?*, <https://oceanservice.noaa.gov/facts/acidification.html>.

¹⁵ Cheng, L. et al., *How fast are the oceans warming?*, 363 *Science* 128 (2019).

¹⁶ Hughes et al., *Global warming impairs stock-recruitment dynamics of corals*, *Nature* (2019).

¹⁷ Ed Dlugokencky and Pieter Tans, NOAA/ESRL, www.esrl.noaa.gov/gmd/ccgg/trends/.

¹⁸ Frieler, K. et al., *Limiting global warming to 2 degrees C is unlikely to save most coral reefs*, *Nature Climate Change* 3:165-170. (2013); Veron, J., et al; *The coral reef crisis: The critical importance of < 350ppm CO2*, *Marine Pollution Bulletin* 58:1428-1436 (2009); Hughes, T. et al., *Spatial and temporal patterns of mass bleaching of corals in the Anthropocene*, *Science* 359: 80-83 (2018); Hughes, T. et al. *Global warming impairs stock-recruitment dynamics of corals*, *Nature* (2019).

reefs could disappear as soon as 2030 (the IPCC also predicts 99% of coral reefs will die with 2°C warming).¹⁹ Even the recent National Climate Assessment acknowledged that coral reefs in Florida, Hawaii, Puerto Rico, and the U.S. Virgin Islands have been harmed by mass bleaching and coral diseases and could disappear by mid-century as a result of warming waters.²⁰ Scientists believe we can protect marine life and prevent massive bleaching and die-off of coral reefs only by rapidly returning CO₂ levels to below 350 ppm.²¹

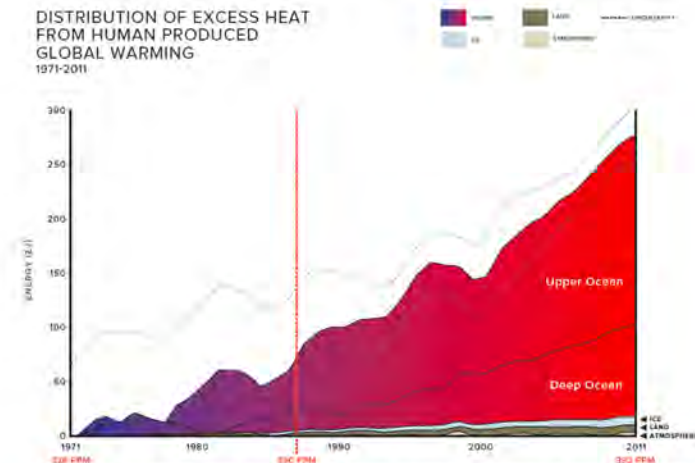


Figure 4: Over 90% of the excess energy from human caused climate change has been absorbed by the oceans, adding energy to storms and harming coral reefs around the globe.

No scientific institution, including the IPCC, has ever concluded that 2°C warming or 450 ppm would be safe for ocean life. According to Dr. Ove Hoegh-Guldberg, one of the world's leading experts on ocean warming and acidification, and a Coordinating Lead Author on the "Oceans" chapter of the IPCC's Fifth Assessment Report and on the "Impacts of 1.5°C global warming on natural and human systems" of the IPCC's Special Report on 1.5°C:

¹⁹ Hoegh-Guldberg, Ove, et al., *Impacts of 1.5°C Global Warming on Natural and Human Systems*. In *Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* at pp. 225-226 (2018); IPCC, *Summary for Policymakers of IPCC Special Report on Global Warming of 1.5°C Approved by Governments* (2018).

²⁰ Pershing, A. J., et al., *Oceans and Marine Resources*. In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, USGCRP (2018).

²¹ Veron, J., et al., *The coral reef crisis: The critical importance of <350 ppm CO₂*, 58 *Marine Pollution Bulletin* 1428 (2009).



Figure 5: Healthy coral like this are already gravely threatened and will likely die with warming of 1.5°C.

"Allowing a temperature rise of up to 2°C would seriously jeopardize ocean life, and the income and livelihoods of those who depend on healthy marine ecosystems. Indeed, the best science available suggests that coral dominated reefs will completely disappear if carbon dioxide concentrations exceed much more than today's concentrations. Failing to restrict further increases in atmospheric carbon dioxide will eliminate coral reefs as we know them and will deny future generations of children from enjoying these wonderful ecosystems."²²



Figure 6: Bleached coral from warmer ocean temperatures.

ADDITIONAL OBSERVATIONS ILLUSTRATE THE DANGERS OF INCREASED WARMING

In addition to the evidence discussed above which illustrates the necessity of ensuring that the atmospheric CO₂ concentration returns to no more than 350 ppm, based on present day observations about climate impacts occurring **now**, it is clear that the present level of 1°C is already causing significant climate impacts and additional warming will exacerbate these already dangerous impacts. Climate impacts that are already being experienced today include:

- Declining snowpack and rising temperatures are increasing the length and severity of drought conditions, especially in the western United States and Southwest, causing problems for agriculture users, forcing some people to relocate, and leading to water restrictions.²³
- In the western United States, the wildfire season is now almost three months longer (87 days) than it was in the 1980s.²⁴

²² *Id.*

²³ Steven W. Running, *Declaration in Support of Plaintiffs, Juliana v. United States*, No. 18-36082, Doc. 21-12 (9th Cir. Feb. 7, 2019).

²⁴ Steven W. Running, *Declaration in Support of Plaintiffs, Juliana v. United States*, No. 18-36082, Doc. 21-12 (9th Cir.

- Extreme weather events, such as intense rainfall events that cause flooding, are increasing in frequency and severity because a warmer atmosphere holds more moisture.²⁵ What are supposedly 1-in-1000-year rainfall events are now occurring with alarming frequency – in 2018 there were at least five such events.²⁶
- Tropical storms and hurricanes are increasing in intensity, both in terms of rainfall and windspeed, as warmer oceans provide more energy for the storms (we saw this with Hurricanes Harvey, Irma, and Maria in 2017) (Figure 7).²⁷
- Terrestrial ecosystems are experiencing compositional and structural changes, with major adverse consequences for ecosystem services.²⁸
- Terrestrial, freshwater, and marine species are experiencing a significant decrease in population size and geographic range, with some going extinct and others are facing the very real prospect of extinction – the rapid rate of extinctions has been called the 6th mass extinction.²⁹
- Human health and well-being are already being affected by heat waves, floods, droughts, and extreme events; infectious diseases; quality of air, food, and water.³⁰ Doctors and leading medical institutions are calling climate change a “health emergency.”³¹ Children are being uniquely impacted by climate change.³²
- In addition to physical harm, climate change is causing mental health impacts, ranging from stress to suicide, due to exposure to climate impacts, displacement, loss of income, chronic stress, and other impacts of climate change.³³



Figure 7: Flooding in Port Arthur, Texas on August 13, 2018 after Hurricane Harvey.

Feb. 7, 2019).

²⁵ Kevin E. Trenberth, *Declaration in Support of Plaintiffs, Juliana v. United States*, No. 18-36082, Doc. 21-3 (9th Cir. Feb. 7, 2019).

²⁶ Belles, F., *America's 'One-in-1,000-Year' Rainfall Events in 2018*, The Weather Channel (Sept. 27, 2018).

²⁷ Kevin E. Trenberth, *Declaration in Support of Plaintiffs, Juliana v. United States*, No. 18-36082, Doc. 21-3 (9th Cir. Feb. 7, 2019).

²⁸ Nolan et al., *Past and future global transformation of terrestrial ecosystems under climate change*, Science (2018).

²⁹ G. Ceballos, et al., *Accelerated modern human-induced species losses: Entering the sixth mass extinction*, Science Advances (2015); Steven W. Running, *Expert Report, Juliana v. United States*, No. 6:15-cv-01517-TC, Doc. 264-1 (D. Or. June 28, 2018).

³⁰ Ebi, K. L., et al., *Human Health*, In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, USGCRP (2018).

³¹ Solomon, C. G. & LaRocque R. C., *Climate Change – A Health Emergency*, N. Engl. J. Med. 380:3 (2019).

³² May, C., et al., *Northwest*, In *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II*, USGCRP (2018); Watts, N., et al., *The 2018 report of the Lancet Countdown on health and climate change: shaping the health of nations for centuries to come*, Lancet, Vol. 392 at 2482 (2018); *Brief of Amici Curiae Public Health Experts, Public Health Organizations, and Doctors in Support of Plaintiffs*, No. 18-36082, Doc. 47 (9th Cir. Mar. 1, 2019).

³³ Lise Van Susteren, *Expert Report, Juliana v. United States*, No. 6:15-cv-01517-TC, Doc. 271-1 (D. Or. June 28, 2018).



Figure 8: Offutt Air Force Base was impacted by flood waters during flooding in Nebraska during spring 2019.

• As Congress has recognized, “climate change is a direct threat to the national security of the United States and is impacting stability in areas of the world both where the United States Armed Forces are operating today, and where strategic implications for future conflict exist.”³⁴ Senior military leaders have called climate change “the most serious national security threat facing our Nation today.”³⁵ a conclusion similarly recognized by our Nation’s intelligence community.³⁶ Climate change is increasing

food and water shortages, pandemic disease, conflicts over refugees and resources, and destruction to homes, land, infrastructure, and military assets, directly threatening our military personnel and the “Department of Defense’s ability to defend the Nation” (see Figure 8).³⁷

- Climate change is already causing vast economic harm in the United States. Since 1980 the United States has experienced 246 climate and weather disasters that each caused damages in excess of \$1 billion, for a total cost of \$1.6 trillion.³⁸ In 2018 alone, Congress appropriated more than \$130 billion for weather and climate related disasters.³⁹

These already serious impacts will grow in severity and will impact increasingly large numbers of people and parts of the world if CO₂ concentrations continue to rise. If we want our children and grandchildren to have a safe planet to live on, full of health and biodiversity rather than chaos and conflict, we must follow the best scientific prescription to restore Earth’s energy balance and avoid the destruction of our planet’s atmosphere, climate, and oceans.

³⁴ National Defense Authorization Act for Fiscal Year 2018, Pub. L. No. 115-91, 131 Stat. 1358.

³⁵ Vice Admiral Lee Gunn, USN (Ret.), *Declaration in Support of Plaintiffs, Juhana v. United States*, No. 18-36082, Doc. 21-17 (9th Cir. Feb. 7, 2019) (emphasis in original); see also CNA Military Advisory Board, *National Security and the Accelerating Risks of Climate Change* (2014), https://www.cna.org/cna_files/pdf/MAB_5-8-14.pdf.

³⁶ National Intelligence Council, *Implications for US National Security of Anticipated Climate Change* (Sept. 2016), https://www.dni.gov/files/documents/Newsroom/Reports%20and%20Pubs/Implications_for_US_National_Security_of_Anticipated_Climate_Change.pdf.

³⁷ U.S. Dep’t of Defense, *2014 Climate Change Adaptation Roadmap* (2014), https://www.acq.osd.mil/cie/downloads/CCARprint_wForward_e.pdf.

³⁸ NOAA, *Billion Dollar U.S. Weather/Climate Disasters 1980-2019* (2019), <http://www.ncdc.noaa.gov/billions/events.pdf>.

³⁹ U.S. House of Representatives Committee on the Budget, *The Budgetary Impact of Climate Change 2* (Nov. 27, 2018).

INTERNATIONAL POLITICAL TARGETS OF 1.5°C OR 2°C ARE NOT SCIENCE-BASED AND ARE NOT SAFE

International, politically-recognized targets like 1.5°C or “well below” 2°C – which are commonly associated with long-term atmospheric CO₂ concentrations of 425 and 450 ppm, respectively – have not been and are not presently considered safe or scientifically-sound targets for present or future generations.

Importantly, the Intergovernmental Panel on Climate Change (“IPCC”) has never established nor endorsed a target of 1.5°C or 2°C warming as a limit below which the climate system will be stable.⁴⁰ It is beyond the IPCC’s declared mandate to endorse a particular threshold of warming as “safe” or “dangerous.”⁴¹ As the IPCC makes clear, “each major IPCC assessment has examined the impacts of [a] multiplicity of temperature changes but has left [it to the] political processes to make decisions on which thresholds may be appropriate.”⁴²

Neither 1.5°C nor 2°C warming above pre-industrial levels has ever been considered “safe” from either a political or scientific point of view. The 2°C figure was originally adopted in the political arena “from a set of heuristics,” and it has retained predominantly political character ever since.⁴³ It has recently been all-but-abandoned as a credible policy goal, in light of the findings in IPCC’s 1.5°C Special Report, and the mounting evidence leading up to its publication, that 2°C would be catastrophic relative to lower, still-achievable levels of warming.⁴⁴

On the other hand, the idea of a 1.5°C target was first raised by the Association of Small Island States (AOSIS) in the negotiations leading up to the ill-fated 2009 UNFCCC Conference of Parties in Copenhagen.⁴⁵ AOSIS, however, was explicitly advocating a *well below* 1.5°C and *well below* 1°C target, on the basis of the research of Dr. James Hansen and his colleagues.⁴⁶ Political compromise on this science-based target then led to the adoption of a goal of “pursuing efforts to limit the

⁴⁰ Dec. of Dr. James E. Hansen, *Jufiana et al., v. United States et al.*, No. 6:15-cv-01517-TC, 5 (D. Or. Aug. 12, 2015).

⁴¹ IPCC, *Climate Change 2014: Mitigation of Climate Change, Contribution of Working Group III to the Fifth Assessment Report*, 125 (2014), http://report.mitigation2014.org/reports/ipcc_wg3_ar5_chapter1.pdf.

⁴² Randalls, S. *History of the 2°C Temperature Target*, 1, WIREs Climate Change 598, 603 (2010); Jaeger, C., and J. Jaeger, *Three views of two degrees*, 11(Suppl 1) Regional Environmental Change S15 (2011).

⁴³ IPCC, *Summary for policymakers* at 13-14, *Climate Change 2014: Impacts, Adaptation, and Vulnerability* (2014), http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ar5_wgII_spm_en.pdf; UNFCCC, *Report on the structured expert dialogue on the 2013–2015 review*, 18 (2015),

<http://unfccc.int/resource/docs/2015/sb/eng/inf01.pdf>; Petra Tschakert, *1.5°C or 2°C: a conundrum's view from the science-policy interface at COP20 in Lima, Peru*, *Climate Change Responses* 8 (2015), <http://www.climatechangeresponses.com/content/2/1/1>; IPCC, *Global warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* (2018), <https://www.ipcc.ch/sr15/>.

⁴⁴ See Webster, R. *A brief history of the 1.5°C target*, *Climate Change News* (December 10, 2015), <http://www.climatechangenews.com/2015/12/10/a-brief-history-of-the-1-5c-target/>; *Submission from Grenada on behalf of AOSIS to the Ad Hoc Working Group on Further Commitments for Annex I Parties Under the Kyoto Protocol*, U.N. Doc. FCCC/KP/AWG/2009/MISC.1/Add.1 (25 March 2009),

<https://unfccc.int/sites/default/files/resource/docs/2009/awg7/eng/misc11a01.pdf>.

⁴⁵ *Submission from Grenada on behalf of AOSIS to the Ad Hoc Working Group on Further Commitments for Annex I Parties Under the Kyoto Protocol*, U.N. Doc. FCCC/KP/AWG/2009/MISC.1/Add.1 (25 March 2009), <https://unfccc.int/sites/default/files/resource/docs/2009/awg7/eng/misc11a01.pdf>, citing Hansen, J. et al. *Target Atmospheric CO₂: Where Should Humanity Aim?* 2 *The Open Atmospheric Science Journal* 217 (2008).

temperature increase to 1.5°C above pre-industrial levels” in Article 2 of the Paris Agreement. Yet the 2018 IPCC Special Report on 1.5°C has made clear that allowing a temperature rise of 1.5°C:

is **not considered ‘safe’** for most nations, communities, ecosystems, and sectors and poses significant risks to natural and human systems as compared to current warming of 1°C (*high confidence*).⁴⁶

Dr. James Hansen warns that “distinctions between pathways aimed at 1°C and 2°C warming are much greater and more fundamental than the numbers 1°C and 2°C themselves might suggest. These fundamental distinctions make scenarios with 2°C or more global warming far more dangerous, so dangerous, we [James Hansen et al.] suggest, that aiming for the 2°C pathway would be foolhardy.”⁴⁷ This target is at best the equivalent of “flip[ping] a coin in the hopes that future generations are not left with few choices beyond mere survival. This is not risk management, it is recklessness and we must do better.”⁴⁸

Tellingly, more than 45 eminent scientists from over 40 different institutions have published in peer-reviewed journals finding that the maximum level of atmospheric CO₂ consistent with protecting humanity and other species is 350 ppm, and no one, including the IPCC, has published any scientific evidence to counter that 350 is the maximum safe concentration of CO₂.⁴⁹

A 1.5° OR 2°C TARGET RISKS LOCKING-IN DANGEROUS FEEDBACKS

The longer the length of time atmospheric CO₂ concentrations remain at dangerous levels (i.e., above 350 ppm) and there is an energy imbalance in the atmosphere, the risk of triggering, and locking-in, dangerous warming-driven feedback loops increases. The 1.5°C or 2°C target reduces the likelihood that the biosphere will be able to sequester CO₂ due to carbon cycle feedbacks and shifting climate zones.⁵⁰ As temperatures warm, forests burn and soils warm, releasing their carbon. These natural carbon “sinks” become carbon “sources” and a portion of the natural carbon sequestration necessary to drawdown excess CO₂ simply disappear. Another dangerous feedback includes the release of methane, a potent greenhouse gas, as the global tundra thaws.⁵¹ These feedbacks might show little change in the short-term, but can hit a point of no return, even at a 1.5°C or 2°C temperature increase, which will trigger accelerated heating and sudden and *irreversible* catastrophic impacts. Moreover,

⁴⁶ Roy, J., et al., *Sustainable Development, Poverty Eradication and Reducing Inequalities*. In *Global Warming of 1.5°C: An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* at 447 (2018) (emphasis added).

⁴⁷ *Id.* at 15.

⁴⁸ Matt Vespa, *Why 350? Climate Policy Must Aim to Stabilize Greenhouse Gases at the Level Necessary to Minimize the Risk of Catastrophic Outcomes*, 36 *Ecology Law Currents* 185, 186 (2009), http://www.biologicaldiversity.org/publications/papers/Why_350.pdf.

⁴⁹ James Hansen, et al., *Target Atmospheric CO₂: Where Should Humanity Aim?* (2008); James Hansen, et al., *Assessing “Dangerous Climate Change”: Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature* (2013); James Hansen, et al., *Ice Melt, Sea Level Rise and Superstorms: Evidence From Paleoclimate Data, Climate Modeling, and Modern Observations That 2°C Global Warming Could Be Dangerous* (2016); James Hansen, et al., *Young People’s Burden: Requirement of Negative CO₂ Emissions* (2017); Veron, J., et al., *The Coral Reef Crisis: The Critical Importance of <350 ppm CO₂* (2009); Frieder, K., et al., *Limiting global warming to 2 °C is unlikely to save most coral reefs* (2012).

⁵⁰ *Id.* at 15, 20.

⁵¹ *Id.*

an emission reduction target aimed at 2°C would “yield a larger eventual warming because of slow feedbacks, probably at least 3°C.”⁵² Once a temperature increase of 2°C is reached, there will already be “additional climate change ‘in the pipeline’ even without further change of atmospheric composition.”⁵³

**IT IS TECHNOLOGICALLY AND ECONOMICALLY FEASIBLE TO
REDUCE CO₂ LEVELS TO 350 PPM BY 2100**

There are two steps to reducing CO₂ levels to 350 ppm by the end of the century: 1) reducing CO₂ emissions; and 2) sequestering excess CO₂ already in the atmosphere. Carbon dioxide emission reductions of approximately 80% by 2030 and close to 100% by 2050 (in addition to the requisite CO₂ sequestration) are necessary to keep long-term warming to 1°C and the atmospheric CO₂ concentration to 350 ppm. Emission reduction targets that seek to reduce CO₂ emissions by 80% by 2050 are consistent with long-term warming of 2°C and an atmospheric CO₂ concentration of 450 ppm, which, as described above, would result in catastrophic and irreversible impacts for the climate system and oceans. Importantly, it is economically and technologically feasible to transition the entire U.S. energy system to a zero-CO₂ energy system by 2050 and to drawdown the excess CO₂ in the atmosphere through reforestation and carbon sequestration in soils.⁵⁴

Deep Decarbonization Pathways Project and Evolved Energy Research recently completed research and very sophisticated modeling describing a nearly complete phase out of fossil fuels in the U.S. by 2050.⁵⁵ They describe six different technologically feasible pathways to drastically, and quickly, cut our reliance on fossil fuels and achieve the requisite level of emissions reductions in the U.S. while meeting our nation’s forecasted energy needs. All of the 350 ppm pathways rely on four pillars of action: a) investment in energy efficiency; b) electrification of everything that can be electrified; c) shifting to very low-carbon and primarily renewable electricity generation; and d) carbon dioxide capture as fossil fuels are phased out. The six scenarios are used to evaluate the ability to meet the targets even absent one key technology. For example, one scenario describes a route to 350 absent construction of new nuclear facilities; another illustrates getting to 350 with extremely limited biomass technology; still another describes a way to 350 without any carbon capture and storage. Even absent a key technology, each of these six routes are viable and cost effective.

The study also concludes that the cost of the energy system transition is affordable. The total cost of supplying and using energy in the U.S. in 2016 was about 5.6% of GDP (see Figure 9).⁵⁶ A transition from fossil fuels to low carbon energy sources is expected to increase those costs by no more than an additional two to three percent of GDP. Even with this small and temporary added expense, the cost would still be well below the 9.5% of GDP spent on the energy system in 2009 (not to mention well below the harm to the economy caused by climate change). Once the transition is complete, the cost

⁵² Hansen, Assessing “Dangerous Climate Change,” at 15.

⁵³ *Id.* at 19.

⁵⁴ See Mark Z. Jacobson et al., *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States*, 8 Energy & Env’tl. Sci. 2093 (2015) (for plans on how the United States and over 100 other countries can transition to a 100% renewable energy economy see www.thesolutionsproject.org); see also Arjun Makhijani, Carbon-Free, Nuclear-Free: A Roadmap for U.S. Energy Policy (2007); B. Haley et al., *350 ppm pathways for the United States* (2019).

⁵⁵ B. Haley et al., *350 ppm pathways for the United States* (2019).

⁵⁶ B. Haley et al., *350 ppm pathways for the United States* (2019).

of energy will remain low and stable because we will no longer be dependent on volatile global fossil fuel markets for our energy supplies. As Nobel Laureate Economist Dr. Joseph Stiglitz has stated: "[t]he benefits of making choices today that limit the economic costs of climate change far outweigh any economic costs associated with limiting our use of fossil fuels."⁵⁷

Other experts have already prepared plans for all 50 U.S. states as well as for over 139 countries that demonstrate the technological and economic feasibility of transitioning off of fossil fuels toward 100% of energy, for all energy sectors, from clean and renewable energy sources: wind, water, and sunlight by 2050 (with 80% reductions in fossil fuels by 2030).⁵⁸

Products already exist that enable new construction or retrofits that result in zero greenhouse gas buildings. We have the technology to meet all electricity needs with zero-emission electric generation. We know how to achieve zero-emission transportation, including aviation. These actions result in other benefits, such as improved health, job creation, and savings on energy costs.

The amount of natural carbon sequestration required is also proven to be feasible. Researchers have evaluated the potential to drawdown excess carbon dioxide in the atmosphere by increasing the carbon stored in forests, soils, and wetlands, and have found significant potential for these natural systems to support a return to 350 ppm by the end of the century.⁵⁹ We know the agricultural, rangeland, wetland, and forest management practices that decrease greenhouse gas emissions and increase sequestration.

There is no scientific, technological, or economic reason to *not* adopt a 350 ppm and 1°C by 2100 target. There are abundant reasons for doing so, not the least of which is to do our best through human laws to respect the laws of nature and create a safe and healthy world for children and future generations who will walk this Earth.

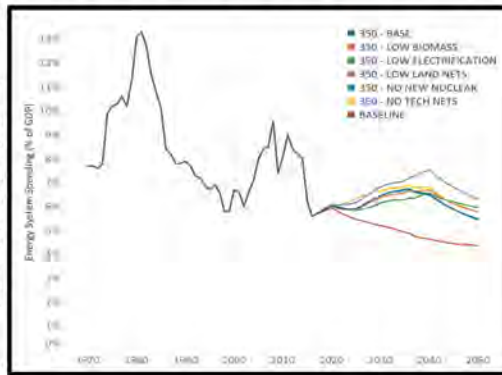


Figure 9: Historic and Projected Costs of Energy in the U.S.

⁵⁷ Joseph E. Stiglitz, Ph.D., *Declaration in Support of Plaintiffs, Juliana v. United States*, No. 18-16082, Doc. 21-14 (9th Cir. Feb. 7, 2019).

⁵⁸ Mark Z. Jacobson et al., *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmap for the 50 United States*, 8 Energy & Env'tl. Sci. 2093 (2015). For a graphic depicting the overview of the plan for the United States see: <https://theclimateproject.org/why-clean-energy/11map/countries/location/USA>.

⁵⁹ Benson W. Griscom et al., *Natural Climate Solutions*, Proceedings of the National Academies of Sciences (2017); Joseph E. Fargione et al., *Natural Climate Solutions for the United States*, Science Advances (2018).

Exhibit C.1:

350 PPM Pathways for the United States (2019)
Executive Summary
Evolved Energy Research

EXECUTIVE SUMMARY

350 PPM PATHWAYS
FOR THE UNITED STATES

May 8, 2019



EVOLVED
ENERGY
RESEARCH

Prepared by

Ben Haley, Ryan Jones, Gabe Kwok, Jeremy Hargreaves & Jamil Farbes

Evolved Energy Research

James H. Williams

University of San Francisco

Sustainable Development Solutions Network

DEEP DECARBONIZATION PATHWAYS PROJECT

DDPP

Executive Summary

This report describes the changes in the U.S. energy system required to reduce carbon dioxide (CO₂) emissions to a level consistent with returning atmospheric concentrations to 350 parts per million (350 ppm) in 2100, achieving net negative CO₂ emissions by mid-century, and limiting end-of-century global warming to 1°C above pre-industrial levels. The main finding is that 350 ppm pathways that meet all current and forecast U.S. energy needs are technically feasible using existing technology, and that multiple alternative pathways can meet these objectives in the case of limits on some key decarbonization strategies. These pathways are economically viable, with a net increase in the cost of supplying and using energy equivalent to about 2% of GDP, up to a maximum of 3% of GDP, relative to the cost of a business-as-usual baseline. These figures are for energy costs only and do not count the economic benefits of avoided climate change and other energy-related environmental and public health impacts, which have been described elsewhere.¹

This study builds on previous work, *Pathways to Deep Decarbonization in the United States* (2014) and *Policy Implications of Deep Decarbonization in the United States* (2015), which examined the requirements for reducing GHG emissions by 80% below 1990 levels by 2050 ("80 x 50").² These studies found that an 80% reduction by mid-century is technically feasible and economically affordable, and attainable using different technological approaches. The main requirement of the transition is the construction of a low carbon infrastructure characterized by high energy efficiency, low-carbon electricity, and replacement of fossil fuel combustion with decarbonized electricity and other fuels, along with the policies needed to achieve this transformation. The findings of the present study are similar but reflect both a more stringent emissions limit and the consequences of five intervening years without aggressive emissions reductions in the U.S. or globally.

¹ See e.g., *Risky Business: The Bottom Line on Climate Change*, available at <https://riskybusiness.org/>

² Available at <http://usddp.org/>.

The 80 x 50 analysis was developed in concert with similar studies for other high-emitting countries by the country research teams of the Deep Decarbonization Pathways Project, with an agreed objective of limiting global warming to 2°C above pre-industrial levels.³ However, new studies of climate change have led to a growing consensus that even a 2°C increase may be too high to avoid dangerous impacts. Some scientists assert that staying well below 1.5°C, with a return to 1°C or less by the end of the century, will be necessary to avoid irreversible feedbacks to the climate system.⁴ A recent report by the IPCC indicates that keeping warming below 1.5°C will likely require reaching net-zero emissions of CO₂ globally by mid-century or earlier.⁵ A number of jurisdictions around the world have accordingly announced more aggressive emissions targets, for example California's recent executive order calling for the state to achieve carbon neutrality by 2045 and net negative emissions thereafter.⁶

In this study we have modeled the pathways – the sequence of technology and infrastructure changes – consistent with net negative CO₂ emissions before mid-century and with keeping peak warming below 1.5°C. We model these pathways for the U.S. for each year from 2020 to 2050, following a global emissions trajectory that would return atmospheric CO₂ to 350 ppm by 2100, causing warming to peak well below 1.5°C and not exceed 1.0°C by century's end.⁷ The cases modeled are a 6% per year and a 12% per year reduction in net fossil fuel CO₂ emissions after 2020. These equate to a cumulative emissions limit for the U.S. during the 2020 to 2050 period of 74 billion metric tons of CO₂ in the 6% case and 47 billion metric tons in the 12% case. (For comparison, current U.S. CO₂ emissions are about 5 billion metric tons per year.) The emissions in both cases must be accompanied by increased extraction of CO₂ from the atmosphere using land-based negative emissions technologies ("land NETs"), such as reforestation, with greater extraction required in the 6% case.

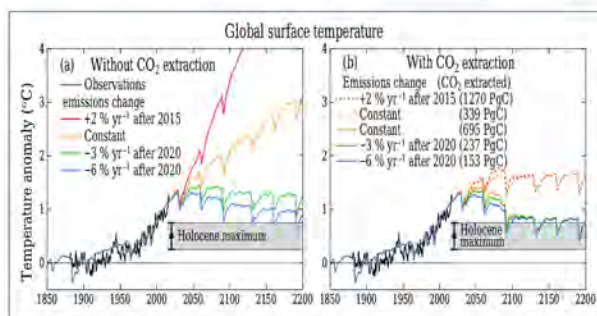
³ Available at <http://deepdecarbonization.org/countries/>.

⁴ James Hansen, et al. (2017) "Young people's burden: requirement of negative CO₂ emissions," *Earth System Dynamics*, <https://www.earth-syst-dynam.net/B/577/2017/esd-8-577-2017.html>.

⁵ Available at <https://www.ipcc.ch/sr15/>.

⁶ Available at https://www.gov.ca.gov/wp-content/uploads/2018/09/19_18-Executive-Order.pdf.

⁷ Hansen et al. (2017).

Figure ES1 Global surface temperature and CO₂ emissions trajectories. Hansen et al., 2017.

We studied six different scenarios: five that follow the 6% per year reduction path and one that follows the 12% path. All reach net negative CO₂ by mid-century while providing the same energy services for daily life and industrial production as the *Annual Energy Outlook (AEO)*, the Department of Energy's long-term forecast. The scenarios explore the effects of limits on key decarbonization strategies: bioenergy, nuclear power, electrification, land NETs, and technological negative emissions technologies ("tech NETs"), such as carbon capture and storage (CCS) and direct air capture (DAC).

Table ES1. Scenarios developed in this study.

Scenario	Average annual rate of CO ₂ emission reduction	2020-2050 maximum cumulative fossil fuel CO ₂ (million metric tons)	Year 2050 maximum net fossil fuel CO ₂ (million metric tons)	Year 2050 maximum net CO ₂ with 50% increase in land sink (million metric tons)
Base	6%	73,900	830	-250
Low Biomass	6%	73,900	830	-250
Low Electrification	6%	73,900	830	-250
No New Nuclear	6%	73,900	830	-250
No Tech NETS	6%	73,900	830	-250
Low Land NETS	12%	57,000	-200	-450

The scenarios were modeled using two new analysis tools developed for this purpose, EnergyPATHWAYS and RIO. As extensively described in the Appendix, these are sophisticated models with a high level of sectoral, temporal, and geographic detail, which ensure that the scenarios account for such things as the inertia of infrastructure stocks and the hour-to-hour dynamics of the electricity system, separately in each of fourteen electric grid regions of the U.S. The changes in energy mix, emissions, and costs for the six scenarios were calculated relative to a high-carbon baseline also drawn from the AEO.

Relative to 80 x 50 trajectories, a 350 ppm trajectory that achieves net negative CO₂ by mid-century requires more rapid decarbonization of energy plus more rapid removal of CO₂ from the atmosphere. For this analysis, an enhanced land sink 50% larger than the current annual sink of approximately 700 million metric tons was assumed.⁸ This would require additional sequestration of 25-30 billion metric tons of CO₂ from 2020 to 2100. The present study does not address the cost or technical feasibility of this assumption but stipulates it as a plausible value for calculating an overall CO₂ budget, based on consideration of the scientific literature in this area.⁹

⁸ U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016*, available at <https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016>

⁹ Griscom, Bronson W., et al. (2017) "Natural climate solutions." *Proceedings of the National Academy of Sciences* 114.44 (2017): 11645-11650; Fargione, Joseph E., et al. (2018) "Natural climate solutions for the United States." *Science Advances* 4.11: eaat1869.

Figure ES2 Four pillars of deep decarbonization - Base case



Energy decarbonization rests on the four principal strategies ("four pillars") shown in Figure ES2: (1) electricity decarbonization, the reduction in emissions intensity of electricity generation by about 90% below today's level by 2050; (2) energy efficiency, the reduction in energy required to provide energy services such as heating and transportation, by about 60% below today's level; (3) electrification, converting end-uses like transportation and heating from fossil fuels to low-carbon electricity, so that electricity triples its share from 20% of current end uses to 60% in 2050; and (4) carbon capture, the capture of otherwise CO₂ that would otherwise be emitted from power plants and industrial facilities, plus direct air capture, rising from nearly zero today to as much as 800 million metric tons in 2050 in some scenarios. The captured carbon may be sequestered or may be utilized in making synthetic renewable fuels.

Achieving this transformation by mid-century requires an aggressive deployment of low-carbon technologies. Key actions include retiring all existing coal power generation, approximately doubling electricity generation primarily with solar and wind power and electrifying virtually all passenger vehicles and natural gas uses in buildings. It also includes creating new types of infrastructure, namely large-scale industrial facilities for carbon capture and storage, direct air capture of CO₂, the production of gaseous and liquid biofuels with zero net lifecycle CO₂, and

the production of hydrogen from water electrolysis using excess renewable electricity. The scale of the infrastructure buildout by region is indicated in Figure ES3.

Figure ES3 Regional infrastructure requirements (Low Land NETS scenario)

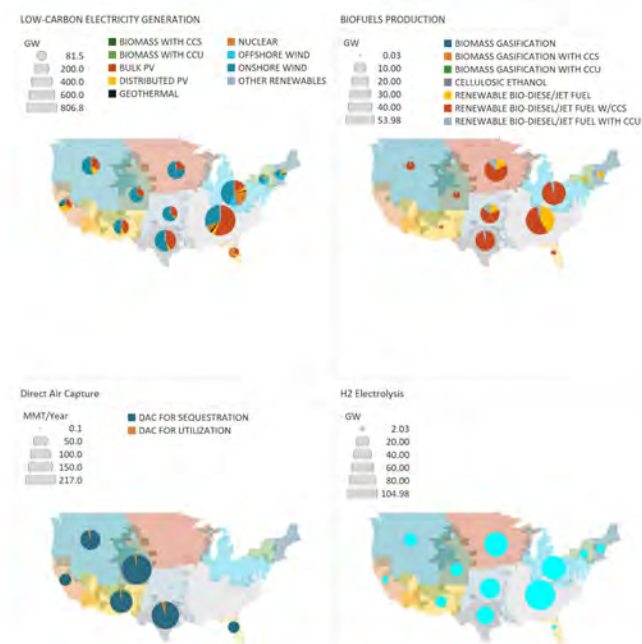


Figure ES4 shows that all scenarios achieve the steep reductions in net fossil fuel CO₂ emissions to reach net negative emissions by the 2040s, given a 50% increase in the land sink, including five that are limited in one key area. This indicates that the feasibility of reaching the emissions goals is robust due to the ability to substitute strategies. At same time, the more limited scenarios are, the more difficult and/or costly they are relative to the base case with all options available. Severe limits in two or more areas were not studied here but would make the emissions goals more difficult to achieve in the mid-century time frame.

Figure ES4 2020-2050 CO₂ emissions for the scenarios in this study

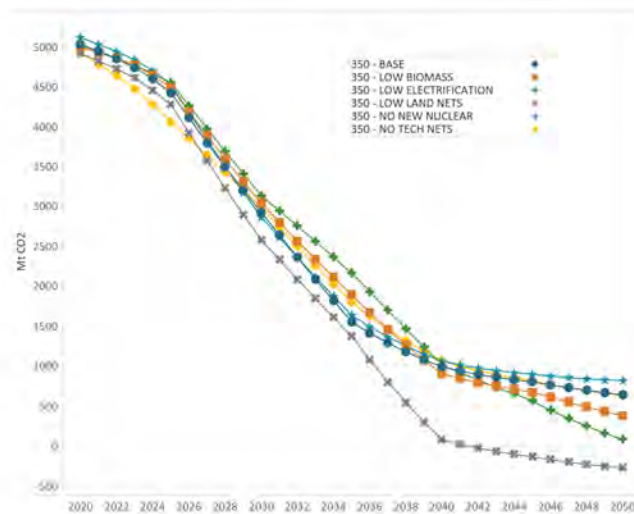
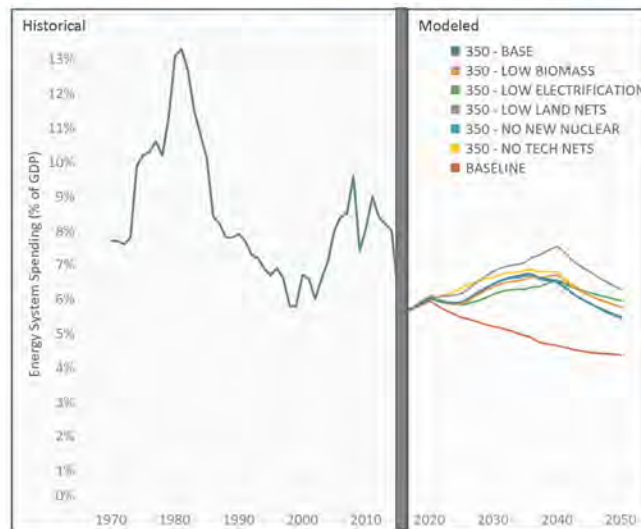


Figure ES5 shows U.S. energy system costs as a share of GDP for the baseline case and six 350 ppm scenarios in comparison to historical energy system costs. While the 350 ppm scenarios have a net cost of 2-3% of GDP more than the business as usual baseline, these costs are not out of line with historical energy costs in the U.S. The highest cost case is the Low Land NETs

scenario, which requires a 12% per year reduction in net fossil fuel CO₂ emissions. By comparison, the 6% per year reduction cases are more closely clustered. The lowest increase is the Base scenario, which incorporates all the key decarbonization strategies. These costs do not include any potential economic benefits of avoided climate change or pollution, which could equal or exceed the net costs shown here.

Figure ES5. Total energy system costs as percentage of GDP, modeled (R.) and historical (L.)



A key finding of this study is the potentially important future role of “the circular carbon economy.” This refers to the economic complementarity of hydrogen production, direct air capture of CO₂, and fuel synthesis, in combination with an electricity system with very high levels of intermittent renewable generation. If these facilities operate flexibly to take advantage of periods of excess generation, the production of hydrogen and CO₂ feedstocks can provide an economic use for otherwise curtailed energy that is difficult to utilize with electric energy

storage technologies of limited duration. These hydrogen and CO₂ feedstocks can be combined as alternatives for gaseous and liquid fuel end-uses that are difficult to electrify directly like freight applications and air travel. While the CO₂ is eventually emitted to the atmosphere, the overall process is carbon neutral as it was extracted from the air and not emitted from fossil reserves. A related finding of this work is that bioenergy with carbon capture and storage (BECCS) for power plants appears uneconomic, while BECCS for bio-refineries appears highly economic and can be used as an alternative source of CO₂ feedstocks in a low-carbon economy.

There are several areas outside the scope of this study that are important to provide a full picture of a low greenhouse gas transition. One important area is better understanding of the potential and cost of land-based NETs, both globally and in the U.S. Another is the potential and cost of reductions in non-CO₂ climate pollutants such as methane, nitrous oxide, and black carbon. Finally, there is the question of the prospects for significant reductions in energy service demand, due to lifestyle choices such as bicycling over cars, structural changes such as increased transit and use of ride-sharing, or the development of less-energy intensive industry, perhaps based on new types of materials.

"Key Actions by Decade" below provides a blueprint for the physical transformation of the energy system. From a policy perspective, this provides a list of the things that policy needs to accomplish, for example the deployment of large amounts of low carbon generation, rapid electrification of vehicles, buildings, and industry, and building extensive carbon capture, biofuel, hydrogen, and synthetic fuel synthesis capacity.

Some of the policy challenges that must be managed include: land use tradeoffs related to carbon storage in ecosystems and siting of low carbon generation and transmission; electricity market designs that maintain natural gas generation capacity for reliability while running it very infrequently; electricity market designs that reward demand side flexibility in high-renewables electricity system and encourage the development of complementary carbon capture and fuel synthesis industries; coordination of planning and policy across sectors that previously had little interaction but will require much more in a low carbon future, such as transportation and electricity; coordination of planning and policy across jurisdictions, both vertically from local to state to federal levels, and horizontally across neighbors and trading partners at the same level;



mobilizing investment for a rapid low carbon transition, while ensuring that new investments in long-lived infrastructure are made with full awareness of what they imply for long-term carbon commitment; and investing in ongoing modeling, analysis, and data collection that informs both public and private decision-making. These topics are discussed in more detail in *Policy Implications of Deep Decarbonization in the United States*.

Key Actions by Decade

This study identifies key actions that are required in each decade from now to mid-century in order to achieve net negative CO₂ emissions by mid-century, at least cost, while delivering the energy services projected in the *Annual Energy Outlook*. Such a list inherently relies on current knowledge and forecasts of unknowable future costs, capabilities, and events, yet a long-term blueprint remains essential because of the long lifetimes of infrastructure in the energy system and the carbon consequences of investment decisions made today. As events unfold, technology improves, energy service projections change, and understanding of climate science evolves, energy system analysis and blueprints of this type must be frequently updated.

2020s

- Begin large-scale electrification in transportation and buildings
- Switch from coal to gas in electricity system dispatch
- Ramp up construction of renewable generation and reinforce transmission
- Allow new natural gas power plants to be built to replace retiring plants
- Start electricity market reforms to prepare for a changing load and resource mix
- Maintain existing nuclear fleet
- Pilot new technologies that will need to be deployed at scale after 2030
- Stop developing new infrastructure to transport fossil fuels
- Begin building carbon capture for large industrial facilities

2030s

- Maximum build-out of renewable generation
- Attain near 100% sales share for key electrified technologies (e.g. EVs)
- Begin large-scale production of bio-diesel and bio-jet fuel
- Large scale carbon capture on industrial facilities
- Build out of electrical energy storage
- Deploy fossil power plants capable of 100% carbon capture if they exist





Maintain existing nuclear fleet.

2040s

- Complete electrification process for key technologies, achieve 100% stock penetration
- Deploy circular carbon economy using DAC and hydrogen to produce synthetic fuels
- Use synthetic fuel production to balance and expand renewable generation
- Replace nuclear at the end of existing plant lifetime with new generation technologies
- Fully deploy biofuel production with carbon capture



Exhibit C.2:

350 PPM Pathways for Florida (2020)
Executive Summary and
U.S. Data from the Technical Supplement
Evolved Energy Research

350 PPM PATHWAYS FOR
FLORIDA

October 6, 2020



EVOLVED
ENERGY
RESEARCH

350 PPM Pathways for Florida

Prepared by

Ben Haley, Gabe Kwok, and Ryan Jones

Evolved Energy Research

October 6, 2020



Executive Summary

This study evaluates multiple scenarios to radically reduce the greenhouse gas emissions that result from Florida's energy system, and can serve as a tool to inform statewide energy system decisions.

We detail five technically and economically feasible pathways to reduce carbon dioxide emissions and remain within a small enough "carbon budget" to enable a return to 350 parts per million of carbon dioxide in the atmosphere by 2100, a level identified by scientists as a safe limit necessary to preserve a stable climate. These scenarios limit emissions while providing the same energy services for daily life and industrial production as the Department of Energy's long-term forecast.

This study builds upon the research conducted by Evolved Energy Research and the Sustainability Development Solutions Network (SDSN) and published on May 8, 2019, titled *350 PPM Pathways for the United States*.

Scenarios

This study evaluates five energy decarbonization¹ scenarios for the energy system of Florida:

Central: The least constrained scenario, this uses all options to decarbonize the energy system.

Low Biomass: This scenario reduces the development of new biomass feedstocks² by 50%.

Low Electrification: This scenario assesses the impact of a delayed adoption of electric vehicles and heat pumps.

¹ "Decarbonization" is the process of removing sources of carbon dioxide (and other greenhouse gases) from a system – in this case, removing fossil fuel emissions from Florida's energy system.

² Biomass feedstocks are plant-based and animal-based sources of fuel, like trees, grasses, or animal fats, for example.

100% Renewable Primary: This scenario describes an energy system based solely on biomass, wind, solar, hydro, and geothermal sources by 2050.

No New Regional Transmission (TX): This scenario limits the development of new electricity transmission lines between regions within the U.S.

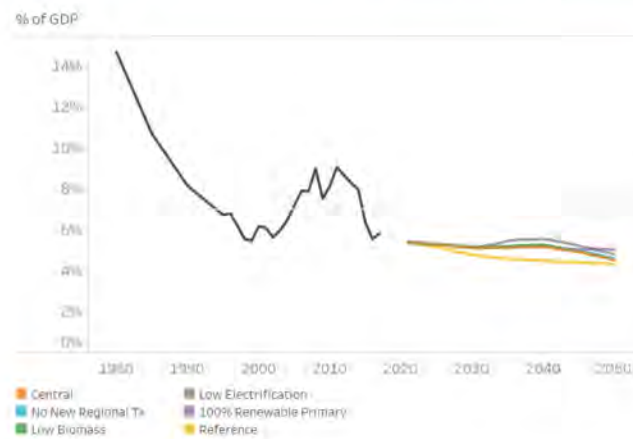
Florida Energy System Results

Energy decarbonization in Florida relies on four principal strategies: (1) **Electricity decarbonization** requires reducing the amount of fossil fuels used for electricity generation, thereby reducing the amount of greenhouse gas emissions from every unit of electricity delivered by about 95% by 2050; (2) **Energy efficiency** is the reduction in energy required to provide energy services such as heating and transportation, and energy use per unit GDP is reduced by about 50% below today's level; (3) **Electrification** involves switching energy uses including transportation and building heating off of fossil fuels and onto low-carbon electricity, and (4) **Capturing carbon** that would otherwise be emitted from power plants and industrial facilities – with the captured carbon either stored permanently (sequestered) or used to create fuels like synthetic natural gas or synthetic diesel, by combining the carbon with renewably-generated hydrogen.

Figure 1 shows historical and projected energy system costs as a share of State Gross Domestic Product (GDP). All scenarios evaluated in this study are in line with historical energy costs in Florida and, even with decarbonization, energy system costs are anticipated to decline as a share of GDP. The highest cost scenario is the 100% Renewable Primary pathway due to the emphasis on displacing *all* fossil fuels by 2050, rather than continuing to use some small amount of the lowest-cost fossil fuels and capturing and storing the associated carbon. The lowest cost scenario is the Central scenario, which allows for the most flexibility in terms of key decarbonization strategies.

Note that the costs within this chart do not reflect any of the macroeconomic benefits of transitioning off of fossil fuels, including improved air quality, avoided climate impacts (like avoided sea level rise), reduced energy price volatility, and energy independence, which could equal or exceed the net costs shown here.

Figure 1. Total energy system costs as percentage of GDP, historical and projected for Florida



Key Actions by Decade

Achieving the transition described above is not expensive but requires significant changes in public policy. Some of the **key policy challenges** that must be managed in all scenarios include:

- a) managing tradeoffs between using land for low carbon electricity generation (like wind farms and solar arrays) and improving natural carbon storage in forests and soils ; b) electricity market designs that maintain natural gas generation capacity for reliability while using gas generators very infrequently; c) developing electricity rates that incentivize customers to flex their energy use to better match periods of electricity surplus and shortage that come with intermittent renewables like wind and solar; d) encourage the development of carbon capture industries that can leverage periods of excess electricity generation ; e) coordination of planning and policy across sectors that previously had little interaction, such as transportation and electricity; f) coordination of planning and policy across jurisdictions; g) mobilizing investment for a rapid

low carbon transition; and e) investing in ongoing modeling, analysis, and data collection that informs both public and private decision-making. These topics are discussed in more detail in *Policy Implications of Deep Decarbonization in the United States*.

Achieving this transformation in Florida by mid-century at lowest cost requires an **aggressive deployment of low-carbon technologies**, including:

2020s

- Begin large-scale transition to electric technologies in key sectors; moving to electric light duty vehicles and electric heat pumps.
- Use coal fired power plants only when absolutely necessary, prioritizing all other sources of electricity generation first. Begin retiring coal assets.
- Ramp up construction of renewable electricity generation and upgrade electricity transmission where needed.
- Allow strategic replacement of natural gas power plants to support rapid deployment of low-carbon generation. These power plants must be financed with the understanding that they will run very infrequently to provide capacity, not as they are operated today.
- Maintain existing nuclear power plants.
- Pilot new technologies that will need to be deployed at scale after 2030.
- Stop developing new infrastructure to transport and process fossil fuels.
- Begin building carbon capture for large industrial facilities.

2030s

- Maximum build-out of renewable electricity generation.
- Nearly 100% of new vehicle sales and new building heating systems using electric technologies.
- Begin large-scale production of biodiesel and bio-jet fuel.
- Large scale carbon capture on industrial facilities.
- Build out electrical energy storage.
- Deploy new natural gas power plants capable of 100% carbon capture if they exist.
- Maintain existing nuclear power plants.
- Continue to reduce generation from gas-fired power plants.

2040s

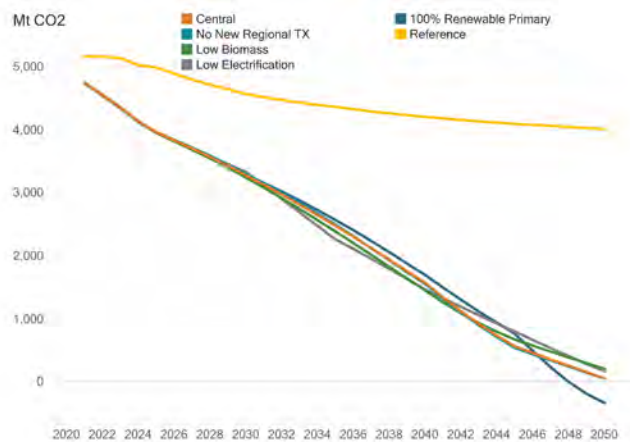
- Complete the transition to electric technologies for key sectors; virtually 100% of light duty vehicles and building heating systems run on electricity.
- Produce large volumes of hydrogen for use in freight trucks and fuel production.
- Use synthetic fuel production to balance and expand renewable generation.
- Fully deploy biofuel production with carbon capture.
- Further limit gas generation to infrequent periods when needed for system reliability.

Technical Supplement

The following technical supplement shows results for the U.S. as a whole as well as scenario figures not shown in the body of the main report for Florida.

U.S. Results

Figure 30 E&I CO₂ emissions trajectories – U.S.



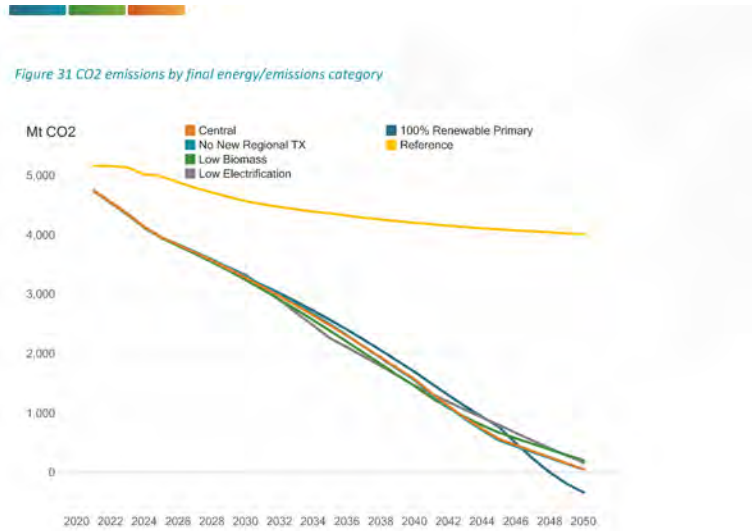


Figure 32 Cumulative E&I CO₂ emissions trajectories

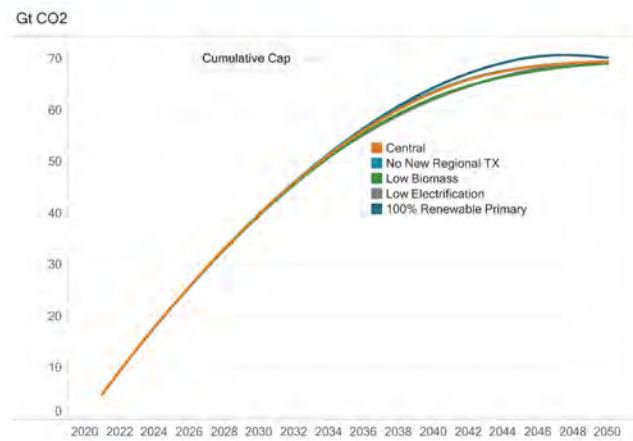


Figure 33 Four pillars of deep decarbonization—U.S.



Figure 34 Final and primary energy demand for all scenarios from 2021 – 2050 – U.S.

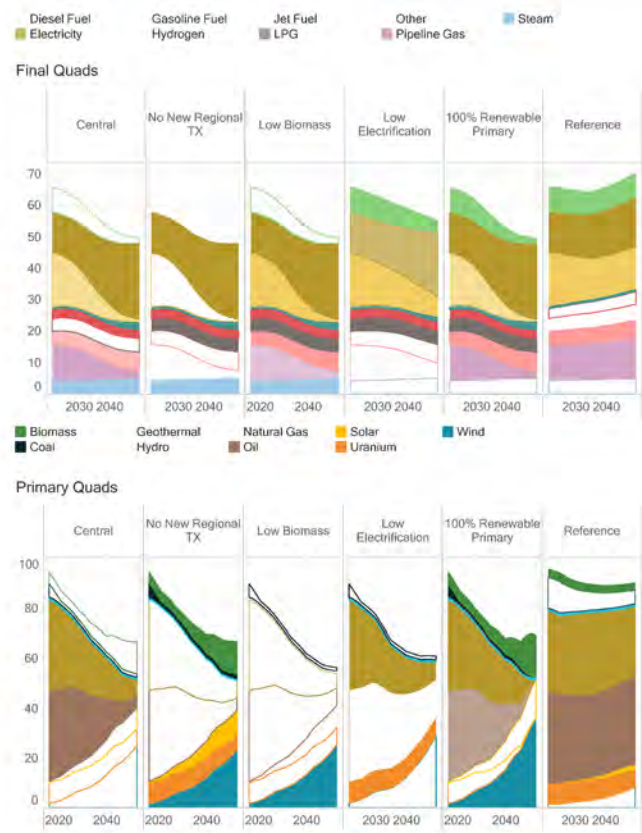


Figure 35 Components of emissions reductions in the Central scenario – U.S.

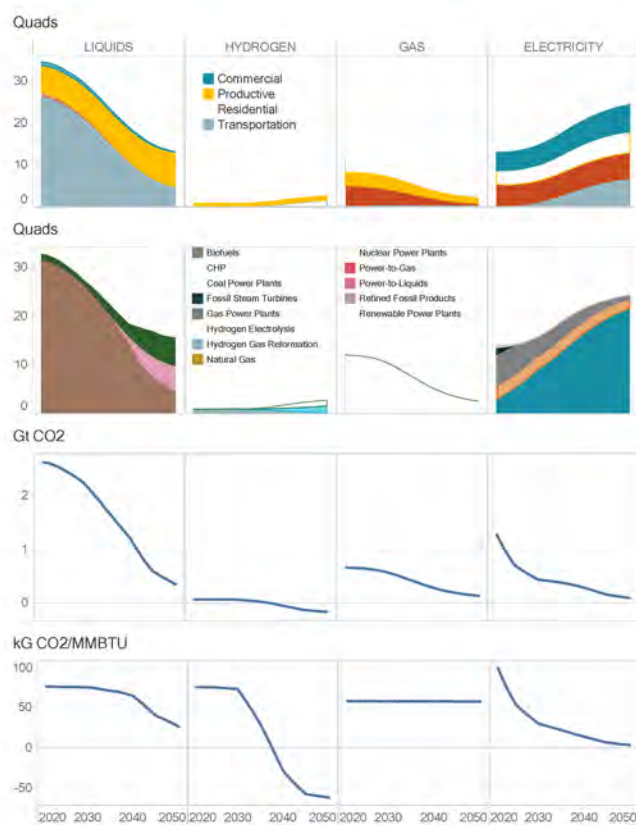


Figure 36 Components of emissions reductions in the Low Biomass scenario – U.S.

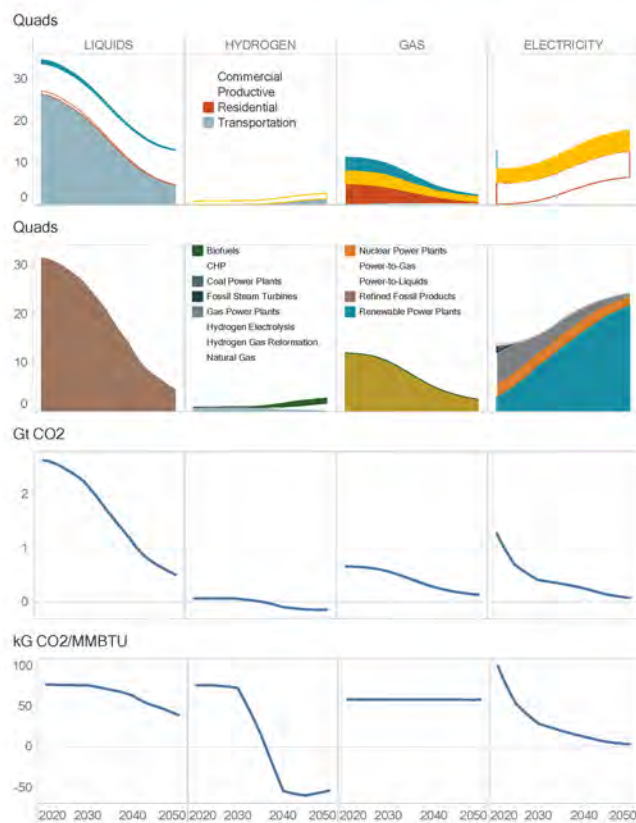


Figure 37 Components of emissions reductions in the Low Electrification scenario – U.S.

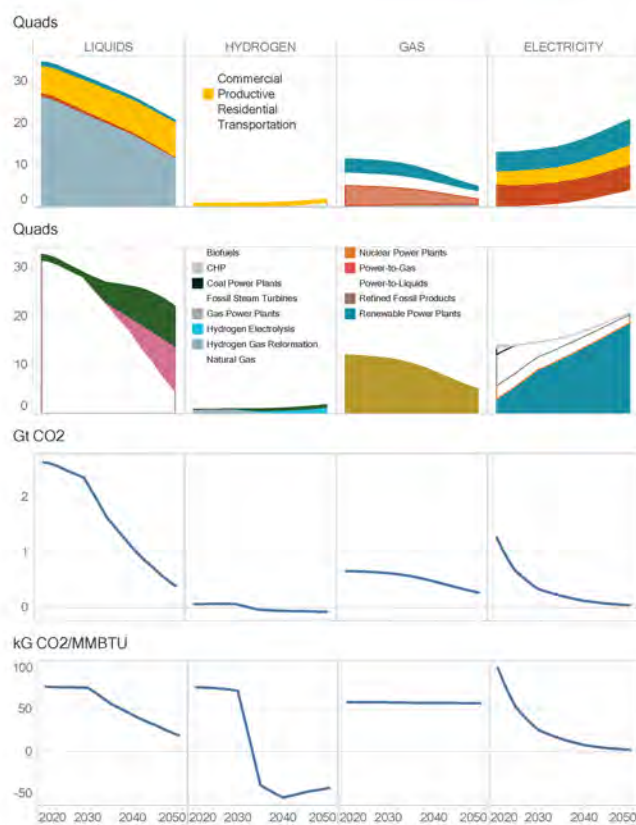


Figure 38 Components of emissions reductions in the No New Regional TX scenario – U.S.

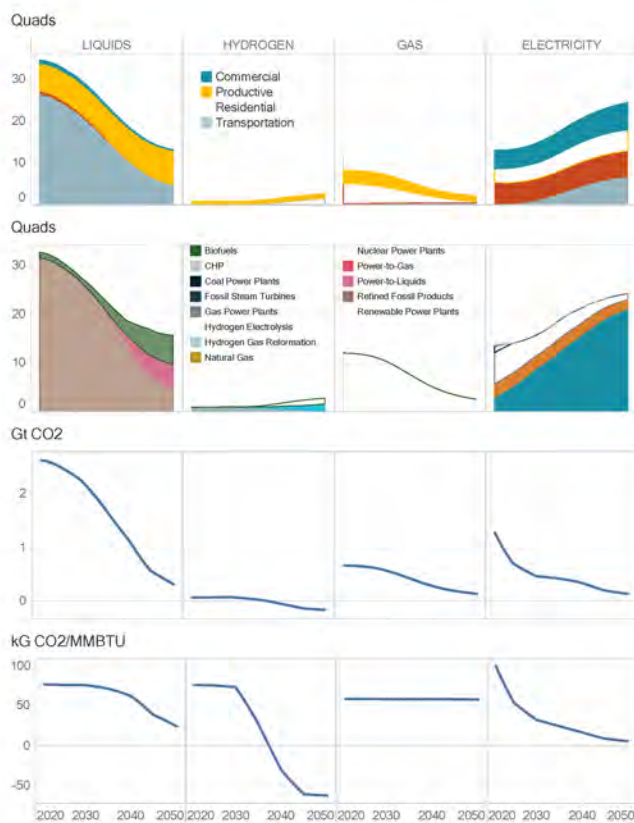


Figure 39 Components of emissions reductions in the 100% Renewable Primary scenario – U.S.

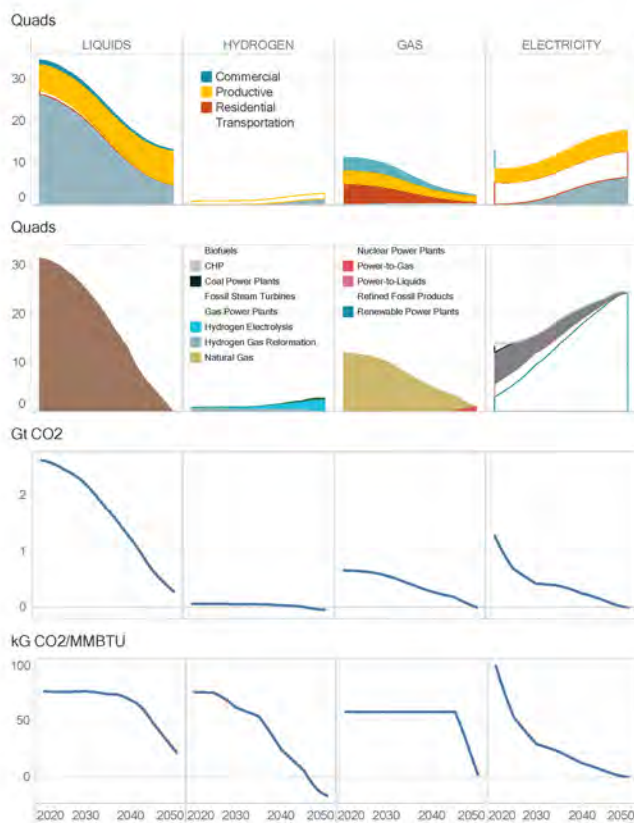
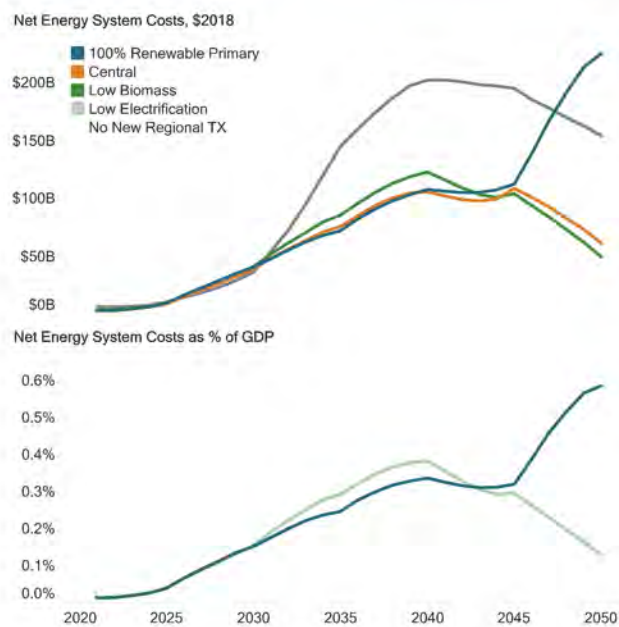
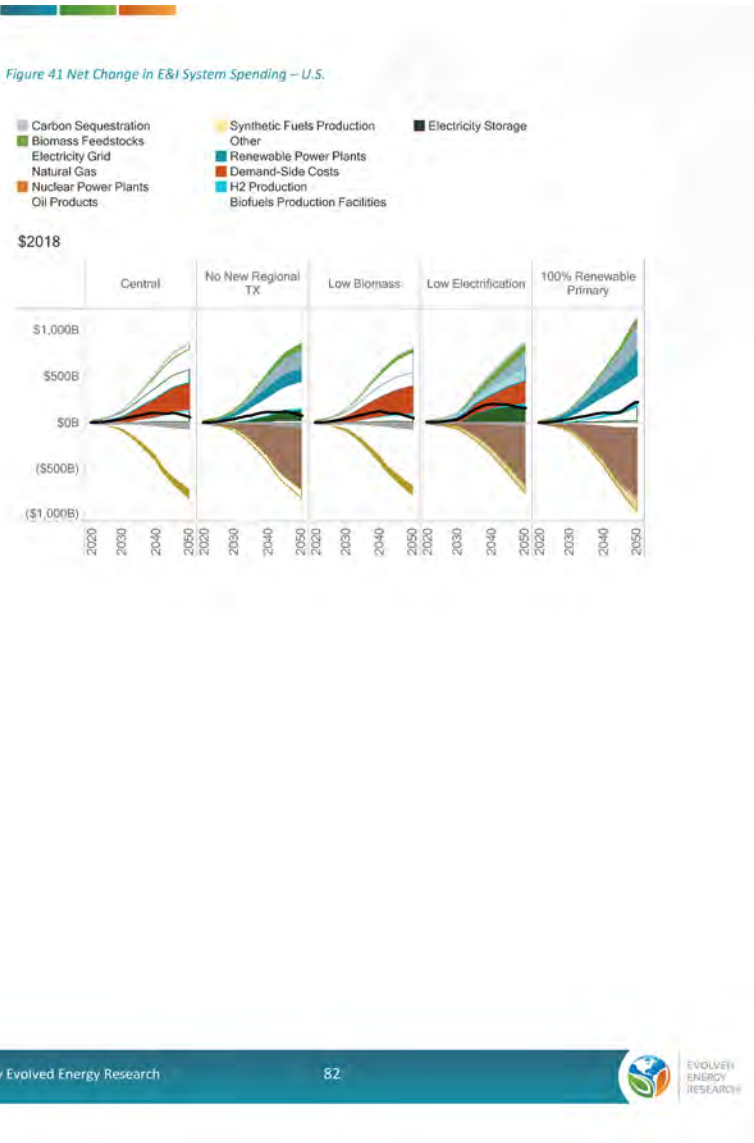


Figure 40 Annual net system cost premium above baseline in \$2018 and as % of GDP – U.S.





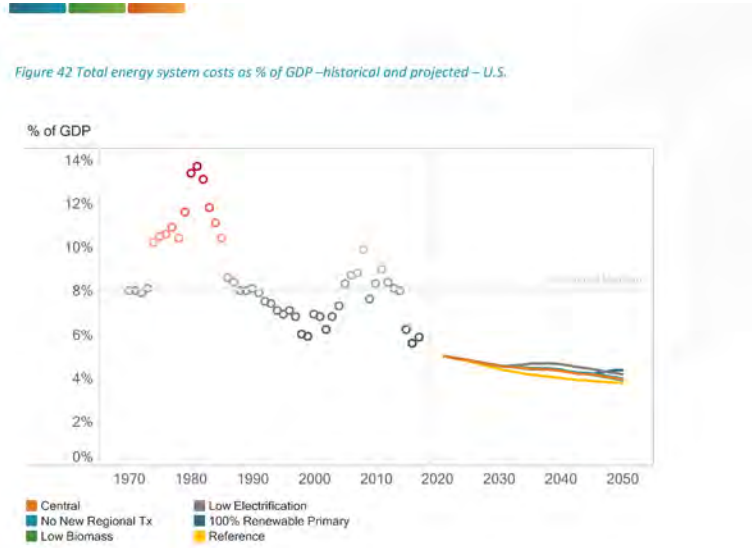


Exhibit D:

Expert Report of James H. Williams, Ph.D.

**EXPERT REPORT
OF
JAMES H. WILLIAMS, Ph.D.**

Associate Professor, University of San Francisco
Director of Deep Decarbonization Pathways Project

Kelsey Cascadia Rose Juliana, Xiuhtezcatl Tonatiuh M.,
through his Guardian Tamara Roske-Martinez; et al.,
Plaintiffs,

v.

The United States of America; Donald Trump,
in his official capacity as President of the United States; et al.,
Defendants.

IN THE UNITED STATES DISTRICT COURT
DISTRICT OF OREGON

(Case No.: 6:15-cv-01517-TC)

Prepared for Plaintiffs and Attorneys for Plaintiffs:

Julia A. Olson
JuliaAOlson@gmail.com
Wild Earth Advocates
1216 Lincoln Street
Eugene, OR 97401
Tel: (415) 786-4825

Philip L. Gregory
pgregory@gregorylawgroup.com
Gregory Law Group
1250 Godetia Drive
Redwood City, CA 94062
Telephone: (650) 278-2957

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TABLE OF ACRONYMS AND ABBREVIATIONS

80 x 50:	80% reduction in greenhouse gas emissions by 2050
BAU:	business as usual
BEV:	battery electric vehicle
C:	Celsius
CCS:	carbon capture and storage
CH ₄ :	methane
CO ₂ :	carbon dioxide
CO ₂ e:	carbon dioxide equivalent
DDP-LAC:	Deep Decarbonization Pathways for Latin America and the Caribbean
DDPP:	Deep Decarbonization Pathways Project
Decarbonization:	deep reductions in greenhouse gas emissions from a system
EIA:	Energy Information Agency
FCV:	hydrogen fuel cell vehicle
GDP:	gross domestic product
GHG:	greenhouse gas
ICE:	internal combustion engine
IDDRI:	Institute for Sustainable Development and International Relations
IPPC:	Intergovernmental Panel on Climate Change
NEMS:	National Energy Modeling System
ppm:	parts per million
PV:	photovoltaic – a type of solar electric generating technology
SDSN:	Sustainable Development Solutions Network

INTRODUCTION

I, James H. Williams, have been retained by the Plaintiffs to provide expert testimony regarding the feasible pathways to achieve deep decarbonization of the U.S. energy system in line with best available science for stabilizing the climate system, and the policies that could be used to achieve this outcome. In this report, I examine how the federal government, including the agencies listed as Defendants in this case, can transform the U.S. energy system from one powered by fossil fuels to one powered by renewable energy and other low carbon forms of energy, if it plans for, and implements policies to achieve, that objective.

This expert report contains my opinions, conclusions, and the reasons for them. A copy of my full CV is attached as Exhibit A. A current and complete copy of a list of publications I authored or co-authored within the last ten years is attached as Exhibit B. In preparing this expert report, I have reviewed a number of documents. My expert report contains a list of citations to the documents that I have used or considered in forming my opinions, listed in Exhibit C.

In preparing my expert report and testifying at trial, I am deferring my expert witness fees to be charged to the Plaintiffs given the financial circumstances of these young Plaintiffs. If a party seeks discovery under Federal Rule 26(b), I will charge my reasonable fee of \$300 per hour for the time spent in addressing that party's discovery. I have not provided previous testimony within the preceding four years as an expert at trial or by deposition.

The opinions expressed in this expert report are my own and are based on the data and facts available to me at the time of writing, as well as based upon my own professional experience and expertise. All opinions expressed in it are to a reasonable degree of scientific certainty, unless otherwise specifically stated. Should additional relevant or pertinent information become available, I reserve the right to supplement the discussion and findings in this expert report in this action.

QUALIFICATIONS

I, James H. Williams, currently serve as Associate Professor in the graduate program in Energy Systems Management at the University of San Francisco. I also serve as Director of the Deep Decarbonization Pathways Project (DDPP) for the Sustainable Development Solutions Network (SDSN). The DDPP is an international consortium of research teams that was convened at the request of the United Nations Secretary General and is led by the SDSN and the Institute for Sustainable Development and International Relations (IDDRI). I also consult with Evolved Energy Research on energy planning.

I received my B.S. in Physics from Washington and Lee University, and my M.S. and Ph.D. in Energy and Resources from U.C. Berkeley. I have spent the past three decades studying various aspects of energy planning, energy technology applications, and energy policy and regulation, most recently as Chief Scientist at the San Francisco consulting firm Energy and Environmental Economics, Inc. (E3).

I was the Principal Investigator for two studies, *Pathways to Deep Decarbonization in the United States* (2014) and *Policy Implications of Deep Decarbonization in the United States* (2015), funded by the Earth Institute at Columbia University. As the Principal Investigator, I led a research team from E3, Lawrence Berkeley National Laboratory, and Pacific Northwest National Laboratory in the preparation of these studies.

In 2007, I led an analysis for the State of California on greenhouse gas (GHG) emission reduction strategies, which became a key input into implementation of Assembly Bill 32, the State's main law governing mitigation of climate change. I was lead author of a 2012 article in the journal *Science* that analyzed California's options for reducing GHGs 80% below 1990 levels by 2050, the target set by AB 32. In 2017, I was a contributing author of a study commissioned by the State of Washington Governor's office on options for reducing GHGs 80% below 1990 levels in that state by 2050.

As a scientist who also has a background in Asian studies, I previously served as Associate Professor of International Environmental Policy at the Middlebury Institute of International Studies, where my research addressed the technical and institutional challenges of reducing carbon emissions from China's power sector.

I have worked with numerous international forums and research teams. For example, I am the lead author of a 2018 technical report on expanding the coordination of deep decarbonization activities between the northeastern states of the U.S. and the Canadian province of Quebec. I am a technical advisor to the Inter-American Development Bank on their Deep Decarbonization Pathways for Latin America and the Caribbean (DDP-LAC) project, which expands on the work done by the DDPP under my leadership.

I served as the Program Director for the China-U.S. Climate Change Forum held at U.C. Berkeley in 2006, on the Steering Committee for the Asia Society's *Roadmap for California-China Collaboration on Climate Change* starting in 2013, and the U.S.-China Collaboration on Clean Air Technologies and Policies starting in 2015. I have co-authored several technical journal articles and policy analyses with colleagues at universities and research institutes in China.

Since 2004, I have served on the Board of Advisors of Palangthai, a Thailand-based NGO focused on clean and equitable energy development in southeast Asia. Since 2005, I have served on the Board of Advisors of EcoEquity, a U.S.-based NGO focused on improving international climate equity by producing analyses that highlight equity issues, and by developing practical proposals for equitable climate policies.

I have, in the past or currently, served as an advisor or invited member for numerous energy or climate change-related committees and task forces, including the California's Energy Future Policy Committee of the California Council for Science and Technology, the California Climate Policy Modeling Forum, and the American Geophysical Union Energy Engagement Task Force.

I have served as a reviewer for scholarly publications including *Nature Climate Change*, *Energy Policy*, *Environmental Science and Technology*, *Energy*, *Pacific Affairs*, and *China Quarterly*.

EXECUTIVE SUMMARY

Federal government policy can transform the U.S. energy system from one powered by fossil fuels to one powered by renewable and other low carbon energy sources, if the federal government takes that path. My past work has already demonstrated that it is technically feasible to develop and implement a plan to achieve an 80% greenhouse gas reduction below 1990 levels by 2050 in the United States. Multiple alternative pathways exist to achieve these reductions using existing commercial or near-commercial technologies; however, to be successful, each pathway requires the leadership of the federal government, including the agencies listed as Defendants in this case, and comprehensive systemic planning as well as periodic interim targets that must be met to achieve the long-term (such as mid-century and beyond) targets. We determined in our studies that reductions can be achieved through high levels of energy efficiency, decarbonization of electric generation, electrification of most end uses, and switching the remaining end uses to lower carbon fuels. The cost of achieving this level of reductions within this timeframe is affordable, estimated to have an incremental cost for supplying and using energy in the U.S. equivalent to 0.8% of a forecast 2050 GDP, with a range of -0.2% to +1.8% of GDP. These incremental costs do not include potential non-energy savings and benefits including, for example, avoided human and infrastructure costs of climate change and air pollution. Our 80 x 50 analysis demonstrated that the changes required to achieve this level of emissions reductions will support the same level of energy services and economic growth as a reference case based on the U.S. Department of Energy's *Annual Energy Outlook*. Starting immediately on the deep decarbonization path would allow infrastructure replacement to follow natural replacement rates, reducing costs and allowing gradual consumer adoption.

The target of 80% reductions below 1990 levels by 2050 is used by many countries. However, climate scientists have shown that this level of reductions is not sufficient to avoid dangerous anthropogenic interference with the climate system over the long term, and the negative impacts on human, ecological, and economic health that would result from that. My research team is therefore currently modeling the requirements to meet a more stringent target in which fossil fuel CO₂ emissions in 2050 are reduced by as much as 96% below current levels, consistent with achieving an atmospheric CO₂ concentration of 350 ppm by 2100. In my expert opinion, based upon our 80 x 50 work and our early modeling results, I believe that this level of reductions is technologically feasible using current and emerging technologies; that it will likely have a higher per-unit cost for the remaining reductions beyond 80% by 2050; that it will likely require some early retirements of fossil fuel infrastructure; and that it could be aided by changes in consumption of energy services and/or rates of consumption growth, but will not diminish basic quality of life and standards of living.

EXPERT OPINION

Scientific evidence makes it increasingly clear that human-caused climate change requires rapid, aggressive mitigation action if humanity is going to avoid the most catastrophic climate change outcomes. Government policy, and the environment it creates for business and individual actions and investments, drives the shape and future of the U.S. energy system. These same

influences can move the U.S. energy system decisively away from fossil fuels to an economy powered by renewable and other low carbon energy sources, if the federal government, including the agencies listed as Defendants in this case, takes that path.

I coined the term “deep decarbonization” and have studied it extensively. As the Principal Investigator for the U.S. Deep Decarbonization Pathways Project modeling and scenarios research conducted from 2013 to 2015, I led a team of researchers from Energy and Environmental Economics, Inc., Lawrence Berkeley National Laboratory, and Pacific Northwest National Laboratory. This research was focused on achieving reductions in GHG emissions 80% below 1990 levels by 2050, a target that many governments around the world have adopted.

Based on the lessons from this research, we now know it is entirely possible to rapidly remove greenhouse gas emissions from the U.S. economy while maintaining a healthy economy and modern standard of living. We also know that even deeper emission cuts beyond 80%, which science indicates is necessary to avoid dangerous anthropogenic interference with the climate system, are feasible with greater costs. We also know that there are multiple pathways to achieve deep decarbonization in the U.S., but each of them requires federal government leadership and comprehensive systemic planning as well as periodic interim targets that must be met to achieve the long-term targets (such as mid-century and beyond).

United States Deep Decarbonization Research and Conclusions

The U.S. Deep Decarbonization Pathways Project modeling and scenarios research conducted from 2013 to 2015 demonstrated the feasibility and affordability of rapidly transitioning away from fossil fuels. The research focused on achieving reductions in GHG emissions 80% below 1990 levels by 2050 (referred to hereafter as “80 x 50”).

Our research asked the following questions:

- a) Is achieving this target technically feasible, given realistic constraints?
- b) What changes in physical infrastructure and technology are required?
- c) What is the expected cost of these changes?
- d) What are the policy and political economy implications of these changes?

We made the following assumptions:

- a) Future U.S. population, gross domestic product, and energy service demand are consistent with the U.S. Department of Energy’s *Annual Energy Outlook* Reference Case, a transparent, conservative, and well-vetted long-term forecast produced using the U.S. Energy Information Agency’s National Energy Modeling System (NEMS).
- b) Only commercially-demonstrated or near-commercial technologies are used. Their modeled costs and performance are based on those in the *Annual Energy Outlook* and other conservative and well-vetted public sources, such as studies by the National Academies of Science and Engineering. Changes in forecast technology and fuel prices

are addressed through sensitivity analyses.

- c) The time required to change the emissions characteristics of the U.S. energy system – sometimes referred to as its technological inertia – is well-represented in the analysis by the rate at which energy-related infrastructure and equipment is retired and replaced by new equipment, using an annual stock-rollover model and following conventional turnover times based on well-vetted public sources. Equipment and infrastructure that is retired before the conventionally accepted end of its economic life is subject to full cost recovery and appears as a cost in the economic modeling.
- d) Electricity system operability and reliability is well-represented in the analysis using a regionally-specific hourly dispatch model of the electricity system. All future scenarios contain realistic costs of balancing supply and demand, including in scenarios with high levels of inflexible generation, such as intermittent renewable energy.
- e) Environmental limits are adhered to as constraints on low-carbon resources. For example, future use of biomass resources and hydroelectric resources are constrained by transparent and well-vetted analysis conducted by the U.S. Department of Energy and its associated national laboratories. The terrestrial carbon sink on managed lands is held constant at 2012 levels in the Environmental Protection Agency's U.S. GHG inventory (the most recent available at the time of analysis).
- f) All emissions reductions are the result of physical measures within the U.S., not "offsets" related to emission reductions in other countries. All emissions reductions involve the replacement of one kind of infrastructure or equipment with a higher-efficiency and/or lower carbon alternative, and this change entails a net cost that includes all conventionally assumed factors such as overnight cost, operating and maintenance cost, and finance cost over the lifetimes of the equipment involved.

Below are the key conclusions of our 80 x 50 study:

- a) It is technically feasible to reduce total U.S. GHG emissions (in CO₂e) to 80% below 1990 levels by 2050. This includes reducing energy CO₂ emissions below 750 Mt, which is 84% less than the 1990 level.
- b) Incremental changes in energy use and policy will not be sufficient to drive this level of change (and in some cases, may prove counter-productive). Rather, a complete transformation of the energy system is required.
- c) Achieving the targets relies on three principal strategies:

- (1) *Highly efficient end use of energy in buildings, transportation, and industry.*
Energy intensity of GDP (energy consumed per dollar of GDP) must decline by 70% from now to 2050, with final energy use reduced by 20% despite

forecast increases of 40% in population and 166% in GDP. Relative to the reference case, 2050 energy intensity and final energy use are 33% lower.

(2) *Nearly complete decarbonization of electricity, and reduced carbon in other kinds of fuels.* The carbon intensity of electricity must be reduced by at least 97%, from more than 500 g CO₂/kWh today to 15 g CO₂/kWh or less in 2050.

(3) *Electrification where possible and switching to lower-carbon fuels otherwise.* The share of end-use energy coming directly from electricity or fuels produced from electricity, such as hydrogen, must increase from less than 20% in 2010 to over 50% in 2050. Deeply decarbonized electricity and other fuels must displace most direct fossil fuel combustion in the absence of carbon capture and storage.

- d) We examined four different scenarios with different technology mixes – referred to as “High Renewable,” “High Nuclear,” “High Carbon Capture and Storage (CCS),” and “Mixed” – scenarios – that met the 80 x 50 target. This demonstrates that multiple pathways exist to achieve these reductions using existing commercial or near-commercial technologies, and that the results are robust in the absence of any given technology or technologies. Many more scenarios that meet the target are possible.
- e) Deep decarbonization requires ongoing replacement of conventional fossil fuel-based energy supply and end use infrastructure and equipment with efficient, low emissions technologies. In all four scenarios, the 80 x 50 target could be achieved through natural replacement at the end of the existing infrastructure’s economic life, and early retirement was not required. However, making any new investments in fossil fuel infrastructure *today* risks the creation of stranded assets.
- f) The 80 x 50 target was demonstrated to be affordable. In the year 2050, the net energy system cost—the net change in capital, fuel, and operating costs of supplying and using energy — across the four deep decarbonization scenarios has an average median value of \$300 billion, equivalent to 0.8% of a forecast 2050 GDP of \$40 trillion. Uncertainty analysis shows a range across scenarios of -0.2% to +1.8% of GDP (negative \$90 billion to \$730 billion).¹
- g) The 80 x 50 reduction targets could be met without requiring changes in people’s behaviors or consumption patterns. That means that the physical energy system will need to change but the use of “energy services” in the U.S. economy would not have to in order to meet an 80 x 50 target. Deep decarbonization will profoundly transform the physical energy system of the U.S. On average across the four scenarios, fossil fuel use decreases by two-thirds from today while decarbonized energy supplies expand by a

¹ This represents the interquartile range of a Monte Carlo simulation of key cost parameters, primarily technology costs and fossil fuel prices.

factor of five.² However, this can be achieved while supporting all anticipated demand for energy services – for example, current or higher levels of driving, home heating and cooling, and use of appliances.

- h) Deep decarbonization would profoundly transform the U.S. energy economy, in terms of what money is spent on and where investment will flow. In contrast to today's system in which more than 80% of energy costs go to fossil fuel purchases, in a deeply decarbonized system more than 80% of energy costs will go to fixed investments in low-carbon infrastructure such as wind generation and electric vehicles. However, the net change in consumer costs for energy services is shown to be relatively small because of savings from avoiding conventional energy costs.
- i) Deep decarbonization would have a small net cost relative to U.S. GDP, as increased spending on low-carbon infrastructure and equipment is offset by reduced spending on fossil fuels. In all deep decarbonization scenarios, U.S. energy costs actually decrease as a share of GDP over time, from about 7% in 2015 to about 6% in 2050.
- j) While the overall impact on energy costs is modest, the transition to deep decarbonization nonetheless offers significant benefits for the U.S. macro-economy, such as insulation from oil price shocks, even without counting the potential economic benefits of avoiding severe climate change and avoiding the public health costs of fossil fuel-related air pollution.
- k) Though not a part of our initial research, a third party conducted an analysis of impacts of the deep decarbonization scenarios we modeled on the U.S. macro-economy in terms of jobs, household income, and GDP (ICF International, 2015). The study found that, compared to business as usual, deep decarbonization scenarios would result in net gains in U.S.-wide employment (1 million more jobs by 2030, up to 2 million more jobs by 2050), gains in GDP (0.6% by 2030, up to 0.9% by 2050), and increased disposable household income (\$300 by 2030, up to \$600 by 2050).
- l) As part of our research, we discovered a number of important policy implications of deep decarbonization in the U.S. Some of the key policy challenges indicated by our analysis include:
 - o *Sustained transformation.* Deep decarbonization requires the economic intensity of GHG emissions to decrease 8% per year, and per capita emissions to decrease 5.5% per year.³ These rates of change can be achieved technically and at an

² Fossil fuel use is reduced by approximately 80% from today in the high renewables scenario, 70% in the mixed and high nuclear scenarios, and 40% in the high CCS scenario.

³ For comparison, from 2014 to 2015, economic intensity of energy-related CO₂ emissions fell by 5.2% per year and per capita emissions fell by 3.3% per year. Over the prior decade, the average rate of economic intensity decline was 2.4% per year, and per capita decline was 1.9%.

affordable cost, but *require a sustained commitment to infrastructure transformation over decades*. Incremental improvements that do not facilitate complete transformation are likely to result in technology lock-in and emissions dead ends (**Figure 1**). Pathway A, the dotted black line, represents a linear trajectory from 2010 emissions of energy-related CO₂ to the 80 x 50 target level. Pathway B, the dotted red line, represents policies that reduce emissions in the short-term but do not lead to deep decarbonization in the long-term. Some examples of potential dead-ends include a pathway focused solely on energy efficiency in buildings that does not also include end-use electrification; a transition from coal to natural gas power generation without a further transition to zero carbon generation; or improvement in the fuel economy of gasoline internal combustion engine vehicles without widespread deployment of electric or fuel cell light duty vehicles.

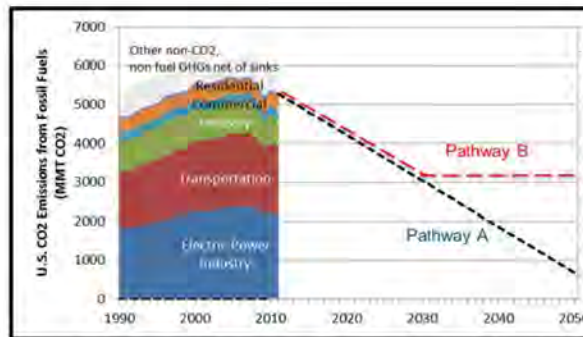


Figure 1: Illustrative Deep Decarbonization 80 x 50 Trajectory (Pathway A) and "Dead End" Trajectory (Pathway B).

A sustained transformation requires stable policy and a predictable investment environment, and it also requires *planning*. Deferring responsibility to a carbon market, *ad hoc* decisions, and inconsistent incentives are not likely to produce a sustained or sufficiently rapid transition to full decarbonization.

- *Timely replacement.* 80 x 50 could be achieved in the U.S. without retiring existing equipment before the end of its economic lifetime, defined as the time required to recoup initial capital investment including financing costs.⁴ However,

per year. See EIA, *US Energy-Related Carbon Dioxide Emissions 2015*, available at <https://www.eia.gov/environment/emissions/carbon/>.

⁴ While this indicates that it is possible to deeply decarbonize the economy without creating the problem of stranded investments, the question of what to do with fully depreciated coal plants

because these lifetimes are long, there is only one natural replacement cycle before mid-century for some of the most important infrastructure, such as electric power plants, buildings, and industrial boilers. Failure to replace retiring infrastructure with efficient and low-carbon successors would lead either to failure to meet emissions goals or to potentially costly early retirement of the replacement equipment.

- *Cross-sector coordination.* As deep decarbonization proceeds, interactions between mitigation measures in different sectors (for example, electricity and transportation) become dominant in determining overall emissions. Purely sectoral policies that do not recognize the importance of these interactions will produce sub-optimal outcomes, yet there is currently little institutional coordination across sectors. Anticipatory development of shared institutional structures, both market and regulatory, will be required for efficient coordination of operations, planning, investment, and research.
- *Integration of supply- and demand-side planning and procurement.* Related to the cross-sector coordination challenge is the supply-demand side challenge within the electricity sector. Maintaining reliability in an electricity system with high levels of wind and solar, or baseload nuclear, will require corresponding levels of flexible demand, such as EV charging and hydrogen production. Currently these are seen as outside the purview of electricity planning. To build a low-carbon system that matches supply and demand resources at the required spatial and time scales, however, will require integrated planning and procurement well beyond the scope of what is currently thought of as “integrated resource planning.”
- *Suitable investment environment.* The annual investment requirement for low carbon and efficient technologies rises from under \$100 billion today to over \$1 trillion in a span of about 20 years. This is a large increase from the standpoint of energy sector capital investment, *but not from the standpoint of the share of investment in U.S. GDP as a whole.* Financial markets can supply this level of capital *if investment needs are anticipated and a policy framework is constructed that limits risk and ensures adequate returns.*
- *The right kinds of competition.* Competition is potentially an important tool for driving innovation and reducing costs, but poorly informed policies can lead to unproductive competition. An example of this is current policies that have biofuels competing with gasoline; in the long run, this will be a poor use of scarce biomass resources, because gasoline ICE vehicles have preferred substitutes such as BEVs and FCVs, while the biomass will be needed for production of low

and other highly emitting equipment continuing to operate after their financial lifetimes are complete is a separate policy challenge.

carbon fuels used in applications that are difficult to electrify. Long-term pathways analysis will help policy makers and investors understand what types of competition have value. Federal policy will play an important role in driving market response.

- *High rates of consumer adoption.* Achieving necessary rates of consumer adoption of equipment ranging from heat pumps to alternative vehicles will require a combination of incentives, financing, market strategies, and supporting infrastructure. This requires a high level of public-private cooperation among, for example, government agencies, auto manufacturers, and utilities in rapidly expanding alternative vehicle markets in tandem with the expansion of fueling or charging infrastructure, not unlike the public-private cooperation that originally created the fossil-fuel based energy system and infrastructure supporting ICEs.
- *Cost reductions in key technologies.* Policy makers can drive cost reductions in key technologies by helping to create large markets. High production volumes drive technological learning, efficient manufacturing, and lower prices. This effect is already visible in battery storage and wind and solar PV generation. Large markets can be built through government procurement, technology standards, consumer incentives, coordinated research and demonstration, trade, and long-term policy certainty.
- *Cost increases faced by consumers.* Businesses, utilities, and policy makers have a mutual interest in limiting the level and rate of consumer cost increases during a low-carbon transition. Coordinating energy efficiency improvements with decarbonization of energy supplies limits increases in total consumer bills even if per unit energy prices increase.
- *Distributional effects.* A low-carbon transition policy can also minimize regressive cost impacts. Distributional effects across regions, sectors, and industries are largely a function of technology strategies, which can be tailored to mitigate these effects.

Going Beyond 80% Reductions by 2050

While most analyses of deep decarbonization, including our own, have focused on 80% reductions in greenhouse gas emissions by 2050, recent studies in climate science indicate that even this level of reductions will not be steep enough to prevent dangerous climate impacts. Hansen (2008, 2013, 2017) shows that returning atmospheric CO₂ concentrations to 350 parts per million (ppm) by 2100 will be required to restore the energy balance of the planet and lower the risk of dangerous anthropogenic interference with the climate system. This objective implies reductions in fossil fuel combustion CO₂ emissions as deep as 96% below present by 2050, in addition to enhanced negative emissions. Many other researchers have also proposed steeper reduction trajectories (e.g. Rogelj, 2017) to avoid the worst impacts of climate change. This is

the subject of a forthcoming IPCC special report on limiting global warming above preindustrial temperatures to 1.5 degrees Celsius or less.

For these reasons, I, along with my deep decarbonization team and in collaboration with colleagues at Evolved Energy Research, have set out to describe the pathways needed to reach an emissions target consistent with these scientific analyses.

In my expert opinion, deep decarbonization beyond 80% by 2050 is feasible, and we are now undertaking the research and analysis to illustrate the possible technical and policy pathways. Based on my extensive experience with these and other decarbonization analyses, in my expert opinion, meeting a target as deep as 96% below 2018 levels by 2050 for fossil fuel CO₂ emissions:

- Is technologically feasible given current and emerging technologies
- Will require immediate and decisive action to develop and implement a plan to cut emissions in the near term in order to meet the target and not overspend a 350 ppm carbon budget
- Will have a higher unit cost for the remaining reductions beyond 80% by 2050
- Will likely require some early retirements of fossil fuel-based infrastructure and equipment
- Will require an unprecedentedly rapid build out of renewable generation capacity – potentially building out more renewable generation capacity on an annual basis for several years than the U.S. has in operation right now.
- Will require overproduction of renewable electricity generation in many hours due to the variable nature of their output – excess power that can be stored or used in other applications that reduce CO₂
- Will require rapidly minimizing coal-fired power generation in the near term
- May require a temporary expansion of natural gas generation as coal-fired generators are phased out, at the same time that rapid electrification of the transportation and building sectors cause demand for electricity to increase more rapidly than renewables can be deployed
- Will likely require an increasing share of new appliances, heaters, and other electricity-consuming devices to be more flexible in order to be responsive to changes in electricity generation from variable renewable sources
- May require extensive use of autonomous vehicle technology in combination with electric vehicle technology to facilitate the rapid electrification of the transportation sector
- May require the use of technology to capture carbon and store it geologically or biologically, or reuse it in the synthesis of fuels
- Could be aided by changes in consumption of energy services and/or rates of consumption growth, but will not diminish basic quality of life and standards of living

CONCLUSION

My previous work demonstrates that it is technically feasible to achieve an 80% reduction in greenhouse gas emissions below 1990 levels by 2050 in the United States, while maintaining current levels of energy services without requiring any conservation measures, consistent with on the U.S. Department of Energy's *Annual Energy Outlook*. Multiple alternative pathways exist to achieve these reductions using existing commercial or near-commercial technologies. The net cost of changing the way energy is supplied and used to achieve this target is small compared to GDP and to what is currently spent on energy, even without including such benefits as avoided human and infrastructure costs of climate change and air pollution. Starting immediately on the deep decarbonization path would allow infrastructure replacement to follow natural replacement rates, reducing costs and allowing gradual consumer adoption. That is why it is important for the federal government, including the agencies listed as Defendants in this case, to promptly develop and implement a plan to reduce U.S. greenhouse gas emissions.

The target of 80% reductions below 1990 levels by 2050 is used by many countries. However, recent work by climate scientists indicates that this level of reductions is not sufficient to avoid dangerous anthropogenic interference with the climate system over the long term, and the negative impacts on human, ecological, and economic health that would result from that. My research team is therefore currently modeling the requirements to meet a more stringent target in which fossil fuel CO₂ emissions in 2050 are reduced as much as 96% below current levels, consistent with achieving an atmospheric CO₂ concentration of 350 ppm by 2100.

In my expert opinion, I believe that a reduction in national emissions as deep as 96% below present levels is technologically feasible given current and emerging technologies; that it will likely have a higher unit cost for the remaining reductions beyond 80% by 2050; that it will likely require some early retirements of fossil fuel infrastructure; and that it could be aided by changes in the consumption of energy services and/or rates of consumption growth, but will not diminish basic quality of life and standards of living.

Signed this 13th day of April, 2018 in Berkeley, California.



James H. Williams

Exhibit E:

Expert Report of Mark Jacobson, Ph.D.

**EXPERT REPORT
OF
MARK JACOBSON, Ph.D.**

Professor, Dept. of Civil and Environmental Engineering
Director, Atmosphere/Energy Program
Senior Fellow, Woods Institute for the Environment
Senior Fellow, Precourt Institute for Energy
Stanford University

Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M.,
through his Guardian Tamara Roske-Martinez; et al.,
Plaintiffs,

v.

The United States of America; Donald Trump,
in his official capacity as President of the United States; et al.,
Defendants.

IN THE UNITED STATES DISTRICT COURT
DISTRICT OF OREGON

(Case No.: 6:15-cv-01517-TC)

Prepared for Plaintiffs and Attorneys for Plaintiffs:

Julia A. Olson
JuliaAOlson@gmail.com
Wild Earth Advocates
1216 Lincoln Street
Eugene, OR 97401
Tel: (415) 786-4825

Philip L. Gregory
pgregory@gregorylawgroup.com
Gregory Law Group
1250 Godetia Drive
Redwood City, CA 94062
Tel: (650) 278-2957

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TABLE OF ACRONYMS AND ABBREVIATIONS

BAU:	business as usual
CCS:	carbon capture and sequestration
coal-CCS:	coal with carbon capture and sequestration
CO ₂ :	carbon dioxide
CSP:	concentrated solar power
DOE:	United States Department of Energy
EIA:	United States Energy Information Administration
EPA:	United States Environmental Protection Agency
HVAC:	heating, ventilation and air conditioning
HVDC:	high-voltage direct-current
IPCC:	United Nations Intergovernmental Panel on Climate Change
kW:	kilowatt (measure of electric power)
kWh:	kilowatt hour
MW:	megawatt (measure of electric power)
OTA:	United States Congress, Office of Technology Assessment
ppm:	parts per million
ppmv:	parts per million by volume
PV:	photovoltaic
R&D:	research and development
RE:	renewable energy
UNFCCC:	United Nations Framework Convention on Climate Change
WWS:	wind, water, and sunlight

INTRODUCTION

I, Mark Jacobson, have been retained by Plaintiffs in the above-captioned matter to provide expert testimony about the feasibility of transitioning the United States of America to 100% clean and renewable energy in all energy sectors by mid-century, including whether this transition would remedy the constitutional violations alleged in the First Amended Complaint in this case. All energy sectors include electricity, transportation, heating/cooling, and industry.

QUALIFICATIONS

Since 1989, I have been researching academically and professionally, the impacts of human emissions of gases (including carbon dioxide and other greenhouse gases) and particles (including black carbon) on air pollution, human health, weather, and climate. Starting in 1999, I began examining in detail clean, renewable energy solutions to these problems. In 2015, this research culminated in the development of roadmaps to transition the all-sector energy infrastructures of each of the 50 United States to 100% clean, renewable energy by 2050 (Jacobson et al., 2015a, which includes a link to the spreadsheets used to derive all numbers in the paper). The research has also resulted in the development of 100% clean, renewable energy roadmaps for 139 countries of the world (Jacobson et al., 2017a, which also includes a link to spreadsheets) and electric power grid stability analyses for the 48 contiguous United States (Jacobson et al., 2015b) and for 20 world regions containing the 139 countries examined (Jacobson et al., 2018) after those states and countries have converted to 100% clean, renewable energy. I carried out this research, analysis, and clean, renewable energy roadmap development primarily with Dr. Mark Delucchi at U.C. Berkeley, but also along with several other experts. The purpose of this report is to summarize the portion of this research related to the United States and its major conclusions and implications on the feasibility of transitioning the country swiftly off of fossil fuels to clean and renewable energy in all sectors by mid-century.

The opinions expressed in this report are my own and are based on the data and facts available to me at the time of writing. All opinions expressed herein are to a reasonable degree of scientific certainty, unless otherwise specifically stated. Should additional relevant or pertinent information become available, I reserve the right to supplement the discussion and findings in this expert report in this action.

My full CV, including a list of publications I authored within the last ten years, is attached as **Exhibit A** to my report. My report contains a list of citations to the principal documents that I have used or considered in forming my opinions, listed in **Exhibit B**. **Exhibit C** contains a summary of my previous expert testimony. **Exhibit D** is a chart summarizing other decarbonization studies of which I am aware. I also attach, as **Exhibits E-H**, my central papers discussed herein.

In preparing my expert report and testifying at trial, I am deferring my expert witness fees to the charged plaintiffs given the financial circumstances of these young plaintiffs. If a party seeks discovery under Federal Rule 26(b), I will charge my reasonable fee of \$200 per hour for the time spent in addressing that party's discovery.

EXECUTIVE SUMMARY

In this report, I summarize research, conclusions, and implications of studies that I and my colleagues previously performed to develop 100% clean, renewable all-sector (electricity, transportation, heating/cooling, industry) roadmaps (plans) for the 50 United States (Jacobson et al., 2015a) and to analyze resulting electric grid stability for the 48 contiguous United States (Jacobson et al., 2015b). I also rely on our updated peer-reviewed research on an energy roadmap for the United States as a whole (Jacobson et al., 2017a) and a grid stability study for the United States plus Canada combined (Jacobson et al., 2018). I set forth a substantive discussion of numbers from the 50-state roadmaps in Jacobson et al. (2015a) where the numbers are set forth both on a state specific basis and for the U.S. as a whole. However, the U.S.-as-a-whole numbers were updated in Jacobson et al. (2017a) based on updated cost, efficiencies, and other data. Jacobson et al. (2017a) does not have an in-depth discussion of those data simply because the 2015a study provides state-by-state breakdowns as well. Nevertheless, both studies provide a consistent conclusion. Namely, I conclude in both studies that it is both technically and economically feasible to transition from a predominantly fossil fuel-based energy system to a 100% clean, renewable energy system for all energy sectors by 2050, with about 80% conversion by 2030, even after taking into account the U.S. Department of Energy's (DOE's) Energy Information Administration's (EIA's) energy demand forecasting and taking into account efficiencies resulting from the transition from fossil fuels to clean, renewable energy.

Presently, fossil fuels supply more than 80% of our all-purpose energy in the United States, not out of necessity, but because of political preference and historic government support that led to the development and maintenance of a widespread fossil-fuel infrastructure. Our plans provide state-by-state roadmaps to replace 80% of existing fossil fuel energy by 2030 and 100% by 2050. The main concept is to electrify all energy sectors with existing or near-existing technologies, and then to generate the electricity for all sectors with 100% wind, water, and sunlight (WWS), namely onshore wind, offshore wind, utility-scale photovoltaics (PV), rooftop PV, concentrated solar power (CSP) with storage, geothermal power, wave power, tidal power, and hydroelectric power. A 100% WWS system would also require electricity storage, heat storage, cold storage, and some hydrogen storage along with an expanded transmission and distribution system.

First, based on our 2015 study (Jacobson et al., 2015a), converting to 100% WWS would reduce the U.S.-average end-use power demand by a mean of ~39.3%. Approximately 82.4% of the reduced power demand is due to a) the higher work output to energy input of electricity compared with fossil-fuels (burning fossil fuels to move vehicles results in much more waste heat than using electricity), and b) eliminating the energy needed to mine, transport, and refine fossil fuels and uranium (because wind and solar energy, for example, come right to the wind turbine or solar panel, respectively). The rest of the reduction in power demand is due to end-use energy efficiency and conservation improvements beyond those expected in a business-as-usual (BAU) case.

Second, averaged over the United States, our roadmaps propose that all-purpose U.S. energy in 2050 could be met with ~30.9% onshore wind, ~19.1% offshore wind, ~30.7% utility-scale photovoltaics (PV), ~7.2% rooftop PV, ~7.3% concentrated solar power (CSP) with storage, ~1.25% geothermal power, ~0.37% wave power, ~0.14% tidal power, and ~3.01% hydroelectric

power (where virtually all hydroelectric dams exist already). This is only one of many possible mixes. We have run our model with other mixes as well to demonstrate that a 100% WWS system by 2050 is feasible (e.g., Jacobson et al., 2017a).

Third, over all 50 states, converting from fossil fuel energy to WWS would provide an estimated 3.9 million 40-year full-time construction jobs and about 2.0 million 40-year full-time operation jobs for the energy facilities alone.

Fourth, converting from fossil fuel energy to WWS would also eliminate ~62,000 (19,000-115,000) U.S. air pollution premature mortalities per year today and ~46,000 (12,000-104,000) per year in 2050, avoiding ~\$600 (\$85-\$2,400) billion per year (2013 dollars) in 2050, based on statistical cost of life as defined by the U.S. government, equivalent to ~3.6 (0.5-14.3) percent of the 2014 U.S. gross domestic product.

Fifth, converting from fossil fuel energy to 100% WWS would further eliminate ~\$3.3 (1.9-7.1) trillion per year in 2050 global warming costs to the world due to U.S. emissions.

Sixth, these plans will result in each person in the U.S. in 2050 saving ~\$260 (190-320) per year in energy costs (\$2013 dollars) and U.S. health and global climate costs per person decreasing by ~\$1,500 (210-6,000) per year and ~\$8,300 (4,700-17,600) per year, respectively.

Seventh, the new footprint over land required to implement our plan would be ~0.42% of U.S. land. The spacing area between wind turbines, which can be used for multiple purposes, will be ~1.6% of U.S. land area. 0.42% of U.S. land is equivalent to ~14,800 square miles. For comparison, an upper bound of ~75,000 square miles of land (2.1% of U.S. land area) may have been used to date for roads, well pads, and storage facilities for the 2.5 million inactive and 1.7 million active oil and gas wells alone in the United States to date (Fracktracker Alliance, 2015). Pennsylvania alone has ~560,000 abandoned oil and gas wells (Pennsylvania Department of Environmental Protection, 2016). 20,000 new oil and gas wells are drilled in the United States every year. Allred et al. (2015) estimate that the area taken up by well pads, roads, and storage facilities for natural gas wells sum to 0.0178 square mile per well. Extrapolating this estimate to oil wells and to all abandoned plus active oil and gas wells in the U.S. gives the 75,000 mi² estimate. While this is an upper bound for oil and gas wells, coal and oil extraction has required additional land as have oil and gas pipelines, oil refineries, gas stations, power plants, and other oil, gas, and coal infrastructure, which will become obsolete upon the transition to 100% clean and renewable energy.

Eighth, the state-by-state roadmaps have been calculated to keep the 48 contiguous state U.S. grid stable at low cost in two separate peer-reviewed studies under multiple storage scenarios (Jacobson et al., 2015b; Jacobson et al., 2018). In the latter study, grid stability over the U.S. and Canada combined were found under three different scenarios, including two with no added hydropower turbines and one with added hydropower turbines.

In other words, the roadmaps will keep the lights on. Power supply will continue to match demand as it currently does, every minute of every day. Although the wind doesn't always blow and the sun doesn't always shine, it is possible to match power demand during those periods at a given

location by using stored energy, shifting the time of peak demand for energy with financial incentives (demand response), and by adding some long-distance transmission to connect wind and solar in remote locations to cities. In our studies, storage is in the form of heat (in water, rocks, and thermal mass); cold (in ice and water); electricity (in concentrated solar power (CSP) with storage, batteries, pumped hydropower systems, and existing hydropower dams), and hydrogen (for use in transportation). In our studies, we have found that the grid can stay stable with no coal, natural gas, oil, biofuels, or nuclear power. The resulting 2050-2055 U.S. electricity social cost (energy cost plus health cost plus climate cost) for a full system is much less than for current energy sources, and the energy cost alone is similar or less.

In sum, conversions of the energy infrastructure of the United States to 100% wind, water, and sunlight for all purposes is technically and economically feasible at low cost and high benefit. Based upon my review of the available information and pertinent literature identified herein, as well as my many years of experience as described herein, I conclude that a transition to 100% clean, renewable energy by mid-century would stop the affirmative government infringement of the youths' constitutional rights as described in the First Amended Complaint, and even though not all of the harm caused by historic emissions would be remediated, it would put the nation on the correct path toward climate stabilization.

EXPERT OPINION

1. Technological and Economic Feasibility of Converting 100% of Our Energy From Fossil Fuels to Clean, Renewable Energy For All Sectors by 2050 and 80% by 2030.

Our research suggests that it is technologically and economically possible to electrify fully the energy infrastructures of all 50 United States and provide that electricity with 100% clean, renewable wind, water, and sunlight (WWS) at low cost, if the transition is commenced immediately (Jacobson et al., 2015a; 2017a). Whereas, a 100% transformation is technically and economically possible by 2030, we believe that, for social and political reasons, a more practical expectation to transition all sectors (electricity, transportation, heating/cooling, industry) is 80% by 2030 and 100% by 2050. These conclusions are based upon the assumption that the transition commences immediately. Our research further finds that the U.S. electric power grid with 100% WWS can stay stable at low cost (similar or less than today's direct energy cost and much less than today's social cost, which includes energy, health, and climate costs) because electrifying transportation and heating creates more flexible loads, allowing grid operators to shift times of peak demand more readily (Jacobson et al., 2015b; 2018). Further, flexible loads allow low-cost storage options for heat and cold to be used to displace electricity demand and store excess electricity rather than wasting it.

The methodology for this research, outlined in detail in Jacobson et al. (2015a,b) and updated in Jacobson et al. (2017a; 2018), is as follows:

- 1) For each of the 50 states, we start with contemporary business-as-usual (BAU) end-use power demand by fuel type in the residential, commercial, transportation, and industrial sectors.

- 2) We use U.S. Department of Energy (DOE) Energy Information Administration (EIA) data and other data to project BAU end-use power demand by fuel type to 2050.
- 3) We electrify end-use demand in 2050 by fuel type in each sector, for each state. For some sectors, electricity is used to produce hydrogen.
- 4) We specify a mix of WWS electric power generators to meet the end-use electric demand in each state. The mix is limited and optimized by the technical potentials of each WWS resource in each state.
- 5) We calculate the required footprint and spacing area required for the WWS technologies.
- 6) We calculate the cost of constructing the WWS infrastructure for each state, including necessary upgrades to national electricity transmission infrastructure.
- 7) We calculate the number of long-term, full-time construction and operation jobs required for the generators and the corresponding number of jobs lost in the BAU energy sectors, primarily in the fossil fuel industry.
- 8) We calculate the air pollution mortality and morbidity reduction and corresponding health cost reduction due to transitioning from BAU to WWS.
- 9) We calculate the greenhouse gas emission reduction and corresponding climate cost reduction due to transitioning from BAU to WWS.
- 10) We use a weather prediction model to predict the time-dependent wind and solar fields in 2050 in each of the 48 contiguous U.S. states under the 100% WWS case in each state.
- 11) We project time-dependent power demand to 2050 from contemporary data.
- 12) We simulate the time dependent matching of power demand with WWS supply over the U.S. every 30 seconds for 6 years, with zero loss of load, accounting for low-cost heat storage (in water and rocks), cold storage (in water and ice), electricity storage (in concentrated solar power with storage, pumped hydroelectric storage, batteries, and hydroelectric power), demand response, and long-distance transmission.
- 13) We calculate the resulting cost of energy matching supply with demand.

The research concludes that converting from fossil fuel combustion to a completely electrified system for all purposes could reduce U.S.-averaged end-use power demand (load) ~39.3%. Approximately 82.4% of the reduced electricity use results from the higher work output to energy input of electricity over fossil fuels and the elimination of energy needed to mine, transport, and refine fossil fuels and uranium. The rest of the reduced electricity use is due to end-use energy efficiency and conservation improvements beyond those expected in a business-as-usual (BAU) case. The conversion to WWS should also stabilize energy prices since fuel input costs will be zero, avoiding much of the market fluctuations in the price of oil, coal, and gas.

Remaining all-purpose annually-averaged end-use U.S. load, based on the Jacobson et al. (2015a) study, is proposed to be met (based on 2050 energy estimates) with ~328,000 new onshore 5-MW wind turbines (providing 30.9% of U.S. energy for all purposes), ~156,000 offshore 5-MW wind turbines (19.1%), ~46,500 50-MW new utility-scale solar-PV power plants (30.7%), ~2,270 100-MW utility-scale CSP power plants (7.3%), ~75.2 million 5-kW residential rooftop PV systems (3.98%), ~2.75 million 100-kW commercial/government rooftop systems (3.2%), ~208 100-MW geothermal plants (1.23%), ~36,000 0.75-MW wave devices (0.37%),

~8,800 1-MW tidal turbines (0.14%), and no new hydroelectric plants in the 48 contiguous states but 3 new hydroelectric plants in Alaska. The output of existing hydroelectric plants would be increased slightly so that hydropower supplies 3.01% of U.S. all-purpose power.

The Jacobson et al. (2015b) grid integration study based on the 50-state plans suggests that an additional ~1,360 CSP plants (providing an additional ~4.38% of annually-averaged load) and 9,380 50-MW solar-thermal collection systems for heat storage in soil (providing an additional 7.21% of annually-averaged load) would be needed as a first estimate to ensure a reliable grid. That study also assumed an increase in the peak hydropower discharge rate while holding the annual-average hydropower output constant. It also assumed a significant amount of underground thermal energy storage. This was just one possible mix of energy generators and storage. While that study faced criticism from authors, the criticisms were not only responded to point-by-point (Jacobson et al., 2016; 2017b) but the most significant ones were also shown to be moot in a follow-up peer-reviewed published study (Jacobson et al., 2018).

The subsequent study (Jacobson et al., 2018) performed a similar calculation as in Jacobson et al. (2015b) but with more storage options, including two with zero added hydropower turbines and one with zero underground or other thermal energy storage. More specifically, the additional simulations included (1) zero increase in the hydropower discharge rate but increasing the discharge rate of concentrated solar power (CSP) and adding battery storage while keeping thermal energy storage; and (2) zero increase in the hydropower discharge rate and zero thermal energy storage but using CSP with storage, batteries, and heat pumps instead.

Simulations for Jacobson et al. (2018) were performed for 20 world regions, including the United States plus Canada, island countries, medium-sized countries, and large countries and continents, rather than just one world region in Jacobson et al. (2015b). All simulations for all world regions resulted in stable grids at low cost over a 5-year simulation period, including with no added hydropower turbines and, in one case, with no thermal energy storage at all. These results for extreme conditions suggest there are multiple intermediate solutions with a variety of combinations of WWS storage technologies and resources. All methods resulted in low-cost solutions and 100% WWS by 2050. The fact that the system works with either increased hydropower discharge or increased CSP and batteries or CSP, batteries, and heat pumps is illustrative of the feasibility of transitioning the nation's energy system to 100% WWS. There is not just one way of achieving the transition, but many pathways. In fact, even critics of our methodology do not disagree with the conclusions we reach.¹

Practical implementation considerations will determine the actual design and operation of the U.S. energy system and may result in technology mixes different than proposed here (e.g., more rooftop PV, less power plant PV).

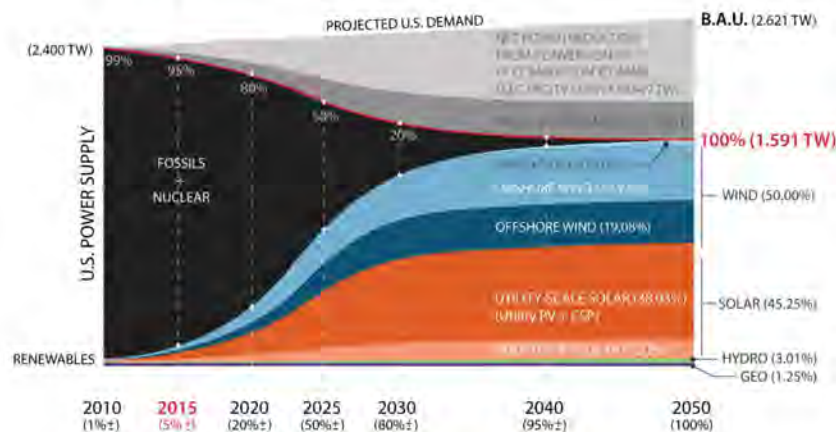
Other studies in the U.S. and abroad provide parallel support for the ability to swiftly move away from fossil fuels. These studies are briefly summarized in **Exhibit D**. While I do not endorse

¹ June 20, 2017 Daniel Kammen Twitter: "A significant misunderstanding here: yes the 100% target is needed AND is feasible, but one must do the analytics correctly to be useful."

each of these studies and not all of the studies consider all energy sectors or 100% clean energy by 2050 as we do, collectively they illustrate the vast potential and feasibility of swift decarbonization and transition to clean, renewable energy. Specifically, several of these published studies conclude that 100% renewable energy for all sectors by 2050 for France, the European Union, and globally is feasible.

The timeline for conversion under either modeled scenario is proposed as follows: 80% of all energy to be WWS by 2030 and 100% by 2050 (**Figure 1**). If this timeline is followed, implementation of these plans and similar ones for other countries worldwide provides the pathway to eliminate energy-related global warming; air, soil, and water pollution; and energy insecurity. Transitioning at this pace should avoid global temperatures from rising more than 1.5°C as a peak temperature increase since 1870 and reduce CO₂ back to 350 ppm by 2100 (Section 2). Transitioning to 100% WWS by 2050 also provides the best opportunity for the federal government to further reduce global surface and ocean temperatures to levels that will over the long term stabilize the planet's ice sheets.

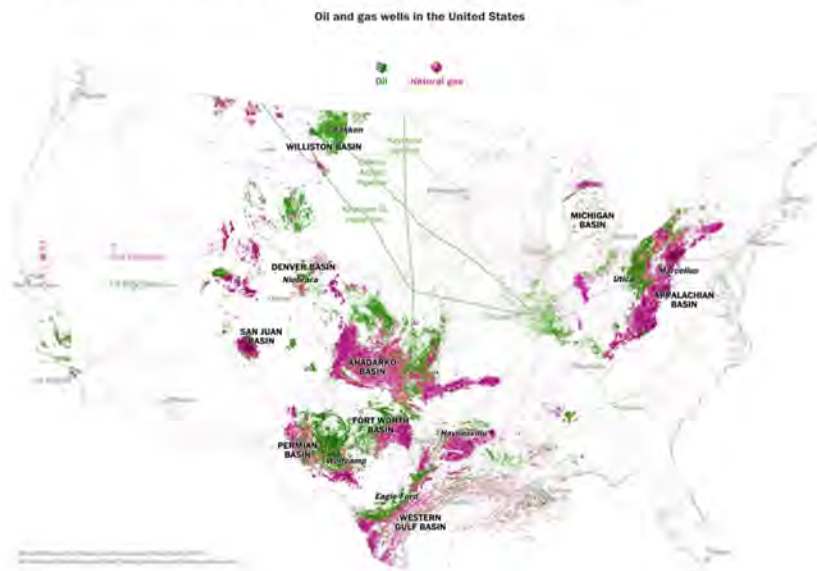
Figure 1. Time-dependent change in U.S. end-use power demand for all purposes (electricity, transportation, heating/cooling, and industry) and its supply by conventional fuels and WWS generators based on the state roadmaps proposed. Total power demand decreases upon conversion to WWS due to the higher work output per unit energy input of electricity over combustion, the elimination of energy used to mine, transport, and refine fossil fuels, and additional end-use energy efficiency measures in the WWS case. The percentages on the horizontal date axis are the percent conversion to WWS that has occurred by that year. The percentages next to each WWS source are the final estimated penetration of the source. The 100% demarcation in 2050 indicates that 100% of all-purpose power is provided by WWS technologies by 2050, and the power demand by that time has decreased. In 2010 nuclear power represented ~4% of the total end-use fossil plus nuclear power (from Jacobson et al., 2015a).



The additional footprint on land for WWS devices is equivalent to about 0.42% of the U.S. land area, mostly for utility scale PV. An additional on-land spacing area of about 1.6% is required for onshore wind, but this area can be used for multiple purposes, such as open space, agricultural land, or grazing land. The land footprint and spacing areas (open space between devices) in the proposed scenario can be reduced by shifting more land based WWS generators to the ocean, lakes, and rooftops.

As described previously, 0.42% of U.S. land is equivalent to ~14,800 square miles. For comparison, an upper bound of ~75,000 square miles of land (2.1% of U.S. land area) may have been used to date for roads, well pads, and storage facilities for the 4.2 active plus inactive oil and gas wells in the United States (Fracktracker Alliance, 2015). Additional land is required for coal and oil extraction, oil and gas pipelines, oil refineries, gas stations, power plants, and other oil, gas, and coal infrastructure (see **Figure 2**). Thus, the roadmaps here will take much less footprint than oil and gas alone in the United States.

Figure 2. Oil and Gas Wells in the United States (Meko and Karklis, Wash. Post, 2017).



Offshore oil and gas infrastructure is similarly extensive for the Gulf of Mexico, as depicted in **Figure 3**.

Figure 3. Gulf Coast Oil and Gas Infrastructure (Meko and Karklis, Wash. Post, 2017).



The 2017 unsubsidized business costs of new onshore wind and utility-scale solar plants is already less than that of new natural gas power plants (Lazard, 2017). Rooftop PV, offshore wind, tidal, and wave are more expensive, but their costs are declining rapidly. By 2030 and

2050, however, the business costs of all WWS technologies are expected to drop, whereas conventional fuel costs are expected to rise (Jacobson et al., 2015a and references therein).

In 2050, the direct (business) cost of a full 100% WWS grid-integrated system (including generation, transmission, distribution, and storage) is calculated to be similar or less than that of a fossil fuel system (Jacobson et al., 2015b, 2018). The total social cost (business cost plus health and climate cost) of a 100% WWS system will be about one-third to one-fourth that of a fossil-fuel system due to the high climate and health costs of fossil fuels (Jacobson et al., 2015b, 2018).

The 50-state WWS roadmaps are anticipated to create ~3.9 million 40-year construction jobs and ~2.0 million 40-year operation jobs for the energy facilities alone, outweighing the ~3.9 million jobs lost to give a net gain of 2.0 million 40-year jobs. Earnings during the 40-year construction period for these facilities (in the form of wages, local revenue, and local supply-chain impacts) are estimated to be ~\$223 billion per year in 2013 dollars and annual earnings during operation of the WWS facilities are estimated at ~\$132 billion per year. Net earnings from construction plus operation minus lost earnings from lost jobs are estimated at ~\$85 billion per year.

The state roadmaps will reduce U.S. air pollution mortality by ~62,000 (19,000-115,000) U.S. air pollution premature mortalities per year today and ~46,000 (12,000-104,000) per year in 2050, avoiding ~\$600 (85-2,400) billion per year (2013 dollars) in 2050, equivalent to ~3.6% (0.5-14.3) of the 2014 U.S. gross domestic product.

Converting to WWS would further eliminate ~\$3.3 (1.9-7.1) trillion per year in 2050 global warming costs to the world due to U.S. greenhouse gas emissions. These plans will result in the average person in the U.S. in 2050 saving ~\$260 (190-320) per year in energy costs (2013 dollars), \$1,500 (210-6,000) per year in health costs, and \$8,300 (4,700-17,600) per year in climate costs for a total annual per capita savings of \$10,060 (5,100-23,920).

Uncertainties remain in terms of the range of energy, health, and climate costs we estimate in our analysis. These ranges may miss costs impacted by unforeseen political/social events. As such, the estimates should be reviewed periodically. However, even recognizing such uncertainties, I conclude to a strong degree of scientific certainty that transitioning to 100% WWS is in the economic best interest of the United States.

Transitioning to 100% WWS will allow the United States to produce as much power as it uses in the annual average at present, thereby reducing its reliance on international competition for energy, potentially reducing international conflict and increasing energy stability within the United States. In addition, the economic benefits of transitioning to 100% WWS would flow toward the citizens of the United States, as we would not be required to purchase fossil fuels from other countries.

Transitioning to 100% WWS will increase access to distributed energy, providing easier and more access to energy for those living in remote areas.

Transitioning to 100% WWS will reduce the risk of large-scale system disruption due to large power plant outages and physical terrorism (but not necessarily due to cyberattack) because much of the world power supply will be decentralized into more, smaller power sources.

Based on the scientific results presented, current barriers to implementing the WWS roadmaps are neither technical nor economic. They are social and political. Such barriers are due partly to the fact that most people are unaware of what changes are possible, what technology is available, and how they will benefit from a transition to WWS in their own lives and partly due to the fact that many with a financial interest in the current energy industry resist change. Because the benefits of converting (reduced global warming and air pollution, new jobs and stable energy prices) far exceed the costs, converting has little downside.

2. What is Needed to Decrease Atmospheric CO₂ to 350 ppm by 2100

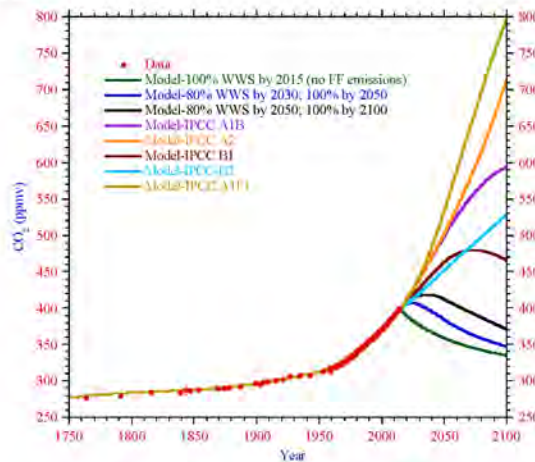
Transitioning 80% of the United States and the world's energy and land-use change emissions to WWS by 2030 and 100% by 2050 is consistent with a trajectory to allow atmospheric CO₂ levels to decrease to near 350 ppm by 2100.

Mathews (2016) estimates the global emission limits to keeping temperature increases under 1.5°C with probabilities of 67% and 50% as 2400 Gt-CO₂ and 2625 Gt-CO₂, respectively.

Between 1870 and the end of 2015, a cumulative ~2050 Gt-CO₂ was emitted globally from fossil-fuel combustion, cement manufacturing, and land use change. (Mathews, 2016). This suggests no more than 350-575 Gt-CO₂ can be emitted for a 67-50% probability of keeping post-1870 warming under 1.5°C. Given the current and projected global emission rate of CO₂, it is necessary to cut energy- and land-use change emissions yearly until emission cuts reach 80% by 2030 and 100% by 2050 to limit warming to 1.5°C with a probability of between 50% and 67%.

Figure 4 illustrates the possible impact on global atmospheric carbon dioxide levels of an 80% conversion to WWS by 2030 and 100% conversion by 2050 as well as possible impacts from less aggressive emission reductions. The 100% by 2050 scenario can reduce CO₂ to near 350 ppm by 2100, a level last measured in the atmosphere around 1988. All IPCC (2000) emission scenarios result in CO₂ levels in 2100, ranging from 460 to 800 ppm. Such scenarios are certain to drive temperatures dangerously higher. A WWS scenario for the United States is essential for stabilizing and ultimately reducing temperatures over the long-term.

Figure 4. Comparison of historic (1751-2014) observed CO₂ mixing ratios (ppmv) from the Siple ice core (Neftel et al., 1994) and the Mauna Loa Observatory (Tans and Keeling, 2015) with GATOR-GCMOM model results (Jacobson, 2005) for the same period plus model projections from 2015-2100 for five Intergovernmental Panel on Climate Change (IPCC) scenarios (IPCC, 2000) and three WWS cases: an unobtainable 100% WWS by 2015 case, an 80% WWS by 2030 and 100% by 2050 case (from Figure 1 above), and a less-aggressive 80% by 2050 and 100% by 2100 case.



The model is set up as in Jacobson (2005) with two columns (one atmospheric box over 38 ocean layers plus one atmospheric box over land). It treats full ocean chemistry in all layers, vertical ocean diffusion with canonical diffusion coefficients, ocean removal of calcium carbonate for rock formation, gas-ocean transfer, and emissions from fossil fuels. It also accounts for photosynthesis, plant and soil respiration, and removal of carbon dioxide from the air by weathering. Fossil-fuel emissions from 1751-1958 are from Boden et al. (2011), from 1959-2014 are from Le Quere et al. (2015), and for 2015 onward from the WWS scenarios scaled from 2014 emission and from the individual IPCC scenarios. Land use change emissions per year are 300 Tg-C/yr for 1751-1849, from Houghton (2012) for 1850-1958, from Le Quere et al. (2015) for 1959-2014, from the IPCC (2000) A1B scenario for the WWS cases for 2015-2100, and from the individual IPCC scenarios for the remaining cases. The net carbon sink over land from 1751-2100 is calculated from the time-dependent photosynthesis, respiration, and weathering processes mentioned.

3. List of Technology Replacements and Timelines for Their Implementation

Below is a list of electric appliances, transportation options, and WWS power generators that are needed to transition to 100% WWS. Most of these technologies are available today, and the rest (e.g., for aircraft and ships in particular) are currently being designed to transform the energy infrastructure of the United States. The list is not a complete list, but demonstrates that 95% of the technological solutions for a complete transition to WWS by 2050 already exist. Future

innovations over the next 30 years and beyond will very likely provide even more technological mechanisms to facilitate the remaining transition to 100% WWS for all purposes by 2050.

A. Technology Replacements

i. Increase Energy Efficiency / Reduce Energy Demand

a. Increase efficiency in buildings through:

Lighting:

- LED lighting
- Advanced lighting controls

Appliances:

- High efficiency pumps and motors
- High efficiency commercial appliances (refrigerators, washers, dryers)
- Energy efficient residential appliances (refrigerators, water heaters, etc.)
- Variable refrigerant flow

Heating and cooling efficiency in buildings through:

- Programmable thermostats
- Improved wall, floor, ceiling, and pipe insulation
- High-efficiency double- and triple-pane windows
- Energy efficient framing practices
- Passive solar design
- Sealing doors, windows, walls, outlets, and fireplaces to reduce heat / cold loss
- Evaporative cooling systems
- Ductless heat pumps for heating and air conditioning
- Water-cooled heat exchanging
- Night ventilation cooling
- Passive ventilation design
- Combined space and water heating
- Air flow management
- Heat recovery ventilation systems
- Building energy monitors to identify opportunities to reduce wasted energy

Water efficiency:

- High efficiency residential and commercial water fixtures
- High efficiency irrigation systems
- Greywater re-use systems

b. Reduced transportation demand through:

- Telecommuting rather than commute by car
- Improved biking infrastructure
- Improved pedestrian infrastructure

- Improved public transportation
- Transportation Demand Management programs that support adoption of low-carbon transportation practices
- Improved carpooling and ride-sharing programs and technologies
- Urban land use practices to reduce transportation demand (i.e. mixed use development, increased residential densities)

c. Improved vehicle efficiency through:

- Low rolling resistance tires
- Lightweight materials (i.e. carbon fiber, aluminum, fiberglass)
- Regenerative braking systems
- High efficiency settings or dashboard fuel efficiency displays

ii. WWS Electric Power Generators

- Onshore/offshore wind turbines
- Solar photovoltaics (PV) for rooftops and power plants
- Concentrated Solar Power (CSP) plants
- Geothermal power plants for electricity
- Tidal turbines
- Wave devices
- Existing large hydroelectric reservoirs used more efficiently
- Small hydroelectric reservoirs
- In-stream hydroelectric turbines

iii. Low-Temperature Heat Generators

- Geothermal heat pumps
- Natural geothermal heating
- Solar thermal collection devices for heat

iv. Electricity Storage

- CSP with storage (either molten salt or phase-change material)
- Pumped hydroelectric storage
- Hydroelectric power plant reservoirs
- Batteries

v. Heat Storage Devices

- Hot water tanks
- Rocks stored underground
- Thermal walls

vi. Cold Storage Devices

- Chilled water tanks
- Ice storage

- vii. **Hydrogen Storage Devices**
 - Electrolyzers to produce hydrogen from electricity
 - Electric compressors to compress hydrogen
 - Tanks to store hydrogen for transportation primarily
- viii. **Demand Response**
 - Technology to enable remote start up and shut down of appliances and equipment that have flexible demand (i.e. water heaters, HVAC equipment, electric vehicles)
 - Utilities provide incentives for industry, companies, and individuals to shift their electricity use for certain uses and processes to non-peak times of day or night – Time of Use electricity pricing
- ix. **Electric Vehicles**
 - Light-, medium-, and heavy-duty on-road automobiles
 - Short-distance trucks, buses, trains, ships, aircraft
 - Motorcycles
 - Non-road vehicles
 - Construction equipment
 - Agricultural equipment
 - Forklifts
- x. **Hydrogen Fuel Cell/Electric Hybrid Vehicles**
 - Long-distance trucks
 - Buses
 - Long-distance trains
 - Long-distance ships
 - Long-distance aircraft
 - Construction equipment
 - Agricultural equipment
- xi. **Electric Car Charging Infrastructure**
 - Home car chargers
 - Chargers installed in parking garages and on streets
- xii. **High-Temperature Industrial Equipment**
 - Electric arc furnaces
 - Dielectric heaters
 - Electric induction furnaces
- xiii. **Electric Appliances to Replace Gas or Gasoline**
 - Heat pump air and water heaters
 - Electric induction cooktop stoves
 - Electric dryers
 - Electric leaf blowers

- Electric lawnmowers
- Electric water sprayers
- Electric fans

xiv. Long-Distance Transmission

- High-voltage direct-current (HVDC) lines

Whereas, much new WWS infrastructure can be installed upon natural retirement of BAU infrastructure, new policies are needed to force remaining existing infrastructure to retire early to allow the complete conversion to WWS by 2050. Because the air-pollution and climate-impact benefits (avoided costs) (28.5 (11.2-72) ¢/kWh-BAU-all-energy) resulting from closing BAU plants early far exceed the annualized remaining *net* asset value of such plants (the difference between the annualized capital cost and the annualized salvage or re-use value) divided by annual energy produced, and because net jobs increase upon replacing BAU plants, retiring them early results in large net health, employment, and climate benefits to society.

B. Timelines for Transitioning Individual Sectors

The overall timeline proposed for transitioning to 100% WWS is 80% by 2030 and 100% by 2050. To meet this timeline, rapid transitions are needed in each technology sector. Below is a list of proposed transformation timelines for individual sectors.

Development of super grids and smart grids: as soon as possible, the United States should develop long-term power-transmission-and-distribution systems to provide “smart” management of energy demand and supply at all scales, from local to international, with a 100% WWS system. This allows supply and demand to be optimized.

Power plants: by 2020 at the latest, no more construction of new coal, nuclear, natural gas, or biomass fired power plants; all new power plants built should be WWS.

Storage: starting immediately, heat, cold, and electric storage technologies should be deployed. Heat storage technologies include underground storage in rocks, storage in hot water tanks, and storage in thermal mass (e.g., wax, cement blocks). Cold storage includes primarily storage in ice and water. Electric storage includes storage in concentrated solar power, pumped hydroelectric power, batteries, and in existing hydroelectric reservoirs. Other types of storage are also possible.

Heating, drying, and cooking in the residential and commercial sectors: by 2020, all new devices, appliances, and machines should be electric.

Industrial heat: by 2023, all new high-temperature heating equipment for industrial applications should be electric.

Large-scale waterborne freight transport: by 2020-2025, all new ships should be electrified and/or use electrolytic hydrogen, all new port operations should be electrified, and port retro-electrification should be well underway.

Rail and bus transport: by 2025, all new trains and buses should be electrified. This requires changing the supporting energy-delivery infrastructure and the manufacture method of transportation equipment.

Off-road transport, small-scale marine: by 2025 to 2030, all new production should be electrified.

Long-distance heavy-duty truck transport: by 2025 to 2030, all new heavy-duty trucks and buses should be electric or hydrogen fuel cell-electric hybrids.

Light-duty on-road transport: by 2025-2030, all new light-duty on-road vehicles should be electric.

Short-haul aircraft: by 2035, all new small, short-range aircraft should be electric.

Long-haul aircraft: by 2040, all remaining new aircraft should be hydrogen fuel cell-electric hybrids.

During the transition, conventional fuels and existing WWS technologies are needed to produce the remaining WWS infrastructure. However, much of the conventional energy would be used in any case to produce conventional power plants and automobiles if the plans proposed here were not implemented. Further, as the fraction of WWS energy increases, conventional energy generation will decrease, ultimately to zero, at which point all new WWS devices will be produced with existing WWS. In sum, the creation of WWS infrastructure may result in a temporary increase in emissions before they are ultimately reduced to zero.

4. Recommended First Steps and Potential Policies

Whereas, much new WWS infrastructure can be installed upon natural retirement of BAU infrastructure, new policies are needed to encourage remaining existing infrastructure to retire early to allow the complete conversion to WWS. Because the annual air-pollution and climate-impact benefits (avoided costs), as quantified here, resulting from closing BAU plants early far exceed the annualized remaining *net* asset value of such plants (the difference between the annualized capital cost and the annualized salvage or re-use value), and because net jobs increase upon replacing BAU plants, retiring them early results in large net benefits to society.

5. Why Nuclear, Biofuels, and Coal with Carbon Capture are Not Included

While some people have suggested that energy options aside from WWS, such as nuclear power, coal with carbon capture and sequestration (coal-CCS), and biofuels, can play a role in solving these problems, all four technologies, while better in several respects than fossil fuel technologies, have some disadvantages relative to fossil fuel technologies and significant

disadvantages relative to WWS technologies. These advantages/disadvantages are listed below and then explained in more detail below that.

With respect to some of the disadvantages, it is important to note that because we must reduce emissions 80% by 2030 (thus only 12 years from 2018), we do not recommend power plant technologies that cannot be installed within the next few years.

Nuclear power

Advantages

- Low carbon and air pollution relative to fossil fuels.
- Requires only modest land use.

Disadvantages

- Requires 10-19 years between planning and operation versus 2-5 years for wind/solar.
- Expensive; cannot be built without significant financial support and insurance guarantee from government.
- Carries weapons proliferation risk.
- Carries meltdown risk (1.5% of all reactors built to date have melted down).
- Nuclear waste disposal issue (where to put the waste).
- Significant water is required for cooling with current and future technology.
- Nuclear material mining risks.
- Nuclear material transportation risks.
- 6-23 times the carbon emissions of wind power per unit energy generated.
- Not a renewable resource.
- Potential terrorism target.

Coal with carbon capture

Advantages

- Less carbon dioxide emissions than coal without carbon capture.
- Keeps coal miners employed in mining.

Disadvantages

- Requires 25% more energy than regular coal → 25% more air pollution emissions than regular coal because carbon capture equipment reduces only carbon dioxide.
- Still produces 50-60 times more CO₂ per unit energy than wind because it doesn't reduce CO₂ from mining or transporting coal, which is one-third of the emissions associated with coal power generation.
- Still results in land/habitat destruction due to coal mining.
- Still results in black lung disease to coal miners.
- Much more expensive than wind or solar power.
- Requires a minimum of 6-9 years between planning and operation versus 2-5 years for wind/solar.
- Coal-CCS can only be placed near specific geological formations.
- Long-term geologic storage of CO₂ is unproven.

- CO₂ stored underground has potential to leak.
- Not a renewable resource.

Biofuels

Advantages

- Carbon produced from burning a biofuel can be recaptured during regrowth of the biofuel.
- Biofuel combustion emits less of some chemicals than gasoline or diesel combustion.
- Biofuels can sometimes be substituted directly for fossil fuels in some automobiles, for example.

Disadvantages

- Biofuels require a significant amount of energy to produce, and a lot of that energy can be from fossil fuel combustion.
- Biofuel combustion emits more of some chemicals than gasoline or diesel combustion.
- Overall ozone production and mortality from burning ethanol as a fuel exceeds that from burning gasoline in the United States.
- The land required for growing biocrops is enormous.
- Solar PV produces 20 times more electricity than a biocrop produces energy over the same amount of land.
- Using land for food instead of fuel raises the price of food and spurs deforestation in parts of the world to create more land for biocrops.

With respect to the cost of nuclear and coal-CCS, the Intergovernmental Panel on Climate Change (IPCC) (2014) states (Section 7.8.2), “*Without support from governments, investments in new nuclear power plants are currently generally not economically attractive within liberalized markets...*”

Similarly, Freed et al. (2017), who are strong nuclear advocates, state, “*...there is virtually no history of nuclear construction under the economic and institutional circumstances that prevail throughout much of Europe and the United States.*”

Further, Cooper (2016), who compared WWS with nuclear and CCS scenarios, concluded, “*Neither fossil fuels with CCS or nuclear power enters the least-cost, low-carbon portfolio.*”

IPCC (2014) further states that, with high penetrations of renewable energy (RE), nuclear and CCS are not efficient (Section 7.6.1.1), “*...high shares of variable RE power...may not be ideally complemented by nuclear, CCS...*”

With respect to the other disadvantages of nuclear, IPCC (2014, p. 517) concludes that there is “*robust evidence*” and “*high agreement*” that “*Barriers to and risks associated with an increasing use of nuclear energy include operational risks and the associated safety concerns, uranium mining risks, financial and regulatory risks, unresolved waste management issues, nuclear weapons proliferation concerns, and adverse public opinion.*” As such, expanding the

use of nuclear to countries where it doesn't exist may increase weapons proliferation and meltdown risks. Wind, water, and solar power have none of these risks. More advanced nuclear cannot be evaluated until it is commercialized, but it does not exist today.

With respect to the time lag between planning and operation of nuclear versus wind/solar, the air pollution emissions of nuclear versus coal-CCS versus biofuels versus wind/solar, please see Jacobson (2007, 2009).

6. Historical WWS Technological Feasibility

The United States could have begun the WWS transition by at least the late 1970s and early 1980s. In my expert opinion, had government promoted a climate-safe national energy policy at that time, the proportion of our nation's energy system powered by WWS would today be much greater than it is currently in my estimation. For example, the graph in **Figure 5** below shows several historical examples of the U.S. government making recommendations, roadmaps, or plans since the early 1980s to decarbonize the national energy system, none of which was implemented. Notwithstanding their knowledge of climate change, and the alternative energy systems available to the country, the Federal Defendants chose to continue a fossil fuel energy system, which still supplies the majority of our energy today across all sectors. The red line shows actual and projected business as usual US emissions by the EIA under the Trump administration, which diverge substantially from the other recommended energy emission pathways.

Figure 5. Known CO₂ reduction pathways proposed by the Federal Government that were never implemented. ((1) EIA Reference Case, 2017 (2) EPA, 1983, (3) EPA, 1990, (4) OTA 1991, (5) Kyoto Protocol, 1997, (6) U.S. White House, 2016, (7) EIA Reference Case: with Clean Power Plan, 2017)



Other Examples:

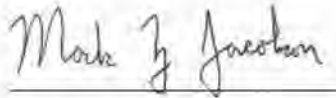
- California developed the first three major wind farms worldwide in the late 1970s and early 1980s. These were Altamont Pass, Tehachapi, and San Geronimo Pass. However, U.S. national policy shifted, and further growth of wind was slowed substantially for 1-2 decades. During that period, the center of wind farm development and manufacturing moved to Europe.
- Similarly, burgeoning U.S. policy in the 1970s encouraged solar energy expansion, but dominant U.S. policies that favored traditional fossil fuels squeezed out solar growth in the 1980s and 1990s. Only in the last decade has solar begun to grow substantially. In a December 5, 1978 Department of Energy Domestic Policy Review of Solar Energy Report to the White House, Defendant DOE projected that technical capacity for solar penetration by the year 2000 was 26-31% of national energy supply (Schlesinger 1978). The same report also confirmed the inefficiency of the energy system where 56% of annual energy use was consumed in conversion, transmission and end-use losses, not in actual energy use. The report confirms that widespread use of solar energy, which was technically available even in the 1970s was "hindered by Federal and state policies and market imperfections that effectively subsidize competing energy sources." The lack of federal R&D and other support, which was largely given to fossil fuels, limited the "long-term contribution of solar energy to the nation's energy supply." (Schlesinger 1978).
- Electric cars have been around for over 180 years (since 1837). The first U.S. electric car was built in 1890. By 1900, 34,000 cars, or 38% of the U.S. fleet was electric. However, their popularity declined in the 1910s due to greater range of fossil fuel cars. Electric cars only began to re-emerge in the U.S. in the 1990s following a push by the California Air Resources Board to reduce emissions. But, pressure by the oil industry combined with U.S. policy that supported the internal combustion engine and fossil fuels, not electric vehicles, caused manufacturers to stop producing and even destroying electric cars. After the development of the Toyota Prius, Tesla began working on an electric car in 2004, successfully producing a long-distance Roadster in 2008. In my expert opinion, if government had given support to electric cars during any decade prior to the mid- to- late 2000s, I believe, the percent of the U.S. automobile market that is electric would be significantly higher than today.
- It is my expert opinion that if the policies of the United States had encouraged more subsidies and R&D for renewable energy, efficiency, electric appliances, and electric cars rather than subsidies and other support for fossil fuels, our country would be a lot further toward a renewable-powered energy system today than it is, the amount of carbon dioxide pollution emitted would be substantially less, and the harms from climate change would not be as severe as they are today and are projected to be in the near and long-term.

CONCLUSION AND RECOMMENDATION

In sum, I conclude that electrification and use of direct heat in all energy sectors in the United States, and providing the electricity and direct heat with 100% wind, water, and sunlight (WWS) by 2050, with 80% by 2030, is technologically and economically feasible. Use of WWS technologies may be the only way to solve the climate, air pollution, and energy security problems in a timely manner. They also involve the least risk of collateral damage and serve multiple public interests, including creating more full-time, long-term jobs than lost, reducing reliance on the international search for energy, providing energy security, and reducing substantial air pollution health and climate problems. Given that 4-7 million people currently die premature each year worldwide due to fossil fuel pollution, including 62,000 (19,000-115,000) in the United States, and climate is changing rapidly due to the increase in human-emitted gases and particles into the atmosphere, the rapid deployment of a 100% WWS solution is important and practical for solving these problems simultaneously. The bottom line is that it is technically and economically feasible to transition off of fossil fuels by 2050 and supply our energy needs with 100% WWS. The primary barrier is the lack of government direction to move energy policy in the WWS direction and government policies and actions that continue to favor a fossil-fuel based energy system.

In my expert opinion, if the U.S. defendants in this case are ordered to plan for, and implement, a 100% WWS transition by 2050, it is feasible to develop such a plan and almost all the technology is available to carry out the plan quickly in a cost-effective manner.

Signed this 6th day of April, 2018 in Palo Alto, California.



Mark Jacobson, Ph.D.



March 15, 2021

The Honorable Joe Manchin
 Chairman
 Committee on Energy and Natural Resources
 United States Senate
 306 Hart Senate Office Building
 Washington, DC 20510

Dear Chairman Manchin,

Electrifying transportation is critical to helping the United States compete for investment, advance technological innovation, grow our economy and address climate change. We have the opportunity - if we make the right policy decisions today - to cultivate an advanced vehicle industry that drives decarbonization, creates jobs, and once again makes us the envy of the automotive world.

Electric vehicles (EVs) support over 300,000 American jobs with new EV manufacturing and infrastructure poised to create hundreds of thousands of new jobs in the years to come. EV growth is projected to accelerate worldwide, whether manufactured in the U.S. or elsewhere. Other countries know this and are moving aggressively to seize the generational opportunity. We must lead this race or we'll cede this economic opportunity to foreign competitors.

In particular, China and the EU have risen to dominance in the critical supply chain and EV sector over the past 15 years. China's moves to control critical material supply chains are not only a threat to EVs but also consumer electronics and national security infrastructure. While some raw materials are sourced in other parts of the world, China controls a full 70-90% of the processing and production. The U.S. has an opportunity to counter this threat, and secure our own economy, by responsibly expanding our ability to source these materials from within our own borders. Not only will domestic sourcing bolster job creation, but it will also ensure high standards for our environment and workforce.

Despite the gains made by other nations, the United States is still strongly positioned to outcompete even the most advanced EV leaders around the globe. In fact, the most sought-after EV technologies are homegrown in the United States. Dozens of aspiring U.S. companies are producing EVs that will alter the landscape in the years ahead.

As you know, transportation is the largest carbon-emitting sector in the economy, responsible for 28% of emissions. Electrification of the transportation sector will significantly reduce emissions and address both climate change and public health effects throughout the country. While any manufacturing process includes some carbon impacts, EVs are cleaner than gasoline-powered cars, and will only get cleaner as we decarbonize the grid.¹ When we evaluate the entire process of manufacturing an EV and sourcing the electricity, EVs generate up to 67% fewer emissions over their lifetime than their gas-powered counterparts.²

¹ [bloomberg.com/news/articles/2019-01-15/electric-cars-seen-getting-cleaner-even-where-grids-rely-on-coal](https://www.bloomberg.com/news/articles/2019-01-15/electric-cars-seen-getting-cleaner-even-where-grids-rely-on-coal)

² [woodmac.com/press-releases/cvs-up-to-67-less-emissions-intensive-than-ice-cars/](https://www.woodmac.com/press-releases/cvs-up-to-67-less-emissions-intensive-than-ice-cars/)

EVs are not just good for reducing emissions, – consumers also benefit from direct fuel and maintenance savings. EV owners can save over \$700 a year in fuel and \$330 in annual maintenance costs. Meanwhile, the retail price of EVs continues to decline as manufacturing scales up. And we are set to manufacture vehicles with 400-500 miles of range and battery packs costing as little as \$60/-per-kwh, two developments that will allow EVs to outperform internal combustion engine vehicles on both range and price. Consumers can now drive zero-emission vehicles without sacrificing on cost or features they have become accustomed to, and federal, state, and local incentives have the ability to drive greater consumer benefits and EV adoption.

For these and other reasons, we must grow and expand consumer incentives for light-, medium- and heavy-duty vehicles, invest in an extensive charging infrastructure network, and send a market signal that electrification is the future by setting strong fuel economy standards. The choices we make now will determine our course for decades to come. We can either embrace the economic and domestic manufacturing opportunities we now face, or risk relying on foreign imports for years to come.

For this reason, the Zero Emission Transportation Association is urging policymakers to act now and invest wisely to help the United States realize the economic potential of an electrified domestic transportation sector. We look forward to working with you as you continue to tackle these difficult decisions and support local economies across the United States.

Sincerely,



Joe Britton
Executive Director
Zero Emission Transportation Association
