EXPOSING THE ENVIRONMENTAL, HUMAN RIGHTS, AND NATIONAL SECURITY RISKS OF THE BIDEN ADMINISTRATION'S RUSH TO GREEN POLICIES

HEARING

BEFORE THE

SUBCOMMITTEE ON ENVIRONMENT, MANUFACTURING, AND CRITICAL MATERIALS

OF THE

COMMITTEE ON ENERGY AND COMMERCE
HOUSE OF REPRESENTATIVES

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C O N T E N T S

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[1] The information has been retained in committee files and is included in the Documents for the Record at https://docs.house.gov/meetings/IF/IF18/20230426/115807/HHRG-118-IF18-20230426-SD095.pdf.

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EXPOSING THE ENVIRONMENTAL, HUMAN RIGHTS, AND NATIONAL SECURITY RISKS OF THE BIDEN ADMINISTRATION'S RUSH TO GREEN POLICIES

WEDNESDAY, APRIL 26, 2023

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENVIRONMENT, MANUFACTURING, AND CRITICAL MATERIALS,
COMMITTEE ON ENERGY AND COMMERCE,
Washington, DC.

The subcommittee met, pursuant to call, at 10:30 a.m., in room 2322, Rayburn House Office Building, Hon. Bill Johnson (chairman of the subcommittee) presiding.

Members present: Representatives Johnson, Carter, Palmer, Crenshaw, Joyce, Weber, Allen, Balderson, Fulcher, Pfluger, Miller-Meeks, Obernolte, Rodgers (ex officio), Tonko (subcommittee ranking member), DeGette, Schakowsky, Sarbanes, Ruiz, Barragán, and Pallone (ex officio).

Also present: Representatives Walberg, Pence, Castor, and Dingell.

Staff present: Sarah Alexander, Professional Staff Member, Energy and Environment; Kate Arey, Digital Director; Jerry Couri, Deputy Chief Counsel for Environment; Sydney Greene, Director of Operations; Sean Kelly, Press Secretary; Peter Kielty, General Counsel; Emily King, Member Services Director; Elise Krekorian, Professional Staff Member, Energy; Mary Martin, Chief Counsel, Energy and Environment; Jacob McCurdy, Professional Staff Member, Energy; Brandon Mooney, Deputy Chief Counsel, Energy; Kaitlyn Peterson, Clerk, Energy and Environment; Carla Rafael, Senior Staff Assistant; Emma Schultheis, Staff Assistant; Olivia Shields, Communications Director; Peter Spencer, Senior Professional Staff Member, Energy; Dray Thorne, Director of Information Technology; Camden Burke, Intern; Timia Crisp, Minority Professional Staff Member; Member; Waverly Gordon, Minority Deputy Staff Director and General Counsel; Tiffany Guarascio, Minority Staff Director; Caitlin Haberman, Minority Staff Director, Environment, Manufacturing, and Critical Materials; Kylea Rogers, Minority Policy Analyst; Medha Surampudy, Minority Professional Staff Member; Rebecca Tomilchik, Minority Junior Professional Staff Member; Tuley Wright, Minority Staff Director, Energy, Climate, and Grid Security; and C.J. Young, Minority Deputy Communications Director.

Mr. JOHNSON. The subcommittee will now come to order.

The Chair will recognize himself for 5 minutes for the purpose of an opening statement.

OPENING STATEMENT OF HON. BILL JOHNSON, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF OHIO

Well, good morning and welcome to today's hearing entitled "Exposing the Environmental, Human Rights, and National Security Risks of the Biden Administration's Rush to Green Policies."

Since day one, President Biden has put Americans at risk by pushing a whole-of-government climate agenda that increases energy costs, undermines consumer choice, and strengthens America's adversaries, especially China and Russia.

This drastic and burdensome policy agenda also appears disconnected from his stated climate goals, in that many of the so-called green energy technologies have significant environmental impacts.

Even worse, this forced march to green is far from over. For instance, I am deeply concerned with the EPA's recent announcement on proposed standards for light- and medium-duty vehicles that would force the electrification of two-thirds of our domestic car market.

Now, I have nothing against electric vehicles. I want to make that clear. But Americans deserve the right and the ability to choose an affordable car that meets their needs rather than being forced to pay more because of a Government mandate.

Democrats and the Biden administration don't want to examine the true cost of these policy choices to the environment, human rights, and national security in the United States and around the world.

In any other line of work, the failure to discuss risks honestly and transparently would be malpractice. We should not be reckless with America's energy future, and today's hearing presents an opportunity to take a more holistic, transparent approach.

So if we want to look at risks to the environment, we need to look at the deployment of renewable energy technologies that require clearing a significant amount of land. The National Renewable Energy Laboratory estimates that solar panels need 5 acres of land to generate 1 megawatt of energy, and wind turbines need 35 acres. To put that in context, you need 30 times the amount of land covered in solar panels to equal the capacity of one natural gas-fired power plant.

Rural communities across the country are voicing concerns with solar and wind operations popping up near their neighborhoods. In Ohio alone, more than 10 counties banned utility-scale solar and wind energy facilities last year.

Achieving President Biden's renewable energy goals would ignore the concerns posed by many of my constituents and others across the country, but that is not all. These same renewable energy technologies pose risks to Americans at the end-of-life stage. The International Renewable Energy Agency projects that global solar panel waste could reach 78 million tons by 2050, with anywhere from 7.5 million and 10 million tons of waste in need of disposal just in the United States. The sheer amount of waste, some of which the EPA considers to be hazardous, is deeply troubling and begs the question of whether existing landfill capacity will be overwhelmed.

And let's consider human rights. The supply chain of critical materials essential for solar wind and EV batteries is tainted with forced labor, slavery, and child abuses. All you got to do is look at this poster, these posters behind me. It gives you a perspective of what is going on in the Congo.

Both the State Department and the Department of Labor have acknowledged violations with more than 40,000 children engaging in artisanal and small-scale mining, digging for cobalt with their bare hands in the Congo, as well as thousands of members of the Uyghur Muslim community forced into labor in China.

We cannot be morally selective. It is our duty to ensure that American energy supply chains do not rely on slavery or child labor. We should also prioritize American national security rather than handing Federal subsidies and American taxpayer dollars to Chinese companies. China controls 50 to 70 percent of lithium and cobalt refining, key inputs for EV batteries, as well as 90 percent of global refining capacity for rare earth elements.

Until we increase U.S. capacity for critical mineral extraction and refining, increasing our reliance on renewable energy and EVs will only benefit China, a country openly seeking to destabilization.

So let me clear: Our goal today is to better understand the serious challenges presented by various energy technologies and their real-life impacts on American consumers. This conversation is especially needed given the speed with which this administration is insisting, with calls for 100 percent EVs and 100 percent wind and solar.

Solar and wind energy and other renewable sources can and should be a part of our energy mix, but not the only part. Energy security and reliability derive from a diverse energy mix. We should not force a rapid transition to entirely intermittent, nondispatchable, unreliable sources of energy.

So I urge proponents of this agenda to ask themselves, why are we doing this? Will the American people suffer under inflation, pay less or more for their necessities and transportation? Will their standard of living improve or decline? What will their lives look like when this so-called transition is complete? It is time that we prioritize them, the people, when we measure success with America's energy and environmental policy.

[The prepared statement of Mr. Johnson follows:]

Chair Bill Johnson
Environment, Manufacturing, and Critical Materials Subcommittee Hearing: Exposing the Environmental, Human Rights and National Security Risks of the Biden Administration's Rush to Green Policies

April 26, 2023

As prepared for delivery

Good morning and welcome to today's hearing entitled "Exposing the Environmental, Human Rights, and National Security Risks of the Biden Administration's Rush to Green Policies."

Since day one, President Biden has put Americans at risk by pushing a "whole-of-government" climate agenda that increases energy costs, undermines consumer choice, and strengthens America's adversaries, especially China and Russia.

This drastic and burdensome policy agenda also appears disconnected from his stated climate goals, in that many of the so-called "green" energy technologies have significant environmental impacts.

Even worse…the rush to green agenda is far from over.

For instance, I am deeply concerned with the EPA's recent announcement on proposed standards for light-and medium-duty vehicles that would force the electrification of two-thirds of our domestic car market.

Now, I have nothing against electric vehicles, but Americans deserve the right and the ability to choose an affordable car that meets their needs, rather than being forced to pay more because of a government mandate.

Democrats and the Biden Administration don't want to examine the true costs of these policy choices to the environment, human rights, and national security in the United States and around the world.

In any other line of work, the failure to discuss risks honestly and transparently would be malpractice!

We should not be reckless with America's energy future, and today's hearing presents an opportunity to take a more holistic, transparent approach.

So, if we want to look at risks to the environment, we need to look at the deployment of renewable energy technologies that require clearing a significant amount of land.

The National Renewable Energy Laboratory estimates that solar panels need 5 acres of land to generate one megawatt of electricity, and wind turbines need 35 acres!

To put that in context, you need ***thirty times*** the amount of land covered in solar panels to equal the capacity of one natural gas fired power plant.

Rural communities across the country are voicing concerns with solar and wind operations popping up near their neighborhoods.

In Ohio alone, more than 10 counties banned utility-scale solar and wind energy facilities last year.

Achieving President Biden's renewable energy goals would ignore the concerns posed by many of my constituents and others across the country.

But, that's not all…
these same renewable energy technologies pose risks to Americans at the end-of-life stage.

The International Renewable Energy Agency projects that global solar panel waste could reach ***78 million tons*** by 2050, with anywhere from 7.5 million and 10 million tons of waste in need of disposal in the United States.

The sheer amount of waste, some of which the EPA considers to be hazardous, is deeply troubling and begs the question of whether existing landfill capacity will be overwhelmed.

And let's consider human rights! The supply chain of critical materials essential for solar, wind, and EV batteries is tainted with forced labor, slavery, and child labor abuses.

Take a look at this photo…

Both the State Department and the Department of Labor have acknowledged violations with more than 40,000 children engaging in "artisanal and small-scale mining," digging for cobalt with their bare hands in the Congo, as well as thousands of members of the Uyghur Muslim community forced into labor in China.

We cannot be morally selective. It is our duty to ensure that American energy supply chains do not rely on slavery or child labor.

We should also prioritize American national security rather than handing federal subsidies and American taxpayer dollars to Chinese companies.

China controls 50-70% of lithium and cobalt refining, key inputs for EV batteries, as well as 90% of global refining capacity for rare earth elements.

Until we increase U.S. capacity for critical mineral extraction and refining, increasing our reliance on renewable energy and EVs will only benefit China, a country openly seeking our destabilization.

So let me be clear: our goal today is to better understand the serious challenges presented by various energy technologies and their real-life impacts on American consumers.

This conversation is especially needed given the speed with which this administration is insisting, with calls for 100% EVs, and 100% wind and solar.

Solar and wind energy, and other renewable sources can and should be a part of our energy mix – but not the only part. Energy security and reliability derive from a diverse energy mix.

We should not force a rapid transition to entirely intermittent, non-dispatchable, unreliable sources of energy.
So, I urge proponents of this agenda to ask themselves, why are we doing this?

Will the American people, suffering under inflation, pay less or more for necessities and transportation? Will their standard of living improve or decline?

What will their lives look like when this so-called "transition" is complete?

It is time that we prioritize ***them***…when we measure success with America's energy and environmental policy.

With that, I recognize the ranking member for his five minutes.

Mr. JOHNSON. With that, I recognize the ranking member for his 5 minutes opening comments.

OPENING STATEMENT OF HON. PAUL TONKO, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW YORK

Mr. TONKO. Thank you, Mr. Chair.

I am always grateful whenever this subcommittee can convene. However, I find the approach from my Republican colleagues this morning regrettable. First and foremost, this hearing's premise completely fails to recognize the underlying reason why the United States and, frankly, the world is pursuing a clean energy transition.

The combustion of fossil fuels is the overwhelming driver of greenhouse gas emissions, which are responsible for climate change. We know the consequences of unmitigated climate change will be significant. It will harm our environment, public health, our economy and national security.

Just yesterday, EPA released a new report which found that climate change is expected to increase incidences of asthma, of Lyme disease, and emergency room visits for our American children.

This is merely the latest data point in a large body of scientific literature that is clear. If we do not respond to climate change effectively, we will be a poorer, sicker, and less competitive nation.

And while my Republican colleagues are suggesting we are rushing toward a clean energy transition, I question whether they support the transition at all on any timeline. It does not sound like they do.

So if people take issue with my support for urgency in transforming our economy to one with less pollution, this urgency is because the scientific community is telling us that we must rapidly and drastically reduce greenhouse gas emissions.

But I am not naive. I appreciate that doing anything on the scale on which science tells us is necessary will have, indeed, challenges, and I am not afraid to have honest discussions about what those challenges are and how we can, in fact, overcome them.

We need clean energy infrastructure to be able to be built faster. We need to take a long-term view of our critical mineral needs and find ways to meet those needs ethically and sustainably.

I would love the opportunity to work across the aisle to solve these challenges and enable the United States to experience the economic boom that will come from dominating global clean energy industries. Unfortunately, today we are going to hear a lot of complaints about clean energy technologies and very few solutions. It honestly does not sound like Republicans even want to do anything about China's lead in these critical industries.

House Democrats, on the other hand, are supporting policies that will enable the American business community to make the United States the global leader. Many of these efforts were enacted last Congress in the Infrastructure Investment and Jobs Act and the Inflation Reduction Act.

And thanks to those incentives included in those given bits of legislation, the private sector is already responding. There have been announcements for hundreds of billions of dollars to build manufacturing facilities, to develop domestic supply chains for

solar, for wind, for EVs, semiconductors and batteries, including the production, processing, and recycling of critical minerals. In addition to responding to the real and urgent threat of climate change, these investments will result in millions of new, well-paying American jobs.

So we have two options: We can keep complaining, pretending or hoping the energy transition is not going to be necessary or happen and believing that, to the extent it is, it will exclusively benefit China, or we can do something about it. We can support American businesses that want to build the clean energy economy here in the United States and export those American-made technologies all over the world.

I think the choice is clear. Evidently, our colleagues in the majority do not. This week, they will vote to repeal key provisions from the IRA, including incentives that are widely supported by the private sector. I believe in American ingenuity. We have the best researchers, entrepreneurs, and skilled workforce in the world.

And certainly, within our DNA is that pioneer spirit. I am confident we can outcompete China and every other country to be the world leader in the clean energy industries that will not only be part of addressing climate change but will also dominate the global economy in the decades to come. I do wish my Republican colleagues shared my confidence in American businesses' and workers' ability to compete. And while Republicans are seemingly content to cede control of these critical industries to China without a fight, Democrats will continue to support the development of domestic supply chains and empower American companies to innovate solutions.

As we move forward, I hope we will have an opportunity to move past the criticisms of clean energy and work together on actual policy solutions that will help us overcome the challenges of transforming our economy and accelerating the clean energy transition. The health, the economy, the national security of future generations depends on us getting this right.

[The prepared statement of Mr. Tonko follows:]

Committee on Energy and Commerce

Opening Statement as Prepared for Delivery
of
Subcommittee on Environment, Manufacturing, and Critical Minerals Ranking Member
Paul D. Tonko

Hearing on Republicans' Attacks on Renewable Energy

April 26, 2023

I am always grateful whenever this subcommittee can convene; however, I find the approach from my Republican colleagues this morning regrettable. First and foremost, this hearing's premise completely fails to recognize the underlying reason why the United States, and frankly the world, is pursuing a clean energy transition.

The combustion of fossil fuels is the overwhelming driver of greenhouse gas emissions, which are responsible for climate change. We know the consequences of unmitigated climate change will be significant. It will harm our environment, public health, economy, and national security. Just yesterday, EPA released a new report which found that climate change is expected to increase incidences of asthma, Lyme disease, and emergency room visits for American children.

This is merely the latest data point in a large body of scientific literature that is clear— if we do not respond to climate change effectively, we will be a poorer, sicker, and less competitive nation. And while my Republican colleagues are suggesting we are rushing toward a clean energy transition, I question whether they support the transition at all, on any timeline. It does not sound like they do.

So, if people take issue with my support for urgency in transforming our economy to one with less pollution, this urgency is because the scientific community is telling us that we must rapidly and drastically reduce greenhouse gas emissions. But I am not naïve. I appreciate that doing anything on the scale on which science tells us is necessary will have challenges. And I am not afraid to have honest discussions about what those challenges are and how we can overcome them.

We need clean energy infrastructure to be able to be built faster. We need to take a long-term view of our critical mineral needs and find ways to meet those needs ethically and sustainably.

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the Infrastructure Investment and Jobs Act and the Inflation Reduction Act. And thanks to the incentives included in those laws, the private sector is already responding.

There have been announcements for hundreds of billions of dollars to build manufacturing facilities to develop domestic supply chains for solar, wind, EVs, semiconductors, and batteries, including the production, processing, and recycling of critical minerals. In addition to responding to the real and urgent threat of climate change, these investments will result in millions of new, well-paying American jobs.

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And while Republicans are seemingly content to cede control of these critical industries to China without a fight, Democrats will continue to support the development of domestic supply chains and empower American companies to innovate solutions.

As we move forward, I hope we will have an opportunity to move past the criticisms of clean energy and work together on actual policy solutions that will help us overcome the challenges of transforming our economy and accelerating the clean energy transition.

The health, economy, and national security of future generations depends on us getting this right.

Mr. TONKO. With that, I thank you, Mr. Chair, and yield back.

Mr. JOHNSON. The gentleman yields back.

And I now recognize the Chair of the full committee, Chair Rodgers, for 5 minutes for an opening statement.

OPENING STATEMENT OF HON. CATHY McMORRIS RODGERS, A REPRESENTATIVE IN CONGRESS FROM THE STATE OF WASHINGTON

Mrs. RODGERS. Thank you, Mr. Johnson, for holding this important hearing to expose the risk of the Biden administration's rush-to-green agenda.

And I want to just start where the ranking member stopped. We must get this right. And I want to emphasize America has led the world in reducing carbon emissions with clean, reliable, affordable energy, while having the highest environmental and labor standards in the world, and that is the record we want to build upon.

This hearing is about having an honest conversation on how the rushed agenda of the Biden administration poses serious environmental risk, because it empowers the world's dirtiest polluter, China. It makes America dependent on supply chains that use slave and child labor. It increases poverty, and it threatens our national security.

Since day one in office, President Biden has waged a war on affordability and availability of American manufacturing and energy. It began with the cancellation of the Keystone XL Pipeline, the green-lighting of the Nord Stream 2 Pipeline, and the moratorium on energy production on Federal lands. Those early decisions strengthened OPEC, including Russia, undermining American energy security as Russia attacked Ukraine. And it also increased our reliance on our adversaries, like China. The President has ordered agencies to slow walk permits to modernize natural gas infrastructure, which would expand U.S. LNG exports, despite record high energy prices for Americans and dangerous supply shortages in Europe.

Today, fingerprints of this rush-to-green agenda can be found on virtually every energy and environmental policy and initiative launched by the administration. This administration's goal is 100 percent wind and solar and 100 percent EVs. This is a radical and an aggressive agenda that rewards environmental special interests at the expense of reliable, affordable, and clean energy for the American people. Look no further than the California example. Just 1 week after announcing his plans to ban gas cars and force people to buy EVs, Governor Newsom pleaded with people not to charge their cars to prevent energy blackouts.

The Biden administration is attempting to force an unrealistic, expensive transition on the American people, from the cars that we drive to the stoves we use to feed our families. This administration is divorced from reality for what it means for America's future. They are downplaying important questions about the environmental, human rights, and national security risk behind rushing to deploy massive amounts of wind, solar, and battery energy.

I am also concerned that many of these decisions are empowering Beijing and the Chinese Communist Party's anti-America campaign. China controls more than 90 percent of the critical minerals

that are used to make wind turbines, solar panels, and batteries for electric vehicles and grid storage. China pollutes more than any other major nation, and it has one of the worst environmental and human rights records, which permeates throughout its supply chains. China is committing genocide and forcing millions of ethnic minority Muslims into slave labor. China controls mineral mines in countries like the Congo, where children are forced to work in inhumane conditions. And, of course, China is one of our greatest geopolitical adversaries.

President Biden has opened the door to allow China to undermine our energy security. Throwing hundreds of billions of dollars in subsidies and tax credits at renewable technologies and EVs is not going to change this reality, and it will only further empower China. This must be reversed, and that is why the Republicans plan to keep building off of our work on H.R. 1, the Lower Energy Costs Act.

Americans, we are at a crossroads. We can choose a path of economic growth, human rights, prosperity, energy security and embrace American energy dominance and innovation to reduce emissions, or we can continue down a path of more reliance on China, less energy affordability and reliability. This later path won't reduce emissions, and it sacrifices American values to achieve a political goal. It will result in overreliance upon wind, solar, and batteries that will increase pollution and require more land for energy production, increase our dependence on critical minerals from nations with much weaker environmental and human rights standards, and it will strengthen China while compromising our energy security and independence.

The choices that we make don't just affect this generation. They are about building a stronger future for our children and our grandchildren for decades to come.

And I would like to thank our witnesses for being here today, appearing before us, and I look forward to your testimony.

[The prepared statement of Mrs. Rodgers follows:]

Chair Cathy McMorris Rodgers
Opening Statement
Subcommittee on Environment, Manufacturing, and Critical Materials
"Exposing the Environmental, Human Rights, and National Security Risks of the Biden Administration's Rush to Green Policies"
April 26, 2023

As prepared for delivery

Thank you, Chair Johnson, for holding this important hearing to expose the risks of the Biden Administration's rush to green agenda.

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...and that is the record we want to build upon.

This hearing is about having an honest conversation on how the rushed agenda of the Biden administration poses serious environmental risks because it empowers the world's dirtiest polluter, China...

… makes America dependent on supply chains that use slave and child labor...

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...and threatens our national security.

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Those early decisions strengthened OPEC, including Russia, undermining American energy security as Russia attacked Ukraine...

It has also increased our reliance on our adversaries, like China.

The President has ordered agencies to slow-walk permits to modernize natural gas infrastructure which would expand U.S. LNG exports...

...despite record high energy prices for Americans and dangerous supply shortages in Europe.

Today, the fingerprints of this rush to green agenda can be found on virtually every energy and environmental policy and initiative launched by the administration.

This administration's goal is 100% wind and solar, and 100% EVs. This radical and aggressive agenda rewards environmental special interests at the expense of reliable and affordable energy for the American people.

Look no further than California as the example. Just one week after announcing his plans to ban gas cars and force people to buy EVs, Governor Newsom pleaded with people not to charge their cars to prevent energy blackouts.

The Biden administration is attempting to force an unrealistic, expensive transition on the American people…

...from the cars that we drive... to the stoves we use to feed our families.

This administration is divorced from reality for what this means for America's future.

They're downplaying important questions about the environmental, human rights, and national security risks behind rushing to deploy massive amounts of wind, solar, and battery energy.

I am also concerned that many of these decisions are empowering Beijing and the CCP's anti-America campaign.

China controls more than 90% of the critical minerals that are used to make wind turbines, solar panels, and batteries for electric vehicles and grid storage.

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China is committing genocide and forcing millions of ethnic minority Muslims into slave labor. China controls mineral mines in countries like the Congo, where children are forced to work in inhumane conditions.

And of course, China is one of our greatest geopolitical adversaries.

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This must be reversed, which is why Republicans plan to keep building off our work on HR 1, the Lower Energy Costs Act.

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We can choose to follow the path of economic growth, human rights, energy security, prosperity, and embrace American energy dominance and innovation to reduce emissions...

...or we can continue down this path of more reliance on China and less energy affordability and reliability for Americans.

This latter path won't reduce emissions and sacrifices American values to achieve a political goal. It will result in an over-reliance upon wind, solar, and batteries that will increase pollution and require more land for energy production...

…...increase our dependence upon critical minerals from nations with weaker environmental and human rights standards...

…...and strengthen China while compromising America's energy security and independence.

The choices we make don't just affect this generation ... they are about building a stronger future for our children and grandchildren for decades to come.

I'd like to thank the witnesses for appearing before us today, and I look forward to their testimony.

Thank you, I yield back.

Mrs. RODGERS. Thank you. I yield back.

Mr. JOHNSON. The gentlelady yields back.

I now recognize the gentleman from New Jersey, Mr. Pallone, for 5 minutes for an opening statement.

OPENING STATEMENT OF HON. FRANK PALLONE, JR., A REPRESENTATIVE IN CONGRESS FROM THE STATE OF NEW JERSEY

Mr. PALLONE. Thank you, Mr. Chairman.

This week, we are seeing just how far House Republicans will go to put the interests of polluters over the American people. Republicans are manufacturing a debt crisis to justify the need for their irresponsible and extreme Default on America Act.

Speaker McCarthy's bill will raise costs for American families, kick millions of people off their health insurance, reverse the progress we have made to combat the worsening climate crisis, and undermine our efforts to lead the world in a transition to a clean energy economy, all so Republicans can provide huge giveaways to billionaires and big corporations.

House Republicans are holding the American economy hostage so they can do the bidding of Big Oil and Gas, increase energy costs for working families, and set American workers up to be left behind as they abandon our homegrown clean energy economy.

A key part of the Republican Default on America Act is H.R. 1, which repeals large portions of the historic climate provisions Democrats delivered with the Inflation Reduction Act last year. The Republican bill would repeal the Greenhouse Gas Reduction Fund, which is deploying clean energy projects all across the country.

It would repeal the Methane Emissions Reduction Program, which curbs methane leaks from the oil and gas industry, protecting people's health and ensuring polluters, not taxpayers, pay for their wasted methane.

It repeals the $4.5 billion Home Electrification Rebate Program designed to lower families' energy bills, and it repeals tax credits for electric vehicles, critical minerals for batteries, domestic battery manufacturing, and solar and wind production.

Republicans want to repeal all these provisions even though the Inflation Reduction Act is already making a big difference. Since its passage, about $28 billion in new domestic manufacturing investments focused on EVs, batteries, and solar have been announced. Companies have announced $242 billion in new clean power capital investments.

And many of the States leading the Nation in these investments are States that committee Republicans represent. Georgia tops the list at 15 billion, followed by Tennessee at 10.9 billion, Michigan at 7.2 billion, South Carolina at 6.2, Texas at 5.1 billion and Ohio at 4.8 billion.

The investments from the Inflation Reduction Act have led to more than 142,000 clean energy jobs being created across the Nation. And those are impressive results, considering the Inflation Reduction Act has not even been law for a year. And yet, House Republicans now want to reverse this program so they can continue to put polluters over people.

It is clear Republicans don't have any real interest in diversifying our energy resources. Last week, at a bipartisan nuclear energy hearing, every witness supported the nuclear tax credit, praising it as a way to support our diversified energy mix. But that very same tax credit is now on the chopping block in the Republicans' Default on America Act.

This hearing also makes it clear that Republicans are not interested in being productive and offering real solutions that help us meet our climate goals and ensure that we outcompete the rest of the world in the clean energy transition. After all, the world is transitioning and we must continue on the path, and Democrats have set us on this path.

There are certainly challenges that we must continue to address in this transition, but that is exactly what we have done. The Bipartisan Infrastructure Law directed the Environmental Protection Agency to develop best practices for battery recycling and voluntary battery labeling guidelines. These are two critical components of strengthening our critical mineral supply chains for clean energy development.

The law also allocated $6 billion for battery processing, manufacturing, and recycling. It also expanded the Department of Energy's Loan Guarantee Program to include projects that increase supply of domestically produced critical minerals. And these are important investments that help us meet our climate goals while also supporting the onshoring of crucial clean energy supplies.

Democrats delivered real solutions, and not one Republican on this committee voted for either the Inflation Reduction Act or the bipartisan infrastructure bill.

So I welcome a productive conversation about strengthening our national security and lowering energy costs by diversifying our energy mix. In my view, these are bipartisan issues that we can work on together. But that is extremely difficult to do so when Republicans continue pushing their polluters-over-people agenda. We simply cannot go back.

[The prepared statement of Mr. Pallone follows:]

Committee on Energy and Commerce

Opening Statement as Prepared for Delivery
of
Ranking Member Frank Pallone, Jr.

Hearing on Republicans' Attacks on Renewable Energy

April 26, 2023

This week we are seeing just how far House Republicans will go to put the interests of polluters over the American people. Republicans are manufacturing a debt crisis to justify the need for their irresponsible and extreme Default on America Act.

Speaker McCarthy's bill will raise costs for American families, kick millions of people off their health insurance, reverse the progress we've made to combat the worsening climate crisis, and undermine our efforts to lead the world in the transition to a clean energy economy – all so Republicans can provide huge new giveaways to billionaires and big corporations.

House Republicans are holding the American economy hostage so they can do the bidding of Big Oil and Gas, increase energy costs for working families, and set American workers up to be left behind as they abandon our homegrown clean energy economy.

A key part of the Republicans' Default on America Act is to repeal large portions of the historic climate provisions Democrats delivered with the Inflation Reduction Act last year.

The Republican bill would repeal the Greenhouse Gas Reduction Fund, which is deploying clean energy projects all across the country. It would repeal the Methane Emissions Reduction Program, which curbs methane leaks from the oil and gas industry, protecting peoples' health and ensuring polluters – not taxpayers – pay for their wasted methane. It repeals the $4.5 billion home electrification rebate program designed to lower families' energy bills. And it repeals tax credits for electric vehicles, critical minerals for batteries, domestic battery manufacturing, and solar and wind production.

Republicans want to repeal all these provisions even though the Inflation Reduction Act is already making a big difference. Since its passage, about $28 billion in new, domestic manufacturing investments focused on EVs, batteries, and solar have been announced. Companies have announced $242 billion in new clean power capital investments. And many of the states leading the nation in these investments are states that Committee Republicans represent. Georgia tops the list at $15 billion, followed by Tennessee at $10.9 billion, Michigan at $7.2 billion, South Carolina at $6.2 billion, Texas at $5.1 billion, and Ohio at $4.8 billion. The investments from the Inflation Reduction Act have led to more than 142,000 clean energy jobs being created across the nation.

Those are impressive results considering the Inflation Reduction Act has not even been law for a year. And yet House Republicans now want to reverse this progress so they can continue to put polluters over people.

It is clear Republicans don't have any real interest in diversifying our energy resources. Last week, at a bipartisan nuclear energy hearing every witness supported the nuclear tax credit, praising it as a way to support our diversified energy mix. That very same tax credit is now on the chopping block in the Republicans' Default on America Act.

This hearing also makes it clear that Republicans are not interested in being productive and offering real solutions that help us meet our climate goals and ensure that we out-compete the rest of the world in the clean energy transition. After all, the world is transitioning, and we must continue on the path Democrats have set us on.

There are certainly challenges that we must continue to address in this transition, but that's exactly what we've done. The Bipartisan Infrastructure Law directed the Environmental Protection Agency (EPA) to develop best practices for battery recycling and voluntary battery labeling guidelines – two critical components of strengthening our critical minerals supply chains for clean energy development.

The law also allocated $6 billion for battery processing, manufacturing, and recycling. It also expanded the Department of Energy's loan guarantee program to include projects that increase supply of domestically produced critical minerals. These are important investments that help us meet our climate goals while also supporting the onshoring of crucial clean energy supply chains.

Democrats delivered real solutions, and not one Republican on this Committee voted for either the Inflation Reduction Act or the Bipartisan Infrastructure Law.

I welcome a productive conversation about strengthening our national security and lowering energy costs by diversifying our energy mix. In my view, these are bipartisan issues that we can work on together. But that's extremely difficult to do when Republicans continue pushing their polluters over people agenda. We simply cannot go back. And with that, Mr. Chairman, I yield back the remainder of my time.

Mr. PALLONE. And, with that, Mr. Chairman, I yield back the remainder of my time.

Mr. JOHNSON. The gentleman yields back.

And I too want to thank our panelists for being with us today. Thank you all for coming out.

Our first witness today is Mr. Mark Mills, a senior fellow with the Manhattan Institute.

Sir, you are recognized for your 5-minute statement

STATEMENTS OF MARK P. MILLS, SENIOR FELLOW, MANHATTAN INSTITUTE; ASHLEY NUNES, PH.D., DIRECTOR, FEDERAL POLICY, CLIMATE AND ENERGY, THE BREAKTHROUGH INSTITUTE; TREVOR HIGGINS, SENIOR VICE PRESIDENT, ENERGY AND ENVIRONMENT, CENTER FOR AMERICAN PROGRESS; AND DANIEL R. SIMMONS, PRINCIPAL, SIMMONS ENERGY AND ENVIRONMENTAL STRATEGIES

STATEMENT OF MARK P. MILLS

Mr. MILLS. Good morning. Thank you to the committee and the Members for the opportunity to testify.

It is clear from opening remarks that we are, indeed, dealing with some high-stakes issues. So permit me to begin by observing two facts that we do know about the future that are indisputable.

First, that economic growth is the fundamental driver of energy demand broadly, and second, that while periods of slow growth and recessions are regrettably inevitable in all societies, those periods always end, but any subsequent growth can be stifled if energy supplies are inadequate or too expensive or unreliable.

An energy supply itself is not as much about finding resources as it is about building machines regardless of the natural resources that are used, whether it is sun or wind or water, oil, gas, oil, coal, uranium.

Those realities around machine building are what determines costs and all the associated environmental, social, and geopolitical impacts. And we know a lot about those impacts, both the good and the bad, of course, associated with energy machines that use hydrocarbons, because we have been using those technologies at scale for a very long time and because that is how roughly 85 percent of America's and the world's energy is supplied.

We have learned a lot less about the impacts from wind, solar, and battery technologies because they are relatively new, frankly, and so far supply only a few percentage points of overall energy for either America or the world.

The administration has a stated policy goal, as we all know, to see America powered increasingly, eventually entirely, by renewable energy. Look, I should stipulate that the future will doubtless see far greater use of wind and solar and electric cars if for no other reason than the sheer scale of future energy demands and because developed countries like ours are wealthy enough to pay higher costs.

However, there are a lot of misconceptions about the realities of renewable energy at scale, especially if the goal is to replace rather than supplement hydrocarbons. It begins with a core reality that

renewables aren't green. In fact, nor are renewable technologies inherently cheaper nor geopolitically more secure.

Renewable energy isn't green as a consequence of an unavoidable feature of wind and solar resources: They have very low energy density. That means, compared to using hydrocarbons, one must build machinery that occupies roughly 10 times more of the Earth's surface to deliver the same amount of energy to society.

And since all life occupies the thin surface interface of our planet, whether it is the land or the water, one of humanity's greatest achievements has been the radical reduction in the amount of that interface that we use to deliver increasing quantities of food and fuel.

The inherent low energy density of renewables, which is locked into the physics of those sources and machines, also means that far more machinery must be fabricated to deliver the same energy as is now supplied by hydrocarbon machines. That, in turn, translates into a radical increase in global mining and minerals processing to supply all the critical materials needed to build renewable machinery.

So renewable plans proposed or underway will require, according to the IEA and others, from a 400 percent to an 8,000 percent increase in mining of dozens of minerals, from copper and nickel to aluminum, graphite, lithium. The IEA says the world will need hundreds of new mines and very soon, immediately. Given regulatory realities, we know those mines won't be here. Almost none of the processing plants will be here. Instead, most will be in emerging economies, and most will be on or near the lands of indigenous people in areas that are culturally and ecologically valuable and fragile.

And given machine realities, the engineering and physics of machines, the huge jump in mining required will increase energy use in that sector, thus offsetting a lot and, in fact, in some cases all of the CO_2 emissions that are saved by later replacing hydrocarbons and power plants and cars.

Global mining today already accounts for about 40 percent of worldwide industrial energy use. This is before the increase in mining needed to build renewable machines. And it is an energy system that is dominated by hydrocarbons and will be for decades.

And it bears noting that renewable energy machines are like all machines: They wear out. That means, of course, in the future we will see megatons of worn-out hardware—trash—much of it at unprecedented scale, because of the unprecedented quantities of energy machinery needed. Some of it can't actually be recycled, some not easily, much of it very expensively.

And the huge land footprint and materials requirements of renewable machinery, it shows up in the economics too. I know there are claims of cost parity, but the fact is in every State and every nation where there is a rising share of wind and solar on grids, electricity costs have risen, not shrunk. EVs, for similar reasons, are locked into inherently higher prices because of greater use of underlying resources. Finally, the claim that renewables are geopolitically superior is exposed by the now well-known fact that China has a 40 to 80 percent market share, as high as a 90 percent market share, in producing or refining the energy materials that

are needed to build renewable machinery. That is a strategic dominance, I should point out, that is over double OPEC's market share in global oil production. Building assembly plants in the United States for EVs and solar panels doesn't change that fact.

There is, however, one common claim for renewables that is true: They create more jobs. That emerges directly from the excess land, materials, and machinery needed to deliver the same energy. The problem is that much of that work isn't in America. And to the extent that it can be, any new jobs come at a time, ironically, when our Nation doesn't necessarily need more jobs as much as it needs more people willing and able to fill the jobs we have, especially the skilled trades.

Thank you, Mr. Chair.

[The prepared statement of Mr. Mills follows:]

Testimony
of
Mark P. Mills, Senior Fellow, Manhattan Institute
Before
Subcommittee on Environment, Manufacturing, and Critical Materials
U.S. House Committee on Energy and Commerce
Hearing on:
"*Exposing the Environmental, Human Rights, and National Security Risks of the Biden Administration's Rush to Green Policies***"**

April 26, 2026

Testimony Summary

Good afternoon. Thank you for the opportunity to testify. I'm a Senior Fellow at the Manhattan Institute where I focus on science, technology, and energy issues. I am also a Faculty Fellow at the McCormick School of Engineering at Northwestern University where my focus is on future manufacturing technologies. And, for the record, I'm a strategic partner in a venture fund focused on energy software, and I'm also a director of an oil-field services company.

Permit me to begin by observing two indisputable facts about our future. First, economic growth is the fundamental driver of energy demand. And second, while periods of slow growth and recessions are inevitable in all societies, those periods always end. But any subsequent growth can be stifled if energy supplies are either unavailable or too expensive.

Energy supply itself is not as much a matter of finding resources as it is one of building machines, regardless of the natural resource used, whether sun, wind, water, oil, gas, coal, or uranium. Thus realities around machine-building determine costs and all the associated environmental, social, and geopolitical impacts.

We know a lot about those impacts—both the good and the bad—associated with energy machines that use hydrocarbons because we've been using those technologies at scale for a long time, and because that's how 85 percent of U.S. and global energy is supplied. We've learned a lot less about impacts from wind, solar, and battery technologies because they're relatively new and, so far, supply only a few percent of society's overall energy.

The Biden Administration has a stated policy goal to see America powered increasingly, eventually entirely by renewable energy. I should like to stipulate that the future will doubtless see far greater use of wind and solar technologies, and electric cars, if for no other reason than the sheer scale of future energy needs, and because developed countries are wealthy enough to pay higher costs.

However, there are many misconceptions about the realities of renewable energy technologies at scale, especially if the goal is to replace rather than supplement hydrocarbons. It begins with the core reality that renewables aren't green. In fact, nor are renewable technologies inherently cheaper, nor more geopolitically secure.

That renewable energy isn't green is a consequence of an unavoidable feature of wind and solar resources; they have very low energy density. That means, compared to using hydrocarbons, one must build machines that occupy roughly ten-times more of the earth's surface to deliver the same amount of energy to society—whether it's an hour of heat, or light, or computing time, or a mile of driving.

Essentially all life occupies the thin, surface interface of our planet, whether it's land or water. One of humanity's greatest achievements has been the radical reduction in the amount of that interface we use to deliver increasing quantities of food and fuel.

The inherent low-energy-density of renewables also means that far more machinery must be fabricated to deliver the same energy as now supplied by hydrocarbon machines. That in turn translates into a radical increase in global mining and minerals processing to supply all the critical materials needed to build renewable machinery.

Renewable plans proposed or underway will require from 400 percent to 8,000 percent more mining for dozens of minerals, from copper and nickel, to aluminum, graphite, and lithium. The IEA says the world will need hundreds of new mines, soon. Given regulatory realities, those won't be here. Instead, most will be in emerging economies and most will be on or near the lands of indigenous people in areas that are culturally and ecologically valuable and fragile.

And given machine realities, the huge jump in mining required will increase energy use in that sector, thus offsetting a lot, in some cases all the CO_2 emissions saved later by replacing hydrocarbons in powerplants and cars. Global mining today already accounts for 40 percent of worldwide industrial energy use, which is dominated by hydrocarbons, and will be for decades.

It bears noting that renewable-energy machines are like all machines; they wear out. This means the near future will see megatons of worn-out hardware, of trash, much at unprecedented scale because of the unprecedented quantities of energy machinery needed. Some of it cannot be recycled at all, some not easily, much of it expensively.

The huge land footprint and materials requirements of renewable machinery shows up in the economics too. Despite claims of cost parity, the fact is that in every state and nation, a rising share of wind and solar on grids

has brought higher electricity costs. EVs, for similar reasons, are locked into inherently higher prices because of greater use of underlying resources.

Finally, the claim that renewables are geopolitically superior is exposed by one now well-known fact: China has a 40 to 80 percent market share in producing or refining energy minerals needed to build renewable machinery. That is a strategic dominance roughly double OPEC's market share in oil. Building assembly plants in the U.S. for EVs and solar panels doesn't change that fact.

There is, however, one common claim for renewables that's true: they create more jobs. That emerges directly from the excess land, materials and machinery needed to deliver the same energy. The problem is that much of that work isn't in America. And, to the extent it can be, any new jobs come at a time when our nation doesn't necessarily need more jobs, as much as it needs more people willing and able to fill the jobs we have, especially in the skilled trades.

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<u>Full Testimony</u>

For everything built or fabricated, including energy-producing machines from gas turbines to wind turbines, one can trace a straight line back upstream to where people use heavy equipment (in some countries, just shovels) to extract materials from the earth. Different forms of energy involve radically different types and quantities of energy-harvesting machines and therefore involve different kinds and quantities of materials, and of land used.

Whether it's liquids extracted from the earth to power an internal combustion engine or solids used to build batteries, any significant increase in materials used per mile will add up because Americans alone drive some 3 trillion road-miles a year. The same is true for delivering kilowatt-hours and all other energy uses. The upstream nature of the underlying minerals and materials needed for civilization has always been important. It is critical now that governments around the world are rushing to embrace if not force expansion of renewable energy.

All machines wear out, and there is nothing inherently renewable about green machines, since one must engage in continual extraction of materials to build new ones and replace those that wear out. All this requires

mining, processing, transportation, and, ultimately, the disposing of millions of tons of materials, much of it functionally or economically unrecyclable.

Assuring access to the minerals that undergird society is a very old concern, one that is woven through history and has even precipitated wars. In the modern era, U.S. policies to address mineral dependencies date to 1922, when Congress, in the aftermath of World War I, developed a list of 42 "strategic and critical materials" for the technologies and machines important to the military at that time.[1] Next came the Strategic Materials Act of 1939, renewed and modified several times since, incorporating ideas to encourage domestic mining and create stockpiles of strategically critical minerals for military equipment.

Over the past century, there have been two significant developments. First, the U.S. has not expanded domestic mining, and, in most cases, the country's production of nearly all minerals has declined. Second, the demand for minerals has dramatically increased. These two intersecting trends have led to significant transformations in supply-chain dependencies. Imports today account for 100% of some 17 critical minerals, and, for 28 others, net imports account for more than half of demand.[2]

The Material Cost of "Clean Tech"

The materials extracted from the earth to fabricate wind turbines, solar panels, and batteries (to store grid electricity or power electric vehicles) are out of sight, located at remote quarries, mine sites, and mineral-processing facilities around the world. Those locations matter in terms of geopolitics and supply-chain risks, as well as in environmental terms. Before considering the supply chain, it is important to understand the scale of the material demands. For green energy, it all begins with the fact that such sources are land-intensive and very diffuse.

For example, replacing the energy output from a single 100-MW natural gas-fired turbine, itself about the size of a residential house (producing enough electricity for 75,000 homes), requires at least 20 wind turbines, each one about the size of the Washington Monument, occupying some 10 square miles of land.[3] Building those wind

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[1] National Research Council, "*Managing Materials for a Twenty-First Century Military*" (Washington, DC: National Academies Press, 2008).

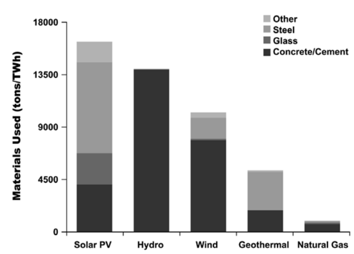
[2] U.S. Department of the Interior (DOI) and U.S. Geological Survey (USGS), "Mineral Commodity Summaries 2020," Feb. 6, 2020, p. 7.

[3] Landon Stevens, "The Footprint of Energy: Land Use of U.S. Electricity Production," Strata, June 2017. The calculation in this paper understates land usage; at least double the number of wind turbines, plus storage, is required if the goal is to replace the continuous availability of electricity from conventional generation.

machines consumes enormous quantities of conventional materials, including concrete, steel, and fiberglass, along with less common materials, including "rare earth" elements such as dysprosium. A World Bank study noted what every mining engineer knows: "[T]echnologies assumed to populate the clean energy shift … are in fact significantly more material intensive in their composition than current traditional fossil-fuel-based energy supply systems."[4]

All forms of green energy require roughly comparable quantities of materials in order to build machines that capture nature's flows: sun, wind, and water. Wind farms come close to matching hydro dams in material consumption, and solar farms outstrip both. In all three cases, the largest share of the tonnage is found in conventional materials like concrete, steel, and glass. Compared with a natural gas power plant, all three require at least 10 times as many total tons mined, moved, and converted into machines to deliver the same quantity of energy (Figure 1).

Figure 1. Materials Requirements to Build Different Energy Machines



Source: U.S. Department of Energy (DOE), "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities," September 2015, p. 390

For example, building a *single* 100-MW wind farm—never mind thousands of them—requires some 30,000 tons of iron ore and 50,000 tons of concrete, as well as 900 tons of nonrecyclable plastics for the huge blades.[5] With solar hardware, the tonnage in cement, steel, and glass is 150% greater than for wind, for the same energy output.[6]

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[4] Daniele La Porta et al., *The Growing Role of Minerals and Metals for a Low Carbon Future* (Washington, DC: World Bank Group, 2017), p. xii.

[5] Vaclav Smil, "To Get Wind Power You Need Oil," *IEEE Spectrum*, Feb. 29, 2016.

[6] U.S. Department of Energy (DOE), "Quadrennial Technology Review: An Assessment of Energy Technologies and Research Opportunities," September 2015.

If episodic sources of energy (wind and solar) are to be used to supply power 24/7, even greater quantities of materials will be required. One needs to build additional machines, roughly two to three times as many, in order to produce and store energy when the sun and wind are available, for use at times when they are not. Then there are the additional materials required to build electricity storage. For context, a utility-scale storage system sufficient for the above-noted 100-MW wind farm would entail using at least 10,000 tons of Tesla-class batteries.

The handling and processing of such large quantities of materials entails its own energy costs as well as associated environmental implications, explored below. But first, the critical supply-chain issue is not so much the increase in the use of common (though energy-intensive) materials such as concrete and glass. The core challenges for the supply chain and the environment reside with the need for radical increases in the quantities of a wide variety of minerals.

The world currently mines about 7,000 tons per year of neodymium for example, one of numerous key elements used in fabricating the electrical systems for wind turbines. Current clean-energy scenarios imagined by the World Bank (and many others) will require a 1,000%–4,000% increase in neodymium supply in the coming several decades.[7] While there are differing underlying assumptions used in various analyses of mineral requirements for green energy, all reach the same range of conclusions. For example, the mining of indium, used in fabricating electricity-generating solar semiconductors, will need to increase as much as 8,000%. The mining of cobalt for batteries will need to grow 300%–800%.[8] Lithium production, used for electric cars (never mind the grid), will need to rise more than 2,000%.[9] The Institute for Sustainable Futures at the University of Technology Sydney last year analyzed 14 metals essential to building clean-tech machines, concluding that the supply of elements such as nickel, dysprosium, and tellurium will need to increase 200%–600%.[10]

The implications of such remarkable increases in the demand for energy minerals have not been entirely ignored, at least in Europe. A Dutch government–sponsored study concluded that the Netherlands' green ambitions alone would consume a major share of global minerals. "Exponential growth in [global] renewable energy

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[7] La Porta et al., *The Growing Role of Minerals and Metals*.

[8] Matt Bohlsen, "Cobalt Miners News for the Month of November 2019," Seeking Alpha, Nov. 26, 2019; John Petersen, "The Cobalt Cliff Will Crush Tesla's Business and May Restore Some Sanity to the EV Industry," Seeking Alpha, Sept. 29, 2019.

[9] Jamie Smyth, "BHP Positions Itself at Centre of Electric-Car Battery Market," *Financial Times*, Aug. 9, 2017.

[10] Elsa Dominish, Sven Teske, and Nick Florin, "Responsible Minerals Sourcing for Renewable Energy," Institute for Sustainable Futures, University of Technology Sydney, 2019.

production capacity," the study noted, "is not possible with present-day technologies and annual metal production."[11]

Behind the Scenes: Ore Grades and "Overburden"

The scale of these material demands understates the total tonnage of the earth that is necessarily moved and processed. That is because forecasts of future mineral demands focus on counting the quantity of refined, pure elements needed—but not the overall amount of earth that must be dug up, moved, and processed.

For every ton of a purified element, a far greater tonnage of ore must be physically moved and processed. That is a reality for all elements, expressed by geologists as an ore grade: the percentage of the rock that contains the sought-after element. While ore grades vary widely, copper ores typically contain only about a half-percent, by weight, of the element itself: thus, roughly 200 tons of ore are dug up, moved, crushed, and processed to get to one ton of copper. For rare earths, some 20 to 160 tons of ore are mined per ton of element.[12] For cobalt, roughly 1,500 tons of ore are mined to get to one ton of the element.

In the calculus of economic and environmental costs, one must also include the so-called overburden—the tons of rocks and dirt that are first removed to get access to often deeply buried mineral-bearing ore. While overburden ratios also vary widely, it is common to see three to seven tons of earth moved to get access to one ton of ore.[13]

For a snapshot of what all this points to regarding the total materials footprint of the green energy path, consider the supply chain for an electric car battery. A single battery providing a useful driving range weighs about 1,000 pounds.[14] Taking into account various ore grades and typical overburdens, the math works out to providing the refined minerals needed to fabricate a single EV battery requires the mining, moving, and processing of more

[11] Pieter van Exter et al., "Metal Demand for Renewable Electricity Generation in the Netherlands: Navigating a Complex Supply Chain," Metabolic, Universiteit Leiden, and Copper8, 2018.

[12] Laura Talens Peiró and Gara Villalba Méndez, "Material and Energy Requirement for Rare Earth Production," *Journal of the Minerals, Metals & Materials Society (JOM)* 65, no. 10 (August 2013): 1327–40.

[13] McArthur River Mine (Glencore), "Overburden," 2020.

[14] A Tesla 85-kWh battery pack weighs 1,200 lbs.: Neil Brooks, "Tesla Battery Weight Overview—All Models," enrg.io, Jan. 20, 2020.

than 500,000 pounds of materials somewhere on the planet (see sidebar).[15] That's 10 times more than the roughly 25,000 pounds of petroleum that an internal combustion engine uses over the life of a car.

The core issue here for a green energy future is not whether there are enough elements in the earth's crust to meet demand; there are. Most elements are quite abundant, and nearly all are far more common than gold. Obtaining sufficient quantities of nature's elements, at a price that markets can tolerate, is fundamentally determined by technology and access to the land where they are buried. The latter is mainly about government permissions.

However, as the World Bank cautions, the materials implications of a "clean tech" future creates "a new suite of challenges for the sustainable development of minerals and resources."[16] Some minerals are difficult to obtain for technical reasons inherent in the geophysics. It is in the underlying physics of extraction and physical chemistry of refinement that we find the realities of unsustainable green energy at the scales that many propose.

Renewables: Hidden Costs of Materials

Today, the most dramatic factor driving the scale of future global mining is not the creation of products that require new uses of minerals (e.g., silicon for computers, aluminum for aircraft) but the push to use green machines to replace hydrocarbons to meet existing energy demands. Green machines mean mining more *materials per unit of energy* delivered to society. Since clean tech is about supplying energy in a more "sustainable" fashion, one needs to consider not just the physical mining realities but also the hidden energy costs of the underlying materials themselves, i.e., the "embodied" energy costs.

Embodied energy arises from the fuel used to dig up and move earth, grind and chemically separate minerals from the ores, refine the elements to purity, and fabricate the final product. Embodied energy costs can add up to surprising levels. For example, while an automobile weighs about 10,000 times more than a smartphone, the car requires only 400 times more energy to fabricate. And the world produces nearly 600,00 *tons* of consumer electronics annually.[17] Epitomizing this reality: the embodied energy to produce about 200 pounds of steel is the

[15] There is, over the life span of a conventional car, a total of about 50,000 pounds of cumulative upstream materials when both gasoline consumption (25,000 pounds) and the 25,000 pounds of coproduction of other associated liquids.

[16] La Porta et al., *The Growing Role of Minerals and Metals*.

[17] Vaclav Smil, "Your Phone Costs Energy—Even Before You Turn It On," IEEE Spectrum, Apr. 26, 2016.

same as used to produce one pound of semiconductor-grade silicon.[18] The world also uses some 25,000 *tons* of (energy-intensive) pure semiconductor-grade silicon, a nonexistent material in the precomputer era.[19]

Embodied energy use starts with the fuel used by giant mining machines, such as the 0.3 mpg Caterpillar 797F, which can carry 400 tons of ore. There are also energy costs for electricity at the mine site (in remote areas, often diesel-powered) to run machines that crush rocks, as well as the energy costs in producing and using chemicals for refining. For minerals with very low ore grades, fuel can be a significant factor in the cost of the final product.

Rare earth elements, used in all manner of tech machines, including green ones, have rare properties but are much more abundant than gold. However, the physical chemistry of rare earths makes them difficult and energy-intensive to refine. It takes about twice as much energy to get access to and refine a pound of rare earth as a pound of lead, for example.[20]

For the mining industry, there is nothing new or surprising about the quantities of energy and chemicals used in the multistep processes needed to purify minerals locked up in rocks. While there are always ways (including, these days, with digital tools) to improve economic efficiency—and improve safety and environmental outcomes—research shows that, with regard to *energy efficiency*, the majority of the underlying mineral processes themselves already operate near technical or physics limits.[21]

This means that, for the usefully foreseeable future, increasing the production of green machines will unavoidably increase embodied energy. For example, analyses show that manufacturing a single battery, one capable of holding energy that is equivalent to one barrel of oil, entails processes that use the energy equivalent of 100 barrels of oil.[22] About half that energy is in the form of electricity and natural gas, and the other half oil. If the

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[18] Timothy G. Gutowski et al., "The Energy Required to Produce Materials: Constraints on Energy-Intensity Improvements, Parameters of Demand," *Philosophical Transactions of the Royal Society A: Mathematical, Physical, and Engineering Sciences*, Mar. 13, 2013.

[19] Semiconductor Industry Association, "Rebooting the IT Revolution: A Call to Action," September 2015.

[20] Talens Peiró and Villalba Méndez, "Material and Energy Requirement for Rare Earth Production."

[21] Julian M. Allwood et al., "Material Efficiency: Providing Material Services with Less Material Production," *Philosophical Transactions of the Royal Society A*, Mar. 13, 2013.

[22] Jens F. Peters et al., "The Environmental Impact of Li-Ion Batteries and the Role of Key Parameters: A Review," *Renewable and Sustainable Energy Reviews* 67 (January 2017): 491–506; Qinyu Qiao et al., "Cradle-to-Gate Greenhouse Gas Emissions of Battery Electric and Internal Combustion Engine Vehicles in China," *Journal of Applied Energy* 204 (October 2017): 1399–1411.

batteries are manufactured in Asia (as 60% of the world's batteries are now), more than 60% of the electricity to do so is coal-fired.[23]

Embodied energy is also necessarily a part of building wind and solar machines, especially since large quantities of concrete, steel, and glass are required.[24] These commodity materials have relatively low embodied energy per pound, but the number of pounds involved is enormous.[25] Natural gas accounts for over 70% of the energy used to fabricate glass, for example.[26] Glass accounts for some 20% of the tonnage needed to build solar arrays. For wind turbines, oil and natural gas are used to fabricate fiberglass blades, and coal is used to make steel and concrete. Some perspective: if wind turbines were to supply half the world's electricity, nearly 2 billion tons of coal would have to be consumed to produce the concrete and steel, along with 1.5 billion barrels of oil to make the composite blades.[27]

One additional energy factor absent from analyses of the embodied energy of clean-tech machines is in how the materials are delivered. More than 75% of all oil and 100% of natural gas are transported to markets via pipelines.[28] (Most of the remaining ton-miles take place on ships.) Pipelines are the world's most energy-efficient means of moving a ton of material. However, nearly all the materials used to construct green machines are solids, and a very large share will be transported by truck. Using trucks instead of pipelines entails a 1,000% increase per ton-mile in the embodied transportation of energy materials.[29]

All the increases in upstream, embodied energy use for mining and mineral processing will collaterally increase the associated CO2 emissions which offsets a significant share, and in some cases all the CO2 emissions saved later by replacing hydrocarbons in powerplants and cars. Global mining today accounts for 40 percent of worldwide industrial energy use, which is dominated by hydrocarbons, and will be for decades.

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[23] International Energy Agency (IEA), "Asia Is Set to Support Global Coal Demand for the Next Five Years," Dec. 17, 2019.

[24] Mia Romare and Lisbeth Dahllöf, "The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-Ion Batteries: A Study with Focus on Current Technology and Batteries for Light-Duty Vehicles," IVL Swedish Environmental Research Institute, May 2017.

[25] Oil and natural gas have embodied energy costs, but one-tenth that of green tech per unit energy delivered.

[26] U.S. Energy Information Administration (EIA), "Glass Manufacturing Is an Energy-Intensive Industry Mainly Fueled by Natural Gas," Aug. 21, 2013.

[27] Smil, "To Get Wind Power You Need Oil."

[28] Jennifer B. Dunn et al., "Update to Transportation Parameters in GREET," Argonne National Laboratory, table 5, Oct. 7, 2013.

[29] Clark W. Gellings ed., *Efficient Use and Conservation of Energy* (Oxford: Eolss, 2009), p. 25.

Finally, in any full accounting of environmental realities, there is the disposal challenge inherent in the very large quantities of batteries, wind turbines, and solar cells after they wear out, a subject discussed below. For now, it bears noting that many wind turbines are already reaching their 20-year end of life; decommissioning and disposal realities are just beginning. The massive, reinforced fiberglass (plastic) blades are very expensive to cut up and handle, are composed of nonrecyclable materials and will end up in a landfill. As for solar farms, the International Renewable Energy Agency forecasts that by 2050, with current plans, solar garbage will constitute double the tonnage of all global plastic waste.[30]

For many green energy proponents, the solution to all these challenges with materials is found in a well-worn call for greater attention to “reduce, reuse, and recycle.” Many people also take refuge in the belief that our future has room in it for more energy materials because technology is “dematerializing” the rest of society. In reality, neither dematerialization nor recycling offers a solution to the heavy costs of a green energy future.

The “Dematerialization” Trope

There is a popular claim in our digital times that the increasingly service-dominated economy means that “the need for resource-intensive manufacturing is not inevitable.”[31] Or, as MIT scientist Andrew McAfee put it: “For just about all of human history our prosperity has been tightly coupled to our ability to take resources from the earth. . . . But not anymore.”[32]

It is true that resource extraction—food, fuel, and minerals—accounts for only a minor share of America’s overall GDP; that has been true for more than a century. However, the foundational requirement for any of those inputs has not decreased in absolute quantity, nor has there been a diminution of the importance of the reliability and security of the supply, and price, of those inputs.

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[30] Stephanie Weckend, Andreas Wade, and Garvin Heath, “End-of-Life Management: Solar Photovoltaic Panels,” International Renewable Energy Agency and International Energy Agency Photovoltaic Power Systems Programme (IRENA & IEA-PVPS), June 2016. Each year, 35 million tons of plastic pollution are produced around the earth. See, e.g., Seth Borenstein, “Science Says: Amount of Straws, Plastic Pollution Is Huge,” phys.org, Apr. 21, 2018.

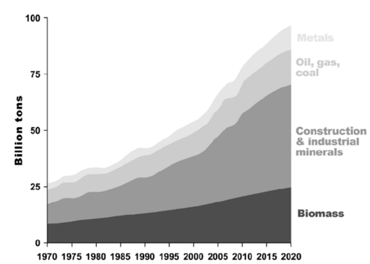
[31] Daniel Tenreiro, “Capitalism Will Save the World,” *National Review*, Oct. 25, 2019.

[32] Andrew McAfee, *More from Less: The Surprising Story of How We Learned to Prosper Using Fewer Resources—and What Happens Next* (New York: Scribner, 2019), p. 1.

For evidence that society is not dematerializing in any fundamental way, we need only compare two iconic products of this and the past century: the smartphone and the automobile. These two products characterize a cultural shift and an apparent shift in material dependencies. As one analyst put it, teenagers have gone from driving cars to the mall to purchase music cassettes to streaming music digitally.[33] But the digital world has not eliminated the use of automobiles or the surprising quantities of minerals and materials used in the upstream production of all things digital. Forecasts for the next two decades see a 300% rise in global demand for common materials such as plastics, paper, iron, aluminum, silica (sand), and calcium (in limestone) for concrete.[34]

Wealthy economies have become more efficient, and the rate of economic growth has outpaced a slower rise in overall material use. But greater economic efficiency in material use *slows the growth rate*—it is not a fundamental decoupling of materials from growth. The world consumes over 100 billion tons each year in materials for construction, food, fuel, and metal parts (Figure 2).[35] That averages out to over 2 million pounds for each person's lifetime on the planet. More than 85% of that, so far, is for nonenergy purposes.

Figure 2. Global Use of Materials



Source: Gillian Foster et al., "Sustainable Consumption and Production," in Stephan Lutter, Fred Luks, and Sigrid Stagl, eds., *Towards a Socio-Ecological Transformation of the Economy*, Institute for Ecological Economics / Vienna University of Economics and Business (January 2019); Circle Economy, "Circularity Gap Report 2020"

Still, it is true that eventually—even if it is a century from now—there will be a slowing in demand for everyday materials as poorer nations approach a saturation level of per-capita use of food, homes, roads, and

[33] Lee Peterson, "The Dematerialization of Society in the Digital Age," *Fast Company*, Aug. 27, 2013.

[34] Gutowski et al., "The Energy Required to Produce Materials."

[35] OECD, *Material Resources, Productivity and the Environment*, Feb. 12, 2015; Circle Economy, "Circularity Gap Report 2020."

buildings.[36] We are a long way away from such saturation: wealthy nations have about 800 cars per 1,000 people, while in countries where billions of poorer people live, the ratio is closer to 800 people per single car.[37] To the extent that a rising share of those cars are electric, the demand for a wide variety of minerals will grow even faster.[38]

Reduce, Reuse, Recycle: No Exit from Renewables' Mineral Dependencies & Epic Waste Production

The mantra to "reduce, reuse, and recycle" ingrained in modern culture has become a feature in virtually all analyses and policy proposals directed at finding a way to reduce the materials demands of green energy. Reuse is generally irrelevant, since the vast majority of all products in society cannot be reused, and this includes green energy machines. The technical and environmental challenges, and thus the costs to reuse, more often than not are greater than those associated with using virgin material.

Reduce

Modern "reduce and recycle" policies and mandates were motivated in large measure by the goal to reduce the amount of trash going to landfills. So what will become of the rapidly increasing number of wind/solar/battery machines that are being produced? Answer: nearly all of them will eventually show up in waste dumps.

As we noted earlier, the International Renewable Energy Agency (IRENA) forecasts that by 2050, with current plans, solar garbage will constitute double the tonnage of all forms of global plastic waste. Similar scales are expected from end-of-life batteries used in electric cars and on power grids. China's annual battery trash alone is already estimated to reach 500,000 tons in 2020. It will exceed 2 million tons per year by 2030.[39] Currently, less than 5% of such batteries are recycled.[40]

When the 20 wind turbines wear out that constitute just one small 100-MW wind farm, decommissioning and trashing them will lead to fourfold more nonrecyclable plastic trash than all the world's (recyclable) plastic

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[36] OECD, *Material Resources*.

[37] Oak Ridge National Laboratories, Transportation Energy Data Book, fig. 3.3.

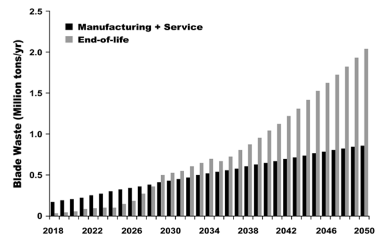
[38] Neil Hume and Henry Sanderson, "Investors Bet on Copper as Electric Car Race Hots Up," *Financial Times*, July 20, 2017.

[39] Mitch Jacoby, "It's Time to Get Serious About Recycling Lithium-Ion Batteries," *Chemical & Engineering News*, July 14, 2019.

[40] Ibid.

straws combined.[41] There are 1,000 times more wind turbines than that in the world today. If current International Energy Agency (IEA) forecasts are met, there will be over 3 million tons per year of unrecyclable plastic turbine blades by 2050 (Figure 3).

Figure 3. Annual Production of Waste from Global Wind Turbine Blades



Source: Pu Liu and Clare Y. Barlow, "Wind Turbine Blade Waste in 2050," Waste Management 62 (April 2017): 229–40

Recognizing the material intensity of clean energy technologies, some environmentalists suggest that what we need for a "real sustainable future is one that doesn't involve most people driving vehicles."[42] Proposals for encouraging or enforcing lifestyle changes are not new. They are no more likely to be effective in the future than they have been in the past.

Innovative engineering can lead to modest reductions in the use of some critical elements in electric motors and magnets. But that only slightly slows the rate of growth in demand. It doesn't eliminate the fact that building green machines is made possible by using the properties of many specific elements. For example: samarium enables smaller and more powerful magnets that are also far more stable at high temperatures. Lithium is, tautologically, the essential element in a lithium-ion battery; and copper remains the best option for electric conductors.

Recycle

[41] Borenstein, "Science Says: Amount of Straws, Plastic Pollution Is Huge."

[42] Paris Marx, "The Electric Vehicle Revolution Will Be Dirty and Unequal: Batteries for New Cars Will Require a Lot of New Mining," *Medium*, June 14, 2019.

For green energy advocates, the idealized vision for recycling encompasses deploying a "circular economy" as a number-one priority for dealing with the material implications of clean tech.[43] But the idea of a green energy circular economy based on the goal of 100% recycling is a pipe dream.[44]

Many materials, especially high-value metals, *can* be significantly recycled. But we can consider the implications and lessons for green waste by looking at the 50 million tons of so-called e-waste generated globally from worn-out or outmoded digital devices that are also built using many critical and rare minerals. The tonnage of global e-waste equals "the weight of all commercial aircraft ever built" and is forecast to double in the next several decades.[45]

The millions of tons of e-waste contain hundreds of tons of gold and thousands of tons of silver (generally the primary target of recyclers, for obvious reasons) as well as more than a dozen other elements.[46] In order to increase e-waste recycling from today's 20% level, the World Economic Forum (among others) proposes various measures to increase consumer "awareness," add new regulations and subsidies, and push to redesign the original devices. The Forum estimates that these efforts would reduce consumer costs by 14% over the next two decades.[47]

But as the scale of global recycling grows, many governments and some environmental organizations are beginning to focus on the serious health and safety issues that have been ignored.[48] So far, the majority of e-waste is recycled—as is much other waste—in poorer nations willing to undertake the labor-intensive, largely unregulated, and sometimes hazardous processes involved. Ghana, for example, is where Europe exports the largest quantity of its e-waste.[49] Meantime, the global recycling industry is still adjusting to a new reality: two years ago, China abruptly banned the importation of waste, asserting that much of it was "dirty" and "hazardous."[50]

The challenge with recycling trace minerals is essentially the same as in mining itself: much depends on concentrations. The concentration of useful minerals in e-waste and green waste is very low and often far lower than

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[43] Frédéric Simon, "Circular Economy Erected as 'Number One Priority' of European Green Deal," EURACTIV.com, Nov. 13, 2019.

[44] Ellen MacArthur Foundation, "Completing the Picture: How the Circular Economy Tackles Climate Change," September 2019.

[45] World Economic Forum, "A New Circular Vision for Electronics: Time for a Global Reboot," Jan. 24, 2019.

[46] Vincent Magnenat, "A World Without Waste: How Gold Mining Is Going Green," *Eco-Business*, Dec. 16, 2019.

[47] World Economic Forum, "A New Circular Vision for Electronics."

[48] Hannah Beech and Ryn Jirenuwat, "The Price of Recycling Old Laptops," *New York Times*, Dec. 8, 2019.

[49] Magnenat, "A World Without Waste."

[50] Leslie Hook and John Reed, "Why the World's Recycling System Stopped Working," *Financial Times*, Oct. 25, 2018.

the ore grades of those minerals in rocks. In addition, the physical nature of trashed hardware is highly varied (again, unlike rocks), making it a challenge to find simple mechanisms to separate out the minerals. Recycling processes are often labor-intensive (hence the pursuit of cheap labor, sometimes child labor, overseas) and hazardous because techniques to burn away unwanted packaging can release toxic fumes.[51]

If "urban mining"—the oft-used locution for capturing minerals hidden in worn-out products—were easier, cheaper, and safer than mining new materials, there would be a lot more of it, and it would not require subsidies and mandates to put into effect. While technology, especially automation and robotics, will eventually bring more economically viable and cleaner ways to recycle, the challenges are daunting and progress has been slow. That's the reason that the overall global levels of net recycling and capture of most metals (for all purposes, not just e-waste and green waste) are below 20%, and much lower than those for all the rare earths.[52]

Even as Apple has championed recycling programs for its products—including inventing a robot to disassemble iPhones (it can only do iPhones)[53] and opening a new Material Recovery Lab in Austin, Texas—the company, along with many other tech companies, vigorously promotes green energy.[54] But there is as much cobalt in a single EV battery, for example, as there is in 1,000 iPhones, as much plastic in a single wind turbine as in 5 million iPhones, and as much glass in a solar array that could power a single data center as in 50 million iPhones.[55]

A recent Department of Energy vision for offshore wind turbines (not counting onshore wind) in the U.S. would lead to nearly 10 thousand tons of neodymium alone "buried" inside more than 4 million tons of machinery that will eventually head for waste dumps.[56] That sounds like a lot of material worth recovering, but it pencils out to a neodymium concentration in the trash that is one-tenth of the natural ore grade for that mineral at a mine site.[57] Such realities can lead to the surprising outcome that the energy required to recover a recycled mineral can be greater than expended to get it from nature's ore.[58] That doesn't mean that recycling won't continue to have a role,

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[51] Ibid.

[52] Edmund Nickless et al., "Resourcing Future Generations White Paper: Mineral Resources and Future Supply," International Union of Geological Sciences, October 2014.

[53] Heather Clancy, "Meet Daisy, Apple's Latest Robot for Recovering and Reusing iPhone Components," *GreenBiz*, Apr. 19, 2018.

[54] Lauren Phipps, "Apple Dials Up Its Circular Materials Aspirations," *GreenBiz*, Apr. 18, 2019.

[55] "iPhone X Environmental Report," Apple.com, Sept. 12, 2017.

[56] DOE, Office of Energy Efficiency & Renewable Energy, "Wind Vision: A New Era for Wind Power in the United States," Mar. 12, 2015.

[57] Talens Peiró and Villalba Méndez, "Material and Energy Requirement for Rare Earth Production."

[58] Bradley S. Van Gosen et al., "Rare-Earth Elements," USGS, Professional Paper 1802-O, 2017.

even a greater one. But its limits are clear. The challenges in meeting the requirements for global minerals in the future will not be met with wishful thinking about "circular economies."

Renewables and Minerals: Ethics, Conflicts and Dependencies

One can trace a straight line from an electric car to Inner Mongolia's massive Bayan Obo mines (for rare earths), and from a smartphone to mines in the Democratic Republic of Congo (for cobalt in batteries), or from a medical MRI to giant trucks in the mines of Brazil (for niobium in superconducting magnets).[59] Each of those regions represents the world's largest supply of rare earths, cobalt, and niobium, respectively.[60]

Politically troubled Chile has the world's greatest lithium resources, although stable Australia is the world's biggest supplier. Elsewhere in the battery supply chain, Chinese cobalt refiners have quietly gained control over more than 90% of the battery industry's cobalt refining, without which the raw cobalt ore is useless.[61]

The Institute for Sustainable Futures in Sydney, Australia, cautions that a global gold rush for green minerals to meet ambitious plans could take miners into "some remote wilderness areas [that] have maintained high biodiversity because they haven't yet been disturbed."[62] And then there are the widely reportedly cases of abuse and child labor in mines in the Congo, where 70% of the world's raw cobalt originates.[63]

Automakers building electric cars have joined smartphone makers in such pledges for "ethical sourcing" of minerals.[64] Car batteries use far more of "conflict" cobalt.[65] Companies can make pledges; but unfortunately, the facts suggest that there is little correlation between such pledges and the frequency of (claimed) abuses in foreign mines.[66] In addition to moral questions about exporting the environmental and labor challenges of mineral extraction, the strategic challenges of supply chains are a top security concern as well.

[59] Júlia Pontés, "I Dream ... that One Day, We'll Also Have a Niobium Valley," *Bloomberg Businessweek*, 2019.

[60] Hong-Rui Fan et al., "The Giant Bayan Obo REE-Nb-Fe Deposit, China: Controversy and Ore Genesis," *Geoscience Frontiers* 7, no. 3 (May 2016): 335–44; DOI and USGS, "Mineral Commodity Summaries 2020."

[61] John Petersen, "The Cobalt Cliff Could Eradicate Non-Chinese EV Manufacturing Before 2030," Seeking Alpha, July 3, 2019.

[62] Ashley Stumvoll, "Are There Potential Downsides of Going to 100% Renewable Energy?" *Pacific Standard*, June 20, 2019.

[63] Douglas Broom, "The Dirty Secret of Electric Vehicles," World Economic Forum, Mar. 27, 2019.

[64] Andreas Cremer, "Automakers Pledge Ethical Minerals Sourcing for Electric Cars," Reuters, Nov. 29, 2017.

[65] Vivienne Walt and Sebastian Meyer, "Blood, Sweat, and Batteries," *Fortune*, Aug. 23, 2018.

[66] Hodal, "Most Renewable Energy Companies."

Strategic Dependencies: Old Security Worries Reanimated

Supply-chain worries about critical minerals during World War I prompted Congress to establish, in 1922, the Army and Navy Munitions Board to plan for supply procurement, listing 42 strategic and critical materials. This was followed by the Strategic Materials Act of 1939. By World War II, some 15 critical materials had been stockpiled, six of which were released and used during that war. The 1939 act has been revised twice, in 1965 and 1979, and amended in 1993 to specify that the purpose of that act was for national defense only.[67]

As recently as 1990, the U.S. was the world's number-one producer of minerals. It is in seventh place today.[68] More relevant, as the United States Geological Survey (USGS) notes, are strategic dependencies on specific critical minerals. In 1954, the U.S. was 100% dependent on imports for eight minerals.[69] Today, the U.S. is 100% reliant on imports for 17 minerals and depends on imports for over 50% of 28 widely used minerals. China is a significant source for half of those 28 minerals.[70]

The Department of Defense and the Department of Energy (DOE) have issued reports on critical mineral dependencies many times over the decades. In 2010, DOE issued the Critical Materials Strategy; in 2013, DOE formed the Critical Materials Institute, the same year the National Science Foundation launched a critical-materials initiative.[71] In 2018, USGS identified a list of 35 minerals as critical to security of the nation.[72]

But decades of hand-wringing over rising mineral dependencies have yielded no significant changes in domestic policies. The truth is that depending on imports for small quantities of minerals used in vital military technologies can be reasonably addressed by building domestic stockpiles, a solution as ancient as mining itself. However, today's massive domestic and global push for clean-tech energy cannot be addressed with small

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[67] National Research Council, *Managing Materials for a Twenty-First Century Military*.

[68] National Mining Association (NMA), "U.S. Mines to Markets," 2014.

[69] USGS, "Risk and Reliance: The U.S. Economy and Mineral Resources," Apr. 12, 2017.

[70] DOI and USGS, "Mineral Commodity Summaries 2020."

[71] GAO, "Strengthened Federal Approach Needed to Help Identify and Mitigate Supply Risks for Critical Raw Materials," September 2016.

[72] USGS, "Interior Releases 2018's Final List of 35 Minerals Deemed Critical to U.S. National Security and the Economy," May 18, 2018.

stockpiles. The options—other than eschewing more green energy—are to simply accept more strategic dependency, or to increase domestic mining.[73]

Renewable Energy's Radical Strategic Dependencies

The U.S. has in the past half-decade achieved strategic energy independence. This comes after decades of political, economic, and geopolitical anxieties over import dependencies for natural gas and oil, in particular. The nation now produces more gas than it consumes and is thus a net exporter; it also produces 90% of net petroleum needs and is thus essentially strategically independent. As with agricultural products, where the U.S. is also a net exporter, achieving net independence does not obviate a need for or value in imports as part of the overall complex structure of commodity exchanges. But strategic "insulation," as well as geopolitical "soft power," comes from a posture of "dominance" in commodities critical to national survival.[74] While it remains to be seen how much damage is inflicted on domestic energy production in the post-coronavirus recession, it is now clear that the nation has significant capabilities in strategic hydrocarbon production *and* exports. Given that 56% of all America's energy comes from oil and gas, this achievement has deep strategic implications.

On the other hand, as of today, just 4% of overall domestic energy needs are supplied by wind and solar machines, and batteries propel less than 0.5% of domestic road-miles. About 90% of solar panels are imported.[75] Even if the panels were assembled here, the U.S. fabricates only 10% of the global supply of the critical underlying silicon material. China produces half.[76] For wind turbines, the U.S. imports some 80% of the electrical components (i.e., excluding fiberglass and steel).[77] And while Tesla (accounting for nearly 80% of all domestic EV sales)[78] manufactures domestically, essentially all the critical minerals originate overseas.

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[73] Dave Keating, "Europe Waking Up to Raw Materials 'Criticality'," EURACTIV.com, Dec. 11, 2019.

[74] Mark P. Mills, "Expanding America's Petroleum Power: Geopolitics in the Third Oil Era," Manhattan Institute, 2016.

[75] EIA, "2018 Annual Solar Photovoltaic Module Shipments Report," July 2019.

[76] Debra Sandor et al., "System Dynamics of Polysilicon for Solar Photovoltaics," *Sustainability* 10, no. 1 (January 2018): 160–87.

[77] Ryan Wiser et al., "2018 Wind Technologies Market Report," DOE, Office of Energy Efficiency & Renewable Energy, August 2019.

[78] Zachary Shahan, "Tesla Gobbled Up 78% of U.S. Electric Vehicle Sales in 2019," CleanTechnica, Jan. 16, 2020.

Thus, any significant expansion in green machines' tiny share of domestic energy will radically increase imports of either those machines, or the green energy minerals, or both. The quantities of imports will be unprecedented.

The strategic implications of green energy materials have not escaped attention in Europe. An analysis from The Hague Centre for Strategic Studies summarized the "security dimension" of the world's rush to promote renewable energy. The analysis points to three obvious macro trends noting that "large unexploited mineral reserves" will gain strategic importance and drily observes that "import dependent countries may use military capabilities to secure mineral resources."[79]

It remains to be seen if Europe's newfound mining ambitions will be greeted by environmentalists and the continent's various green parties, given the hostility of both to extraction industries in general. Just prior to the global coronavirus pandemic, protests started to erupt over plans for new European mines,[80] in response to which industries were spooling up a PR campaign to try to manage "the unfavourable status of mineral extraction."[81]

Even without subsidies, mandates, and policies that favor green energy, the future for both America and the rest of the world will see many more wind and solar farms and many more electric cars. That will happen precisely because those technologies have matured enough to play significant roles. And given the magnitude of pent-up global demand for energy and energy-using machines and services—especially after the world struggles out of recession—it is a truth, not a slogan, that the world will need "all of the above" in energy supplies.

These realities, combined with the immutable reality that green machines require extraordinary quantities of energy minerals, can perhaps form a common intersection of interests that support an expansion of domestic mining. That would be, after all, of strategic and economic benefit to the United States, regardless of the debates over whether renewable energy can replace hydrocarbons, which it cannot, or whether it's a significant addition to energy supplies, which it most assuredly is. <><>

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[79] Marjolein de Ridder, "The Geopolitics of Mineral Resources for Renewable Energy Technologies," The Hague Centre for Strategic Studies, August 2013.

[80] Peter Wise, " 'Lithium Fever' Grips Portugal as Mining Project Raises Hackles," *Financial Times*, Jan. 6, 2020.

[81] "A New Future for Mineral Exploration," INFACT, November 2019.

Mr. JOHNSON. Thank you, Mr. Mills.

Our next witness is Mr. Ashley Nunes, director of Federal policy, climate, and energy at the Breakthrough Institute.

Sir, you are recognized for 5 minutes.

STATEMENT OF ASHLEY NUNES, PH.D.

Dr. NUNES. Thank you, Mr. Chair.

My name is Ashley Nunes. I am a senior research associate at Harvard Law School and the director for Federal policy, climate, and energy at the Breakthrough Institute.

My work focuses on analyzing the cost-effectiveness of emissions reduction efforts in the transportation sector. As this committee is aware, transportation-related emissions have steadily increased since the late 1990s, despite significant Government spending on programs that promote emissions reductions. This mismatch between intent and outcome highlights the need for congressional scrutiny.

I will focus my testimony here on electric vehicles and emissions reduction technology that this administration, its predecessors, and Congress have heavily invested in.

I would like to make four key points: First, just because technology like EVs can lower emissions doesn't mean that they will. Our analysis shows that, without a significant change in existing Government subsidy policy, EV adoption may not meaningfully reduce emissions in the transportation sector.

Second, even with subsidies, EV adoption faces significant and challenging cost barriers. EVs today are pricier than gasoline-powered vehicles. And, more importantly, our analysis of the EV market over the past 15 years shows that not only are EV prices rising, but they are outpacing inflation and outpacing price increases for internal-combustion-engine-powered vehicles. Implicitly mandating EV adoption risks hindering emissions reductions efforts and worsening existing inequities in new vehicle ownership across America.

Third, the path to clean energy requires minerals from numerous countries. Some of these countries are U.S. partners, others less so. Although the Inflation Reduction Act supports U.S. production and processing capability, IRA's benefits may take years to fully bear fruit. In the meantime, local mineral production limits and limited alternatives in lithium ion battery chemistry suggest that EV costs will remain high for American consumers.

Fourth and finally, there is reason for optimism. Although reducing emissions is challenging, this challenge is not, in Breakthrough's view, insurmountable. America can build better, cleaner, and less mineral-intensive cars that consumers want to buy and are, regardless of socioeconomic status, able to afford. Government has a crucial role to play in supporting this effort and, given the seriousness of climate change, should do so.

Thank you, Mr. Chair.

[The prepared statement of Dr. Nunes follows:]

Written Testimony of

Ashley Nunes
Director, Federal Policy, Climate and Energy
The Breakthrough Institute

Before the United States House of Representatives
Committee on Energy and Commerce
Subcommittee on Environment, Manufacturing, & Critical Materials

April 26, 2023

Chairman Johnson, Ranking Member Tonko, and Honorable Members of the Committee,

Thank you for the opportunity to submit a written statement to the House Energy Subcommittee on Environment, Manufacturing, & Critical Materials. My name is Ashley Nunes. I am a Senior Research Associate at Harvard Law School and the Director for Federal Policy, Climate and Energy, at the Breakthrough Institute. The institute is a global research center that identifies and promotes technological solutions to environmental and human development challenges. We believe that human prosperity is compatible with an ecologically vibrant planet, and we are committed to a world that is good for both people and nature.

My work at Breakthrough focuses on analyzing the cost effectiveness of emissions reduction initiatives, particularly in the transportation sector. The U.S. transportation sector is responsible for more greenhouse gas (GHG) emissions than any other sector of our economy, accounting for about 27 percent of total U.S. GHG emissions[1,2]. Moreover, total emissions from the transportation sector have steadily increased since the late 1990s despite significant government spending on programs that promote emissions reductions[3]. This mismatch between intent and outcome highlights the need for Congressional scrutiny and action.

I will focus here on electric vehicles (EVs), an emissions-reduction technology toward which President Joe Biden, his predecessors, and Congress have committed sizable public funds. My assessment of this technology's emissions-reduction potential is based on my own work in this area, alongside that of prominent climate analysts, technologists, and social scientists who have been widely cited in the relevant scholarly literatures.

In my testimony, I would like to make four key points:

- First, just because technologies like EVs can lower emissions doesn't mean that they necessarily will. While existing discourse highlights grid decarbonization as crucial to EV success, Breakthrough's analysis shows that how EVs are driven, by whom, and under what conditions also significantly influence the number of miles an EV must be driven to deliver an emissions advantage over its fossil fuel counterparts. Without a change in existing government policy, EV adoption may not meaningfully decrease transportation sector emissions given consumption patterns in American households.

- Second, EV adoption faces challenging cost barriers. EVs today are more expensive to purchase up front than Internal Combustion Engine (ICE) powered vehicles. Moreover, this price disadvantage doesn't fully capture the state of the EV market. In 2011, the inflation adjusted price of a new EV was nearly $44,000. By 2022, that price had risen to over $66,000. EV prices aren't just going up; they are rising faster than inflation and, as Breakthrough's analysis suggests,

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[1] U.S. Department of Transportation. "Climate Action." *U.S. Department of Transportation*, 13 Jan. 2023, https://www.transportation.gov/priorities/climate-and-sustainability/climate-action.
[2] United States Environmental Protection Agency. "Carbon Pollution from Transportation." *United States Environmental Protection Agency*, 19 May 2022, https://www.epa.gov/transportation-air-pollution-and-climate-change/carbon-pollution-transportation.
[3] United States Environmental Protection Agency. "Sources of Greenhouse Gas Emissions." *United States Environmental Protection Agency*, 18 Apr. 2023, https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

faster than ICE vehicle prices. Should the government nevertheless implicitly mandate EV adoption, an approach recently adopted by the Environmental Protection Agency (EPA), it would risk worsening existing inequities in new vehicle ownership while also encouraging some households to continue driving older, more polluting ICE vehicles for longer than they ordinarily would, potentially hindering emissions reductions efforts.

- Third, the path to clean energy requires wide-ranging specialty raw materials for which the United States currently relies on foreign states. Some of these states—Australia, Canada, and Norway to name a few—are long standing U.S. partners that share our values, interests, and preferences. But that is not the case for all the countries that control, as a manner of extraction or processing, a significant share of minerals value chains. Although the Inflation Reduction Act (IRA) aims to consolidate U.S. production and processing capability, these measures may take years to fully bear fruit. In the meantime, production capacity limits coupled with limited alternatives in lithium-ion battery chemistry suggest that EV costs will remain high for American consumers.

- Fourth and finally, there is reason to be optimistic. Although the pathway towards emissions reduction is fraught with challenges, these challenges are not—in Breakthrough's view—insurmountable. America can build better, cleaner, and less mineral-intensive vehicles that consumers want to buy and are, regardless of socioeconomic status, able to afford. Government has a critical role to play in supporting that effort, and given the seriousness of climate change, should do so. That will mean implementing policies that have been carefully deliberated and being amendable to changing these policies when there is incongruence between the policy intent and observed outcome.

1. EV Emissions Reduction Potential

The rationale for EV adoption seems straightforward. By foregoing reliance on fossil fuels during the driving phase, these vehicles emit less carbon compared to gasoline powered alternatives like ICE and hybrid electric vehicles (HEVs). Researchers estimate that over its lifetime, the average EV produces 50 percent less global warming pollution than a comparable gasoline vehicle[4]. Findings like these imply a clear, consistent, and compelling narrative that establishes an EV's emissions advantage over its gasoline powered counterparts.

However, an EV is only a decarbonizer to the extent that it offsets both gas-powered driving emissions *and* the emissions needed to manufacture the EV[5]. The latter is particularly important because manufacturing an EV imposes a far larger upfront carbon cost than does building an ICE vehicle[6]. Consequently, as Bloomberg's Kyle Stock correctly notes, the only way for an EV to cover its own carbon, so to speak, is in miles. Put another way, the question worth asking is not whether an EV runs cleaner than an ICE vehicle, but rather, after how many miles its total carbon footprint becomes smaller than its counterpart's.

My recent work with Lucas Woodley and Philip Rossetti finds that that EVs must travel between 28,069 and 68,160 miles to realize an emissions advantage over similarly sized and equipped ICE vehicles[7]. Meeting those mileage thresholds may seem undaunting given the large distances Americans travel by automobile each year. Families across America regularly drive upwards of 10,000 miles annually in personally owned vehicles. This implies that EVs can deliver an emissions advantage after as little as three years of ownership. However, EV purchasing, and utilization patterns make the math more complicated.

Research shows that the majority of EVs are purchased and used as secondary (or tertiary) vehicles, rather than primary vehicle in a household[8,9]. Because households owing multiple vehicles put fewer miles on secondary (and tertiary) vehicles, EVs in these households must stay on the road for longer than their primary (gasoline powered) counterparts. We estimate that in many American households, EVs must remain in service for upwards of at least 10 years to deliver an emissions benefit (compared to ICE vehicles). There is little evidence that suggests this outcome is being realized today.

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[4] Reichmuth, David, et al. "Driving Cleaner: How Electric Cars and Pick-Ups Beat Gasoline on Lifetime Global Warming Emissions." *Union of Concerned Scientists*, 25 July 2022, https://www.ucsusa.org/resources/driving-cleaner.

[5] Stock, Kyle. "The Wrong Americans Are Buying Electric Cars." *Bloomberg*, 15 Nov. 2022, https://www.bloomberg.com/news/articles/2022-11-15/the-wrong-americans-are-buying-electric-cars?leadSource=uverify+wall.

[6] Hall, Dale, and Nic Lutsey. "Effects of Battery Manufacturing on Electric Vehicle Life-Cycle Greenhouse Gas Emissions." *International Council on Clean Transportation*, Feb. 2018, https://theicct.org/wp-content/uploads/2021/06/EV-life-cycle-GHG_ICCT-Briefing_09022018_vF.pdf.

[7] Nunes, Ashley, et al. "Re-Thinking Procurement Incentives for Electric Vehicles to Achieve Net-Zero Emissions." *Nature Sustainability*, vol. 5, no. 6, 2022, pp. 527–532., https://doi.org/10.1038/s41893-022-00862-3.

[8] Davis, Lucas W. "Electric Vehicles in Multi-Vehicle Households." *Applied Economics Letters*, 1 June 2022, pp. 1–4., https://doi.org/10.1080/13504851.2022.2083563

[9] Xing, Jianwei, et al. "What Does an Electric Vehicle Replace?" *Journal of Environmental Economics and Management*, vol. 107, May 2021, p. 102432., https://doi.org/10.1016/j.jeem.2021.102432.

2. EV Cost Barriers

EVs are expensive. In 2022, the average price of a new EV was at least $20,000 more than a similarly sized ICE vehicle. While consumer costs could fall as production volume scales, the available empirical evidence suggests otherwise[10,11]. Over the last decade, the inflation adjusted price of a new EV has risen by over 50 percent, despite a concurrent increase in sales. The upfront price of going electric isn't just rising; it is even outpacing inflation and increasingly necessitates committing the near entirety of the average American household's annual income[12]. Should government policy require that all new vehicle sales be electric, further price increases risks widening existing inequities in new vehicle ownership[13]. This is particularly true in the EV market, as high-income households already account for a larger share of new EV purchases compared to lower income households[14,15].

Critics may dismiss EV price concerns on three grounds. First, they will argue that affordable new EVs are available for purchase; second, that the higher upfront purchasing price consumers incur is offset by the long-term savings EVs offer; and third, that the used vehicle market offers middle and low-income households an opportunity to purchase EVs at a more affordable price.

Regarding the availability of lower priced new EVs, such models admittedly do exist. In 2022, the lowest price EV cost less than $30,000. Moreover, since 2011, the least expensive EV has averaged an inflation-adjusted price of approximately $32,000, well within the budgetary constraints of many American households. However, these vehicles rarely address the day-to-day range and interior space needs of most households. This may help explain why in 2022 alone, only 12,025 units of the least expensive EV were sold out of a total of more than 700,000 EVs. Plainly put, practically nobody buys these cars[16].

Where long-term savings are concerned, EVs can offer a superior value proposition largely due to their lower fuel and maintenance costs. Electricity is cheaper than gas, and fewer moving parts in an EV means fewer lifetime mechanical issues (compared to gasoline powered vehicles). However, these savings appear insufficient to overcome accelerated vehicle depreciation rates and the rising insurance-

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[10] Nordhaus, Ted, and Ashley Nunes. "Don't Expect Mass Adoption of Electric Cars Anytime Soon." *The Wall Street Journal*, Dow Jones & Company, 13 Apr. 2023, https://www.wsj.com/articles/dont-expect-mass-adoption-of-electric-cars-anytime-soon-fc60d894?mod=Searchresults_pos1&page=1

[11] Hsieh, I-Yun Lisa, et al. "Learning only buys you so much: Practical limits on battery price reduction." *Applied Energy*, vol. 239, 1 Apr. 2019, pp. 218-224, https://doi.org/10.1016/j.apenergy.2019.01.138.

[12] Nunes, Ashley. "The inequities of electric vehicles." *The Financial Times*, 11 Aug. 2021, https://www.ft.com/content/f0659114-94dc-4181-ae50-db0d86b84feb

[13] Harper, Sam, et al. "Trends in Socioeconomic Inequalities in Motor Vehicle Accident Deaths in the United States, 1995–2010." *American Journal of Epidemiology*, vol. 182, no. 7, 1 Oct. 2015, pp. 606–614., https://doi.org/10.1093/aje/kwv099.

[14] Muehlegger, Erich, and David Rapson. "Understanding the Distributional Impacts of Vehicle Policy: Who Buys New and Used Alternative Vehicles?" *National Center for Sustainable Transportation*, Feb. 2018, https://escholarship.org/content/qt0tn4m2tx/qt0tn4m2tx_noSplash_36244609f162444f3e55c550dfc22cad.pdf.

[15] Wappelhorst, Sandra. "The Role of the Used Car Market in Accelerating Equal Access to Electric Vehicles." *International Council on Clean Transportation*, 27 Apr. 2021, https://theicct.org/the-role-of-the-used-car-market-in-accelerating-equal-access-to-electric-vehicles/.

[16] Nunes, Ashley. "EVs are selling like hotcakes. Don't rejoice just yet." *The Boston Globe*, 1 Dec. 2022, https://www.bostonglobe.com/2022/12/01/opinion/evs-are-selling-like-hotcakes-dont-rejoice-just-yet/

related expenditures that accompany EV ownership[17]. A 2021 study by Argonne National Laboratory finds that over a 15-year horizon, EVs are more expensive to own than their gasoline powered counterparts[18].

Regarding EV adoption via the used vehicle market, the declining price of new EVs sets a benchmark for valuing used EVs sold during that year. Cost reductions for new EVs are assumed to create downward pressure on the used EV market, such that the benefits of both subsidies and cost reductions on new EVs are passed on to used EV buyers[19,20]. However, assertions of cost reductions for new EVs are inconsistent with historical pricing trends. Higher new EV prices imply higher used EV prices (relative to ICE vehicles). And even if the price of new EVs falls significantly, research suggests that *some* ownership inequity will still be perpetuated, owing to limited supply of more affordable used EV models[21].

In either scenario, households that cannot afford an EV (new or used) may continue to drive their older ICE vehicle for longer than they ordinarily would. Since older vehicles are often more polluting than newer ones owing to technological improvements and existing fuel economy standards, this outcome risks hindering emissions reductions efforts.

Finally, whereas price considerations for American households warrant attention, so does the cost firms incur for manufacturing EVs. EV prices may be rising but even at current price points, manufacturers are struggling with profitability. Ford's EV business lost $2.1 billion in 2022 and is expected to lose another $3 billion in 2023[22]. Colin Langan and Kosta Tasoulis, auto analysts at Wells Fargo, have consistently highlighted the challenging economics facing EV manufacturers, noting that where government-imposed EV sales targets are concerned, "proposed rules seem to ignore the large profit impact to the auto industry."[23],[24] Careful deliberation of automotive policy is warranted given the impact this industry has on jobs and economic mobility.

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[17] Schloter, Lukas. "Empirical Analysis of the Depreciation of Electric Vehicles Compared to Gasoline Vehicles." *Transport Policy*, vol. 126, 2022, pp. 268–279., https://doi.org/10.1016/j.tranpol.2022.07.021.
[18] Burnham, Andrew, et al. "Comprehensive Total Cost of Ownership Quantification for Vehicles with Different Size Classes and Powertrains." *Argonne National Laboratory*, U.S. Department of Energy, Apr. 2021, https://publications.anl.gov/anlpubs/2021/05/167399.pdf.
[19] Bauer, Gordon, et al. "When Might Lower-Income Drivers Benefit from Electric Vehicles? Quantifying the Economic Equity Implications of Electric Vehicle Adoption." *International Council on Clean Transportation*, Feb. 2021, https://theicct.org/sites/default/files/publications/EV-equity-feb2021.pdf.
[20] Boudway, Ira. "Used EV Prices Are Falling Just in Time for a New US Tax Credit." *Bloomberg*, 20 Feb. 2023, https://www.bloomberg.com/news/articles/2023-02-20/will-used-ev-prices-keep-going-down-this-year.
[21] Turrentine, Thomas, et al. "The Dynamics of Plug-in Electric Vehicles in the Secondary Market and Their Implications for Vehicle Demand, Durability, and Emissions." *National Center for Sustainable Transportation*, 1 Apr. 2018, https://ncst.ucdavis.edu/research-product/dynamics-plug-electric-vehicles-secondary-market-and-their-implications-vehicle
[22] CBS News. "Ford Says It Will Lose $3 Billion This Year Making Electric Cars." *CBS News*, CBS Interactive, 23 Mar. 2023, https://www.cbsnews.com/news/ford-ev-unit-losing-billions-should-be-seen-as-startup/.
[23] Langan, Colin M., and Kosta Tasoulis. "EPA's Tail-Pipe Dream: Will There Be Enough Lithium for Proposed 2032 Targets?" *Wells Fargo*, 14 Apr. 2023.
[24] Langan, Colin M., and Kosta Tasoulis. "Ford Motor Company (F): Long Road Ahead for BEV Profitability." *Wells Fargo*, 24 Mar. 2023.

3. Critical mineral considerations

Clean energy technologies require more minerals to build compared to their fossil-fuel powered counterparts, owing to functional differences in their underlying energy systems. A typical EV requires six times the critical mineral inputs compared to its ICE powered counterpart[25]. These inputs include lithium, nickel, cobalt, and manganese, all of which are crucial to maintaining battery performance, energy density, and longevity. While reliance on these minerals offers a pathway towards decarbonization, it also imposes a distinct set of challenges.

The United States depends heavily on imports to meet its mineral needs[26]. This dependency has prompted numerous experts to highlight the precarious position the United States finds itself in—at risk of losing our position of global economic leadership and being left vulnerable to supply disruptions and dependent on nations that do not share our values[27,28]. In response, and specific to EV battery minerals, Biden issued the "Presidential Determination Pursuant to Section 303 of the Defense Production Act of 1950, as Amended," which calls for, "the sustainable and responsible domestic mining, beneficiation, and value-added processing of strategic and critical materials for the production of large-capacity batteries for the automotive, e-mobility, and stationary storage sectors are essential to the national defense."[29]

Congress has taken similar action, most notably through the IRA. However, even though laws like the IRA aim to shore up U.S. extraction, processing, and recycling, these efforts offer limited utility because of how minerals are geographically distributed. Breakthrough's analysis of U.S. mine production and recycling capability reveals that the United States will not be able to use local sourcing alone to meet the initial electrification goals set out by the Biden administration (50 percent electrification sales by 2030) (Fig. 1), let alone those announced last week (67 percent electrification sales by 2032). Coordination with our international partners could theoretically help us meet EV mineral needs, but here too challenges persist. Many of our allies have set aggressive electrification goals of their own, and there is, to put it bluntly, only so much mineral supply to go around.

These constraints have prompted renewed interest in alternative battery chemistries, the goal being to alter the mineral requirements of future EV batteries. Among the most promising of these is lithium iron phosphate (LFP), a formulation that forgoes long-standing reliance on manganese and cobalt, minerals that are both expensive and concentrated in nations that do not share our values. However,

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[25] International Energy Agency. "The Role of Critical Minerals in Clean Energy Transitions." *International Energy Agency*, May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions.
[26] Tracy, Brandon S. "Critical Minerals in Electric Vehicle Batteries." *Congressional Research Service*, 29 Aug. 2022, https://sgp.fas.org/crs/misc/R47227.pdf.
[27] Wulf, Abigail. "Testimony Submitted on Behalf of Securing America's Future Energy (SAFE)." *Committee on Energy and Natural Resources*, United States Senate, 31 Mar. 2022, https://www.energy.senate.gov/services/files/79FD8935-292A-4DB3-BD9B-2C0195B9C2FB.
[28] Nkulu, Célestin Banza Lubaba, et al. "Sustainability of artisanal mining of cobalt in DR Congo." *Nature Sustainability*, no. 1, 14 Sept. 2018, pp. 495-504, https://doi.org/10.1038/s41893-018-0139-4.
[29] Biden, Joseph R. "Presidential Determination Pursuant to Section 303 of the Defense Production Act of 1950, as Amended, on Airbreathing Engines, Advanced Avionics Position Navigation and Guidance Systems, and Constituent Materials for Hypersonic Systems." *The White House*, 1 Mar. 2023, https://www.whitehouse.gov/briefing-room/presidential-actions/2023/03/01/presidential-determination-pursuant-to-section-303-of-the-defense-production-act-of-1950-as-amended-on-airbreathing-engines-advanced-avionics-position-navigation-and-guidance-systems-and-constitue/.

Breakthrough's analysis of this battery chemistry suggests that—owing to lower energy density—EVs equipped with LFP batteries may be unable to meet the range expectations of American consumers at the price point these consumers expect.

4. Congressional response

The evidence presented thus far does not—and should not—be construed as a dismissal of EVs' potential to reduce carbon emissions in the transportation sector. To be clear, such a reduction is urgent, and EVs can help achieve it. But there is little assurance that such an outcome will be realized. Moreover, emerging evidence suggests that EV adoption could—owing to adoption and usage patterns in American households—have unintended consequences. Indeed, existing EV adoption policies may not facilitate meaningful reductions in transportation sector emissions. Even when reductions are realized, EVs may not be the most cost-effective emissions reduction pathway, at least from the vantage point of public spending. Three steps could address these concerns.

First, EV subsidies should be reserved solely for vehicle replacement purposes[30]. The composition of operational vehicle stock reflects the accumulation of new vehicle sales less vehicle retirements over time[31]. The goal of EV subsidies is to transform the 'propulsion profile' of this stock, not—as is increasingly being observed—raise the overall number of vehicles in stock[32]. More cars on the road, regardless of propulsion type, risks worsening higher traffic volume-related externalities like congestion, noise, and traffic fatalities. Consequently, EV subsidies should be reserved for consumers seeking to replace, not add to, the number of vehicles in their household. Replacement of primary vehicles in a household should be prioritized.

Second, from the vantage point of public spending, policy makers should consider alternative vehicle powertrains that also offer emissions reduction potential[33]. The most notable of these are hybrid-electric vehicles (HEVs), which rely on electric-drive technologies to boost vehicle efficiency through regenerative braking[34]. Breakthrough's work finds HEVs are a more climate friendly alternative to an EV if the EV covers less than approximately 96,000 miles across its lifetime and an HEV covers 180,000 miles (Fig. 2). Furthermore, we note that because HEVs cost significantly less than EVs, the magnitude of EV cost penalties relative to their GHG emission reduction benefits makes HEVs a more promising near-term emissions reduction pathway[35,36].

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[30] Nunes, Ashley, and Lucas Woodley. "Governments Should Optimize Electric Vehicle Subsidies." *Nature Human Behaviour*, 3 Mar. 2023, https://doi.org/10.1038/s41562-023-01557-1.
[31] Keith, David R, et al. "Vehicle fleet turnover and the future of fuel economy." *Environmental Research Letters,* vol. 14, no. 2, 2019, p. 021001., https://doi.org/10.1088/1748-9326/aaf4d2.
[32] Burlig, Fiona, et al. "Household Vehicle Portfolios and EV Demand." *Economics of Transportation in the 21st Century Conference*, National Bureau of Economic Research, 14 Oct. 2022, https://www.nber.org/conferences/economics-transportation-21st-century-fall-2022.
[33] Woodley, Lucas, et al. "Targeted electric vehicle procurement incentives facilitate efficient abatement cost outcomes." *Sustainable Cities and Society* (In press).
[34] Alternative Fuels Data Center. "Electric Vehicle Benefits and Considerations." *Alternative Fuels Data Center*, U.S. Department of Energy, https://afdc.energy.gov/fuels/electricity_benefits.html.
[35] Nunes, Ashley, et al. "Near-Term Policy Pathways for Reducing Car and Light-Truck Emissions." *Environmental Research Letters*, vol. 16, no. 6, 2021, p. 061003., https://doi.org/10.1088/1748-9326/ac04d9.
[36] Nunes, Ashley. "The Biden Administration shouldn't ignore hybrid cars." *The Financial Times*, 27 April. 2021, https://www.ft.com/content/613d0ac5-a848-4f7c-85f5-69bc8b636363

Third and finally, auto makers should be incentivized to produce EVs that are appealing, profitable, and affordable; an automotive grand challenge of sorts that puts American ingenuity and know-how to the test. Such an effort would emulate similar, longstanding initiatives like the Defense Advanced Research Projects Agency Grand Challenge, a government sponsored competition that awards cash prices for making innovative automotive design concepts a reality. Absent the availability of EVs that meet the mobility *and* affordability needs of American households, caution should be exercised lest a de facto mandate for EV adoption widens existing inequities or keeps older, more polluting ICE vehicles in the national vehicle stock for longer.

Thank you again Chairman Johnson, Ranking Member Tonko, and honorable members of the Committee. If I can be of any assistance to you, please feel free to contact me at the Breakthrough Institute.

Ashley Nunes, PhD
Director, Federal Policy, Climate and Energy
The Breakthrough Institute
923 15th St NW
Washington, DC 20005

	Avg yearly requirement for Biden 2030 EV goals	U.S. avg yearly production, from mining (2018–2022)	U.S. avg yearly production, mining + recyling (2018–2022)	Mine production from allies + partners (2022)[c]	Potential to increase production through recycling	U.S. avg yearly economy-wide consumption	Recent trend in U.S. economy-wide consumption
	Thousands of metric tons						
Aluminum[d]	Low: 71 Middle: 160 High: 290	24[a]	1 524	25 000	High	4 600	Steady →
Cobalt	Low: 5 Middle: 12 High: 23	0.6	2.8	19	High	9	Steady →
Copper	Low: 42 Middle: 96 High: 170	1 242	1 399	9 890	High	1 832	Increasing ↑
Graphite	Low: 110 Middle: 240 High: 430	243 (all synthetic, mostly consumed in non-battery industries, especially steel[b])	243 (all synthetic, mostly consumed in non-battery industries, especially steel[b])	48	Low	490	Increasing ↑
Lithium	Low: 11 Middle: 25 High: 46	1	1	101	Low	2	Will increase sharply ↑↑
Manganese	Low: 4 Middle: 10 High: 20	None	None	3 530	Low	754	Steady →
Nickel	Low: 31 Middle: 74 High: 140	17	123	810	High	220	Increasing ↑
Phosphate	Low: 26 Middle: 57 High: 98	23 000	23 000	61 950	Low	25 000	Steady →

a. U.S. mine production from 2021 only
b. Avg synthetic graphite production from 2017–2021
c. Considers countries with a Free Trade Agreement or mutual defense treaty with the United States
d. Aluminum mine production and reserves are converted to aluminum equivalent from bauxite figures. U.S. mine production rates are based on bauxite mining from 2021 only. Aluminum secondary/recycled production values reflect direct production of refined aluminum and are not converted.

- Sufficient for high EV adoption scenario (green)
- Sufficient for medium EV adoption scenario (yellow)
- Sufficient for low EV adoption scenario (orange)
- Insufficient across all EV adoption scenarios (red)
- Processing, refining, or production supply chains highly concentrated in China (grey)

— High, medium, and low EV adoption scenarios reflect approximately 54, 30, and 13 million EV sales respectively between 2024 and 2030.

Figure 1: Assessment of mineral production capacity based on the Biden Administration's 2030 electrification goals.

Aggregate EV Utilization (mi.)	EV emissions (g/mi.)	EV emissions + battery replacement (g/mi.)
10,000	1,488.77 🟠 🔵	1,913.77 🟠 🔵
20,000	808.77 🟠 🔵	1,021.27 🟠 🔵
30,000	582.10 🟠 🔵	723.77 🟠 🔵
40,000	468.77 🟠 🔵	575.02 🟠 🔵
50,000	400.77 🟠 🔵	485.77 🟠 🔵
60,000	355.44 🔵	426.27 🟠 🔵
70,000	323.06 🔵	383.77 🟠 🔵
80,000	298.77 🔵	351.89 🔵
90,000	279.88 🔵	327.10 🔵
100,000	264.77	307.27 🔵
110,000	252.41	291.04 🔵
120,000	242.10	277.52 🔵
130,000	233.38	266.08
140,000	225.91	256.27
150,000	219.44	247.77
160,000	213.77	240.33
170,000	208.77	233.77
180,000	204.33	227.94

🟠 ICE: Internal combustion engine vehicle less polluting (~372.7 g/mi)

🔵 HEV: Hybrid electric vehicle less polluting (~272.4 g/mi)

Figure 2: EV emissions impact at varying aggregate utilization levels holding HEV/ICE utilization constant (i.e., 180,000 miles)

Mr. JOHNSON. The gentleman yields back.

Our next witness is Mr. Daniel Simmons, principal at Simmons Energy—OK. I am sorry. I skipped Mr. Higgins. I apologize. Here we go.

Our next witness is Mr. Trevor Higgins, senior vice president at the Center for American Progress.

You are recognized for 5 minutes. I had you on the list, I just had the order reversed. I apologize, Mr. Higgins. You are recognized for 5 minutes.

STATEMENT OF TREVOR HIGGINS

Mr. HIGGINS. Thank you, Chair Johnson, Ranking Member Tonko, members of the subcommittee.

Last session, Congress enacted major components of President Biden's Investing in America agenda, including the Infrastructure Investment and Jobs Act, the CHIPS and Science Act, and the Inflation Reduction Act. These pieces of legislation represent the largest investment in climate action in U.S. history, and they really changed the paradigm that we are operating in. The United States now has a fighting chance to cut greenhouse gas emissions to half of peak levels by 2030.

The groundbreaking legislation is already at work today, and it is growing the economy by investing in the middle class. It connects good-paying jobs and apprenticeship programs to clean energy incentives for the first time. It builds supply chains and domestic manufacturing that will equip America to compete in the global energy economy for decades to come. It cleans up air pollution that is concentrated in low-income communities, and it cuts household energy costs in every region of the country.

I will run through each of those four points very briefly.

First, jobs. The Inflation Reduction Act investments will create 1.3 million jobs by 2030. Already today, even though we are less than a year in—or just about a year in—we have seen 140,000 new clean energy jobs already promised and created.

Importantly, the full value of the revised clean electricity tax credits are only available for project developers who pay prevailing wages and employ people in apprenticeship programs, ensuring that the clean energy economy will be built with good jobs.

Second, manufacturing. The Investing in America agenda is onshoring manufacturing and building resilient supply chains already. For example, the Inflation Reduction Act's clean electricity incentives depend on increasing proportions of domestic content. There are new programs for manufacturing investments in energy communities, in advanced industrial facilities, automotive retooling and much more.

Advanced manufacturing tax incentives provide a long-term investment signal for critical mineral processing and battery production, and the structure of the tax credits for electric vehicles depend on domestic assembly and domestic batteries.

Mr. JOHNSON. Mr. Higgins, I apologize for interrupting you. Can I get you to get a little closer to your microphone. I am being told that it is not picking it up on TV.

Mr. HIGGINS. Thank you. Is this better?

Mr. JOHNSON. Yes. Thank you.

Mr. HIGGINS. Thank you.

Since the passage of the Inflation Reduction Act, companies have announced $240 billion in new capital investments for at least 190 new clean energy projects in 41 States, as documented recently by Climate Power. A few examples include Tucson, Arizona; Rochester, New York; and Florence County, South Carolina, which are among those that have plans for 65 new battery manufacturing sites.

Savannah, Georgia, and Montgomery, Alabama, are among the cities with plans for 40 new or expanded EV manufacturing facilities. Pensacola, Florida; Hutchinson, Kansas; and Georgetown, Texas, among others, have plans for 34 expanded wind and solar manufacturing plants.

These investments in U.S. industry will provide decades of job opportunities for communities across the country. Repealing the Inflation Reduction Act would pull the rug out from underneath these investments that are helping the United States to compete with China now.

Third, saving lives. Modeling from energy innovation shows that pollution reductions from the Inflation Reduction Act's clean energy investments would prevent up to 4,500 premature deaths and nearly 120,000 asthma attacks annually by the end of this decade.

Importantly, these pollution-related deaths will decline by an even greater percentage in low-income communities and communities of color because they are disproportionately burdened by environmental harm and pollutants.

Fourth, repealing the Inflation Reduction Act would raise household energy costs. IRA offers households up to $28,500 in rebates and incentives if they choose to install clean appliances in their homes or buy zero-emission vehicles. For low-income houses, these rebates can cover 100 percent of project costs.

Because running on electricity is generally more affordable and less volatile than fossil fuels, home electrification can save the average household up to $1,800, and switching to an EV can save the average driver up to $2,600 a year. Even families that don't take advantage of these programs will save on their energy bills as the investments in affordable clean energy and reduced fuel demand across the economy will actually lower the price of natural gas. These clean energy investments deliver more and more savings every year, which will be felt in every region of the country, ranging from a 9 percent total energy cost savings in New England to 12 percent in the Midwest and up to 24 percent on the West Coast by the end of this decade.

Lastly, although the Inflation Reduction Act was passed with uniform partisan opposition, it does bring benefits to all Americans. In fact, more than half of the announced projects and jobs created from IRA so far are in congressional districts represented by Republican Members of Congress. Republican-leaning States are estimated to receive an average of $4,200 in IRA investments per capita, compared to $2,400 for Democratic-leaning States. These investments aren't partisan. People in all communities stand to benefit.

The Investing in America agenda is building a clean energy economy that will create good-paying middle-class jobs, make the U.S.

competitive in the global economy, cut household energy costs, and save lives.

Thank you very much for the opportunity to be here today, and I look forward to any questions.

[The prepared statement of Mr. Higgins follows:]

Testimony of Trevor Higgins
Senior Vice President, Energy and Environment
Center for American Progress

House Energy and Commerce Committee
Subcommittee on Environment, Manufacturing, and Critical Minerals
Hearing on "Exposing the Environmental, Human Rights, and National Security Risks of the Biden Administration's Rush to Green Policies"

April 26, 2023

Thank you, Chair Johnson, Vice Chair Joyce, Ranking Member Tonko, and members of the Subcommittee. I appreciate the opportunity to appear today to provide testimony on the Inflation Reduction Act's historic investments in American households and jobs aimed at accelerating the U.S. transition to a clean energy economy.

Last August, Congress built on the Infrastructure Investment and Jobs Act and the CHIPS and Science Act to enact the Inflation Reduction Act, which represents the largest investment in climate action in U.S. history. This legislation is projected to cut U.S. greenhouse gas emissions to 40 percent below peak levels by 2030, putting the United States on a path toward its Paris Agreement commitment of reaching 50–52 percent below 2005 levels by 2030.[1] These are critical milestones in the effort to limit global warming to 1.5°C this century.

The groundbreaking legislation is already at work today, growing the economy by investing in the middle class: It connects good-paying jobs and apprenticeship programs to clean energy incentives; it builds supply chains and domestic manufacturing that will equip America to compete in the global clean energy economy for decades to come; it cleans up air pollution that is concentrated in low-income communities; and it cuts household energy costs in every region of the country.

> **IRA connects good-paying jobs and apprenticeship programs to clean energy incentives.**
> IRA is not only expected to create at least 1.3 million new jobs by 2030;[2] it has already created more than 142,000 clean energy jobs across the United States. These aren't just jobs of the future. These are high-quality, fair-wage jobs available right now. Importantly, the full value of the revised clean electricity tax credits is only available for project developers who pay prevailing wages and employ people in apprenticeship programs, expanding opportunities to family-supporting employment and ensuring that the clean energy economy will be built with good jobs.[3]
>
> **IRA supports the build out of secure supply chains and domestic manufacturing.**
> IRA is a continuation of this administration's commitment to onshoring manufacturing and building resilient supply chains. For example, the clean energy investment tax incentives

depend on increasing proportions of domestic content. There are investment programs for investments in new manufacturing in energy communities (Sec. 13501), advanced industrial facilities (Sec. 50161), automotive retooling (Sec. 50143), and more. IRA's advanced manufacturing tax incentives provide a long-term investment signal for critical mineral processing and battery production, and the structure of IRA's tax credits for electric vehicles depend on domestic assembly and domestic batteries.

Since the passage of the Inflation Reduction Act, companies have announced $242 billion in new clean power capital investments for at least 191 new clean energy projects in 41 states, as documented by Climate Power.[4]

- Tucson, Arizona; Rochester, New York; and Florence County, South Carolina, have plans for 65 new battery manufacturing sites.
- Savannah, Georgia, and Montgomery, Alabama, are among the cities with plans for 40 new or expanded electric vehicle manufacturing facilities.
- Pensacola, Florida; Hutchinson, Kansas; and Georgetown, Texas, have plans for 34 expanded wind and solar manufacturing plants.

These investments in U.S. industry are necessary for competing on the advanced technologies that will power the new clean energy economy, and they will provide decades of job opportunities for communities across the country. Repealing the Inflation Reduction Act would pull the rug out from under recent investments that are already helping the United States to compete with China.

IRA investments help clean up air pollution that is concentrated in low-income communities.
Modeling from Energy Innovation shows that pollution reductions from the Inflation Reduction Act's clean energy investments would prevent up to 4,500 premature deaths and nearly 120,000 asthma attacks annually by 2030.[5] This translates to $27 to $42 billion in avoided health damages in 2030 alone. Importantly, these pollution-related deaths will decline by an even greater percentage in low-income communities and communities of color, which are disproportionately burdened by environmental harm and pollutants.

IRA investments cut household energy costs in every region of the country.
Repealing the Inflation Reduction Act would raise household energy costs. IRA offers households up to $28,500 in rebates and incentives to households that choose to install clean appliances in their homes and buy electric vehicles.[6] For low-income households, these rebates can cover 100 percent of project costs, including installation costs. Because running on electricity is generally more affordable and less volatile than fossil fuels, home electrification can save the average household up to $1,800 according to Rewiring America;[7] and switching to an electric vehicle can save the average driver up to $2,600 according to Consumer Reports.[8] Even families that don't take advantage of these programs will still save on their energy bills, as the investments in affordable clean

energy and reduced fuel demand across the economy will actually lower the price of natural gas.[9] These clean energy investments deliver more and more savings every year, which will be felt in every region of the country, ranging from 9 percent total energy cost savings in New England, to 12 percent in the Midwest, to up to 24 percent on the West Coast by the end of this decade.[10]

And although the Inflation Reduction Act was passed with uniform partisan opposition, it brings benefits to all Americans. In fact, according to new reporting, more than half of the announced projects and jobs created from IRA are in Republican-led congressional districts.[11] Further, Republican districts are receiving $198 billion from these investments, which is 80% of the total. Republican-leaning states are estimated to receive an average of $4,200 in IRA investments per capita, compared to $2,400 for Democratic-leaning states.[12] The top 10 states with clean energy projects since IRA's passage that have been documented by Climate Power are Arizona, Georgia, Michigan, North Carolina, Ohio, South Carolina, Tennessee, and Texas—a wide cross-section of the country.

The Invest in America Agenda is building a clean energy economy that will create good-paying middle-class jobs, make the United States competitive in the global economy, cut household energy costs, and save lives.

Thank you for the opportunity to be here today. I look forward to any questions you may have.

Endnotes

[1] John Larsen and others, "A Turning Point for US Climate Progress: Assessing the Climate and Clean Energy Provisions in the Inflation Reduction Act" (New York: Rhodium Group, 2022), available at https://rhg.com/research/climate-clean-energy-inflation-reduction-act/.
[2] Megan Mahajan and others, "Updated Inflation Reduction Act Modeling Using the Energy Policy Simulator" (Washington: Energy Innovation, 2022), available at https://energyinnovation.org/wp-content/uploads/2022/08/Updated-Inflation-Reduction-Act-Modeling-Using-the-Energy-Policy-Simulator.pdf.
[3] Mike Williams, Marina Zhavoronkova, and David Madland. "The Inflation Reduction Act Provides Pathways to High-Quality Jobs" (Washington: Center for American Progress, 2022), available at https://www.americanprogress.org/article/the-inflation-reduction-act-provides-pathways-to-high-quality-jobs/.
[4] Climate Power, "Clean Energy Boom: The 142,016 (and Counting) New Clean Energy Jobs Across the United States," March 31, 2023, available at https://climatepower.us/wp-content/uploads/sites/23/2023/04/Clean-Energy-Boom-Report-%E2%80%94-April-2023.pdf.
[5] Ibid., p. 2.
[6] Rachel Chang and others, "The Inflation Reduction Act Will Save Families Thousands of Dollars," Center for American Progress, September 12, 2022, available at https://www.americanprogress.org/article/the-inflation-reduction-act-will-save-families-thousands-of-dollars/.
[7] Rewiring America, "The Electric Explainer: Key programs in the Inflation Reduction Act and what they mean for Americans," available at https://www.rewiringamerica.org/policy/inflation-reduction-act (last accessed April 2023).
[8] Consumer Reports, "New Consumer Reports analysis shows rising gas prices ramp up savings for EV owners," Press release, March 10, 2022, available at https://advocacy.consumerreports.org/press_release/new-consumer-reports-analysis-shows-rising-gas-prices-ramp-up-savings-for-ev-owners/.
[9] John Larsen and others, "Pathways to Paris: A Policy Assessment of the 2030 US Climate Target" (New York: Rhodium Group, 2021), available at https://rhg.com/research/us-climate-policy-2030/.
[10] Sally Hardin and Trevor Higgins, "Clean Energy Will Cut Costs for Families Across the Country," Center for American Progress, February 25, 2022, available at https://www.americanprogress.org/article/clean-energy-will-cut-costs-for-families-across-the-country/.
[11] Climate Power, "The Clean Energy Boom in House Republican Districts," April 25, 2023, available at https://climatepower.us/wp-content/uploads/sites/23/2023/04/Clean-Energy-Boom-Republican-Districts-1.pdf
[12] Oliver Milman, "Republicans in the US 'battery belt' embrace Biden's climate spending," *The Guardian*, February 22, 2023, available at https://www.theguardian.com/environment/2023/feb/22/climate-spending-republican-states-clean-energy-funding.

Mr. JOHNSON. The gentleman yields back, and I thank you.

And now we will now go to our final witness, Mr. Daniel Simmons, principal at Simmons Energy—is it Simmons or Simons?

Mr. SIMMONS. Simmons.

Mr. JOHNSON. Simmons.

Mr. SIMMONS. Yes.

Mr. JOHNSON. Simmons Energy and Environmental Strategies. You are recognized, sir, for 5 minutes.

STATEMENT OF DANIEL R. SIMMONS

Mr. SIMMONS. Thank you, Chairman Johnson, Ranking Member Tonko, and members of the subcommittee. Thank you for the opportunity to testify today.

And today I wanted to highlight the massive mineral and material requirements of President Biden's energy goals as well as offer a solution. And to that end, my friends at the Institute for Energy Research have released this report this week, "The Economic and Strategic Importance of Domestic Mineral Production," that really highlights the mineral requirements as well as some of the challenge that we have in meeting them to meet President Biden's net-zero agenda.

The challenge is that the net-zero energy economy that the Biden administration wants requires massive amounts of minerals and materials, far more than our current energy economy powered mostly by coal, oil, and natural gas. For example, an EV requires 6 times the mineral input of a conventional vehicle, and an offshore wind facility requires 9 times as much material inputs as a natural gas power plant of the same capacity.

The International Energy Agency's Sustainable Development Scenario calls for a 42-fold increase in lithium demand, a 25-fold increase in graphite demand, a 21-fold increase in cobalt demand, a 19-fold increase in nickel demand, and a 7-fold increase in rare earths, all by 2040, a mere 17 years from now.

The problem is that mining and material processing is far more concentrated globally than oil production has been in at least 50 years, and probably longer than that. In fact, China is the world's largest processor of copper, nickel, cobalt, lithium and rare earths, processing between 35 percent and 85 percent of these minerals. By comparison, the 13 members of OPEC together only produce about 40 percent of the world's oil.

Worse, as we have discussed today, China has a terrible human rights track record. The Biden administration and other countries have sanctioned China over China's abuses against the Uyghur people, for example. But these human rights abuses are not just—we don't just see them in China.

For example, the Democratic Republic of Congo has more cobalt resources than the rest of the world combined. However, there is no clean supply chain of cobalt in the DRC, clean in terms of human rights. Much of the DRC's cobalt is mined from so-called artisanal miners, which include children, and are paid just a few dollars a day for very dangerous work.

The problem with production in China and other places—mineral production, that is—is not limited to modern-day slavery and human rights abuses but also environmental degradation. The Ger-

man publication Deutsch Welle argues that battery production, quote, “causes radioactive earth dumps, poisoned groundwater and indigenous population displacement,” close quotes, in places such as China, the DRC, and Rwanda.

But there is a solution, and that is more mineral and material production here in the United States. And to that, we can look to the dramatic increase that we have seen in oil and gas production as a model.

A decade ago, many people, including at the time President Obama, said that more oil and gas drilling was not a strategy to solve our energy challenge. He said it was a bumper sticker. Well, he and the other experts at the time were proved wrong, that it was not only possible, but we actually ended up producing more oil in the last year, in the last decade, than all other countries combined.

In fact, by some measures, globally, the United States has produced about 90 percent of the new oil on the market over the past decade. What that means is greater energy stability and energy security for the United States and the world. Just imagine what would have happened with Russia’s oil going more off the market than if the United States hadn’t been there to support oil and natural gas supplies globally.

And on top of that, even as we have increased our oil and gas production, air quality has continued to increase in the United States, and that is a fantastic success story. So just as “drill, baby, drill” worked for oil and gas production, “mine, baby, mine” can work for minerals.

But one critical overlooked aspect of the shale revolution is the value of non-Federal lands. The shale revolution really occurred on State and private lands, because that is where people could get access to the resources.

But in the case of mining, the Federal Government plays a key role in permitting all new mines, and the Biden administration has stifled almost all new mining development. To name a few examples, the Biden administration has stymied the development of the Twin Metals and Polymet mines in Minnesota, Resolution and Rosemount mines in Arizona, and Pebble Mine in Alaska. They have reduced access to the Ambler Mining District also in Alaska. The Biden administration has been more disposed towards lithium mines, such as Rhyolite Ridge and Thacker Pass, but actual construction has only begun on Thacker Pass.

If the Biden administration is serious about achieving its net-zero goals, it will require massive amounts of new mineral production. The Biden administration should, therefore, work to dramatically increase domestic mining, because that avoids the human rights issues abroad along with the poor environmental standards. And when we produce those minerals here, we improve our national security and, honestly, the national security of the world.

Thank you for your opportunity to testify. I would be happy to take any questions.

[The prepared statement of Mr. Simmons follows:]

TESTIMONY OF

DANIEL R SIMMONS

PRINCIPAL, SIMMONS ENERGY AND ENVIRONMENTAL STRATEGIES

BEFORE THE

U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON ENERGY AND COMMERCE,
SUBCOMMITTEE ON ENVIRONMENT, MANUFACTURING, AND CRITICAL MATERIALS

HEARING: "EXPOSING THE ENVIRONMENTAL, HUMAN RIGHTS, AND NATIONAL SECURITY RISKS OF THE BIDEN ADMINISTRATION'S RUSH TO GREEN POLICIES"

INTRODUCTION

The Biden administration set aggressive net zero goals. The problem is that the net zero energy economy the Biden administration wants requires massive amounts of minerals and materials—far more than our current energy economy that is powered by oil, coal, and natural gas. An EV requires six times the mineral inputs of a conventional car for example. The International Energy Agency's "sustainable development scenario," calls for a 42-fold increase in lithium demand, a 25-fold increase in graphite demand, a 21-fold increase in cobalt demand, a 19-fold increase in nickel demand, and a 7-fold increase in rare earth demand by 2040.

While the earth certainly contains these resources, the problem is access to these critical resources. Mining and mineral processing is far more concentrated than oil production has been in at least 50 years. In fact, China is the largest processor of copper, nickel, cobalt, lithium, and rare earths—processing between 35 percent and 85 percent of these minerals. By comparison, the 13 members of OPEC – together—produce around 40% of the world's oil.

Worse, China has a terrible human rights track record. The Biden administration and other countries have sanctioned China over China's abuses against the Uyghur people for example. It's not just China,

according to experts, the Democratic Republic of Congo has more cobalt reserves than the rest of the world combined, but there are no “clean” supply chains of cobalt in the DRC. Much of the DRC’s cobalt is being mined by so-called “artisanal” miners, which include children, who are paid just a few dollars a day for dangerous work.[1]

The problems with production in China and other places are not limited to modern-day slavery and human rights abuses, but also environmental degradation. The German publication Deutsche Welle argues that battery production “causes radioactive earth dumps, poisoned groundwater and Indigenous population displacement” in places like China, the DRC, and Rwanda.[2]

But there is a solution—more mineral and material production in the United States. A decade ago, many people, including President Obama, said that more oil and gas drilling in the United States was not a strategy to solve our energy challenge.[3] He was proved wrong. The vast majority of new oil production globally over the past decade came from the United States. This new oil production brought greater stability and energy security to the world. Russia’s war in Ukraine, and European dependence on Russian oil and gas, highlighted the benefits of American energy self-sufficiency.

“Drill Baby Drill” worked in the United States and “Mine Baby Mine” will work as well—if people can get access to the mineral resources. Sadly, the Biden administration has worked against almost all new mines in the United States, despite the fact that these mines would produce the minerals the new energy economy requires.

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[1] *See* e.g. Terry Gross, How 'modern-day slavery' in the Congo powers the rechargeable battery economy, NPR, Feb. 1, 2023, https://www.npr.org/sections/goatsandsoda/2023/02/01/1152893248/red-cobalt-congo-drc-mining-siddharth-kara

[2] Michel Penke, *DW.com*, The toxic damage from mining rare elements, Apr. 13, 2021, https://www.dw.com/en/toxic-and-radioactive-the-damage-from-mining-rare-elements/a-57148185#:~:text=Securing%20just%20one%20ton%20of%20rare%20earth%20elements,Research%20Division%20of%20the%20German%20think%20tank%20SWP.

[3] Obama: The American people aren’t stupid, https://www.youtube.com/watch?v=wyFX2iM-dSE&

THERE ARE MASSIVE MINERAL AND MATERIAL REQUIREMENTS FOR NEW ENERGY TECHNOLOGIES

Our energy system is evolving. Regardless of government policies, better technology has driven down the cost of electric vehicles, solar panels, wind generation, and stationary battery technology. Many governments around the world have set targets for net-zero carbon dioxide emissions which rely on these technologies, including the Biden administration.

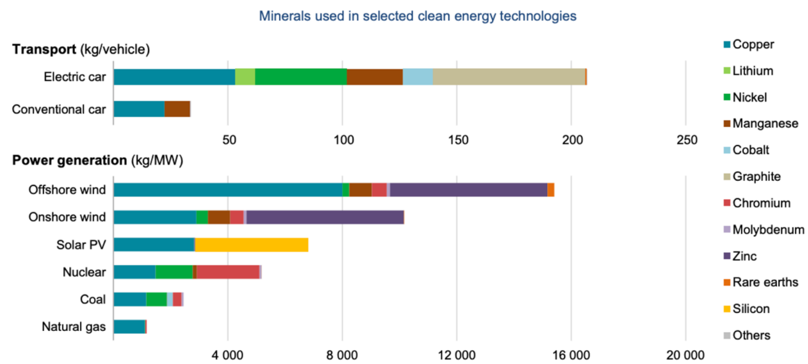
One[4] of the major impediments to net zero goals and the continued rollout of many of the energy technologies that would help reach these goals is that they require far more minerals and materials than are currently being produced. As the International Energy Agency (IEA) explains:

> An energy system powered by clean energy technologies differs profoundly from one fueled by traditional hydrocarbon resources. Solar photovoltaic (PV) plants, wind farms, and electric vehicles (EVs) generally require more minerals to build than their fossil fuel-based counterparts. A typical electric car requires six times the mineral inputs of a conventional car, and an onshore wind plant requires nine times more mineral resources than a gas-fired plant. Since 2010 the average amount of minerals needed for a new unit of power generation capacity has increased by 50% as the share of renewables in new investment has risen.[5]

[4] Note: This section is from the executive summary of the Institute for Energy Research's report, *The Economic and Strategic Importance of Domestic Mineral Production: Unlocking the Value of America's Homegrown Mineral Resources*

[5] International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions,* May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions

The rapid deployment of clean energy technologies as part of energy transitions implies a significant increase in demand for minerals

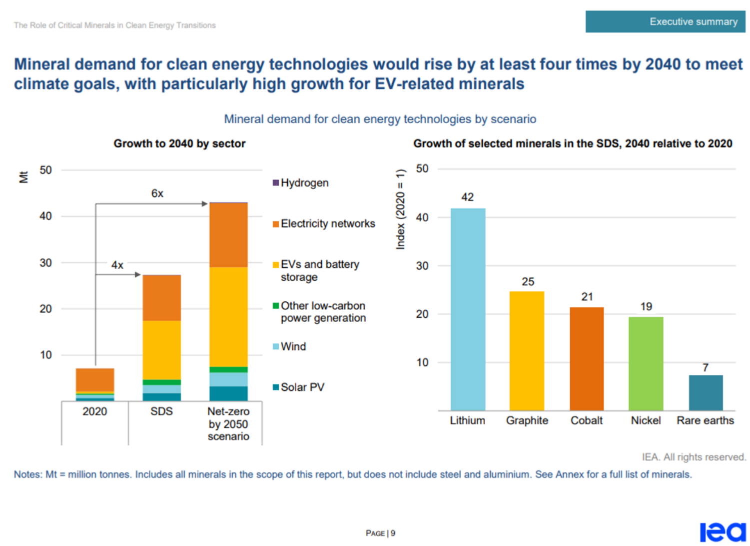


Notes: kg = kilogramme; MW = megawatt. Steel and aluminium not included. See Chapter 1 and Annex for details on the assumptions and methodologies.

Source: International Energy Agency: The Role of Critical Minerals in Clean Energy Transitions

According to the IEA's "sustainable development scenario," these new energy technologies will require a 42-fold increase in lithium demand, a 25-fold increase in graphite demand, a 21-fold increase in cobalt demand, a 19-fold increase in nickel demand, and a 7-fold increase in rare earth demand by 2040 to meet carbon dioxide emissions goals set by some governments around the world. [6]

[6] International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions,* May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions



Source: International Energy Agency: The Role of Critical Minerals in Clean Energy Transitions

Globally, new mining projects are not projected to keep up with this incredible increase in demand. For example, EV expert Steve Levine has explained that "the EV industry is in a decades-long battery metals crisis."[7] Levine estimates, using major metals production forecasts, that by 2030 there will only be enough lithium and cobalt for 15.6 million EVs, while automakers say they want to produce over 40 million in 2030.[8] What makes this situation even more unrealistic is that demand for lithium-ion

[7] Steve LeVine, Twitter, Apr. 26, 2022, https://twitter.com/stevelevine/status/1518913709397131264?s=20&t=VDBSMrbUvCUswbzKJGU_fQ
[8] Steve LeVine, Twitter, Apr. 24, 2022, https://twitter.com/stevelevine/status/1518378692254310401. *See also* Steve LeVine, Just How Many EVs Can Be Made? Far Fewer Than Expected, *The Electric from The Information*, Apr. 24, 2022, https://subscriptions.theinformation.com/newsletters/the-electric/archive/just-how-many-evs-can-be-made-far-fewer-than-expected

batteries is not just coming from EVs, but also storage on the electrical grid made necessary by part-time renewable energy sources being mandated and subsidized into the system.

Not only are there projected shortages for minerals and materials used for EVs and batteries, but there is a massive project shortfall in necessary copper production as some of the world's largest copper mines have operated for more than a century. S&P Global recently released a report which found that "Unless massive new [copper] supply comes online in a timely way, the goal of net zero emissions by 2050 will be short-circuited and remain out of reach."[9] S&P Global projects that copper demand would have to double between now and 2035 to meet the goal of net zero by 2050. This is more than all the copper consumed in the world between 1900 and 2021.

The increase in demand for these minerals and materials is already putting upward pressure on prices. According to Benchmark Minerals Intelligence, from April 2021 to April 2022, the raw materials that constitute NCM (nickel, cobalt, magnesium) lithium-ion batteries have increased in price by 164 percent, and the raw materials that make-up lithium-ion phosphate batteries have increased by 393 percent.[10]

The problem is not just with minerals and materials shortages, but energy security as well. Russia's leverage over Europe due to its dependence on Russian oil and natural gas is a reminder of the importance of energy security and the folly of relying on untrustworthy trading partners.

The United States Geological Survey (USGS) has estimated that there were 50 minerals critical to the security of the United States. In 2021, imports comprised more than half of the U.S. consumption for 47 of these mineral commodities, and the U.S. was 100 percent net import reliant for 17 of them.

[9] S&P Global, *The Future of Copper: Will the looming supply gap short-circuit the energy transition?*, p. 9.
[10] Simon Moore's, https://twitter.com/sdmoores/status/1518680838057213952

Figure 2.—2021 U.S. Net Import Reliance[1]

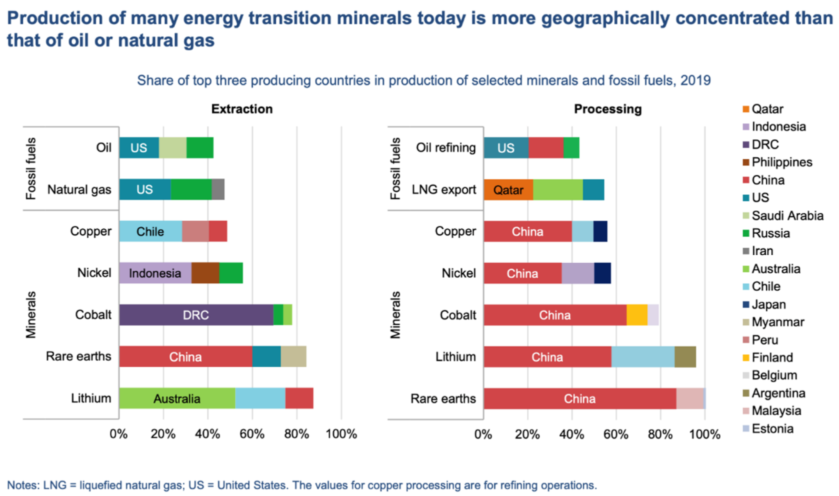
Commodity	Net import reliance as a percentage of apparent consumption	Major import sources (2017–20)[2]
ARSENIC, all forms	100	China, Morocco, Belgium
ASBESTOS	100	Brazil, Russia
CESIUM	100	Germany, China
FLUORSPAR	100	Mexico, Vietnam, South Africa, Canada
GALLIUM	100	China, United Kingdom, Germany, Ukraine
GRAPHITE (NATURAL)	100	China, Mexico, Canada, India
INDIUM	100	China, Canada, Republic of Korea, France
MANGANESE	100	Gabon, South Africa, Australia, Georgia
MICA (NATURAL), sheet	100	China, Brazil, Belgium, India
NEPHELINE SYENITE	100	Canada
NIOBIUM (COLUMBIUM)	100	Brazil, Canada
RUBIDIUM	100	Germany
SCANDIUM	100	Europe, China, Japan, Russia
STRONTIUM	100	Mexico, Germany, China
TANTALUM	100	China, Germany, Australia, Indonesia
VANADIUM	100	Canada, China, Brazil, South Africa
YTTRIUM	100	China, Republic of Korea, Japan
GEMSTONES	99	India, Israel, Belgium, South Africa
TELLURIUM	>95	Canada, Germany, China, Philippines
POTASH	93	Canada, Russia, Belarus
IRON OXIDE PIGMENTS, natural and synthetic	91	China, Germany, Brazil
RARE EARTHS,[3] compounds and metals	>90	China, Estonia, Malaysia, Japan
TITANIUM, sponge	>90	Japan, Kazakhstan, Ukraine
BISMUTH	90	China, Republic of Korea, Mexico, Belgium
TITANIUM MINERAL CONCENTRATES	90	South Africa, Australia, Madagascar, Mozambique
ANTIMONY, metal and oxide	84	China, Belgium, India
STONE (DIMENSION)	84	China, Brazil, Italy, India
CHROMIUM	80	South Africa, Kazakhstan, Russia, Mexico
PEAT	80	Canada
SILVER	79	Mexico, Canada, Chile, Poland
TIN, refined	78	Indonesia, Peru, Malaysia, Bolivia
COBALT	76	Norway, Canada, Japan, Finland
DIAMOND (INDUSTRIAL), stones	76	South Africa, India, Congo (Kinshasa), Botswana
ZINC, refined	76	Canada, Mexico, Peru, Spain
ABRASIVES, crude fused aluminum oxide	>75	China, France, Bahrain, Russia
BARITE	>75	China, India, Morocco, Mexico
BAUXITE	>75	Jamaica, Brazil, Guyana, Australia
SELENIUM	>75	Philippines, China, Mexico, Germany
RHENIUM	72	Chile, Canada, Kazakhstan, Japan
PLATINUM	70	South Africa, Germany, Switzerland, Italy
ALUMINA	58	Brazil, Australia, Jamaica, Canada
GARNET (INDUSTRIAL)	56	South Africa, China, India, Australia
MAGNESIUM COMPOUNDS	55	China, Brazil, Israel, Canada
ABRASIVES, crude silicon carbide	>50	China, Netherlands, South Africa
GERMANIUM	>50	China, Belgium, Germany, Russia
IODINE	>50	Chile, Japan
TUNGSTEN	>50	China, Bolivia, Germany, Canada
CADMIUM	<50	Australia, China, Germany, Peru
MAGNESIUM METAL	<50	Canada, Israel, Mexico
NICKEL	48	Canada, Norway, Finland, Australia
COPPER, refined	45	Chile, Canada, Mexico
ALUMINUM	44	Canada, United Arab Emirates, Russia, China
DIAMOND (INDUSTRIAL), bort, grit, dust, and powder	41	China, Ireland, Republic of Korea, Russia
LEAD, refined	38	Canada, Mexico, Republic of Korea, India
PALLADIUM	37	Russia, South Africa, Germany
FELDSPAR	32	Turkey
SILICON, metal and ferrosilicon	32	Russia, Brazil, Canada, Norway
SALT	29	Chile, Canada, Mexico, Egypt
MICA (NATURAL), scrap and flake	28	Canada, China, India
LITHIUM	>25	Argentina, Chile, China, Russia
BROMINE	<25	Israel, Jordan, China
ZIRCONIUM, ores and concentrates	<25	South Africa, Senegal, Australia, Russia
PERLITE	23	Greece, China, Mexico, Turkey
VERMICULITE	20	South Africa, Brazil

[1]Not all mineral commodities covered in this publication are listed here. Those not shown include mineral commodities for which the United States is a net exporter (boron; clays; diatomite; gold; helium; iron and steel scrap; iron ore; kyanite; molybdenum; rare earths, mineral concentrates; sand and gravel, industrial; soda ash; titanium dioxide pigment; wollastonite; zeolites; and zinc concentrates) or less than 20% net import reliant (abrasives, metallic; beryllium; cement; gypsum; iron and steel; iron and steel slag; lime; nitrogen (fixed)—ammonia; phosphate rock; pumice; sand and gravel, construction; stone, crushed; sulfur; and talc and pyrophyllite). For some mineral commodities (hafnium; mercury; quartz crystal, industrial; thallium; and thorium), not enough information is available to calculate the exact percentage of import reliance.

[2]Listed in descending order of import share.

[3]Data include lanthanides.

It's not just the U.S. As the IEA has stated, "the production of many energy transition minerals today is more geographically concentrated than that of oil or gas."[11] The *processing* of these minerals is even more concentrated.[12] China is the largest processor of copper, nickel, cobalt, lithium, and rare earths—processing between 35 percent and 85 percent of these minerals. For comparison, the newest aluminum production facility in the U.S. was built in 1980, according to CRS.[13]



Source: International Energy Agency World Energy Outlook Special Report

At the moment, the United States and the rest of the world are dependent on China to meet the growing demand for critical minerals and materials necessary for our energy. That doesn't have to be the case in the future. Over the last 15 years, the United States changed the world's energy landscape by

[11] International Energy Agency, *The Role of Critical Minerals in Clean Energy Transitions,* May 2021, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions
[12] *Ibid.*
[13] Congressional Research Service, *U.S. Aluminum Manufacturing: Industry Trends and Sustainability*, Oct. 26, 2022, https://crsreports.congress.gov/product/pdf/R/R47294#:~:text=U.S.%20primary%20smelters%20use%20older,requires%20relatively%20large%20capital%20investments.

dramatically increasing our production of oil and natural gas. In 2012, President Obama said it was "stupid" to think that the United States could lower oil prices by drilling for more oil.[14] He argued that "drill, baby, drill" was just a bumper sticker and wouldn't work—that we couldn't drill our way to energy security.

But it turns out that we could drill our way to energy security. New technologies, including some where the Department of Energy played a key role on R&D, were critical to the massive increase in oil and gas production in the United States. But there is an indispensable part of the equation of the shale revolution that is overlooked—state and private ownership of the mineral estate. The oil and gas revolution that happened in the past 15 years wouldn't have happened if all of the shale resources were on federal lands. State and private lands were critical to the shale revolution and thankfully there are substantial shale resources in Texas, North Dakota, and Pennsylvania to name a few states.

Just as "drill, baby, drill" worked for oil and natural gas production, "mine, baby, mine" can work for minerals. However, the Biden administration is working to stifle any new mining in the United States. Just to name a few examples, the Biden administration has stymied the development of the Twin Metals and Polymet mines in Minnesota, the Resolution and Rosemount mines in Arizona, and the Pebble Mine in Alaska. They have also reduced access to the Ambler Mining District in Alaska. The Biden administration has been more disposed toward lithium mines, such as Rhyolite Ridge and Thacker Pass, but actual construction has only begun at Thacker Pass.

If the Biden administration wants to achieve its net zero goals, it should be aggressively working to open more mines in the United States.

[14] President Barak Obama, *Obama: 'The American People Aren't Stupid'*, Feb. 23, 2012, speech at the University of Miami, https://www.youtube.com/watch?v=wyFX2iM-dSE&ab

MINERAL PRODUCTION COMES AT A GREAT ENVIRONMENTAL COSTS IN DEVELOPING COUNTRIES

As the publication Deutsche Welle explains:[15]

> Securing just one ton of rare earth elements produces 2,000 tons of toxic waste, and has devastated large regions of China, said Günther Hilpert, Head of the Asia Research Division of the German think tank SWP.
>
> He says companies there have adopted a process of spraying acid over the mining areas in order to separate the rare earths from other ores, and that mined areas are often abandoned after excavation.
>
> "They are no longer viable for agricultural use," Hilpert said. "Nature has been overexploited."
>
> China is not the only country with low environmental standards and poor resource governance. In Madagascar, for example, a thriving illegal gem and metal mining sector has been linked to rainforest depletion and destruction of natural lemur habitats.
>
> States like Madagascar, Rwanda and the DRC score poorly on the Environmental Performance Index, which ranks 180 countries on factors including conservation, air quality, waste management and emissions. Environmentalists are therefore particularly concerned that these countries are mining highly toxic materials like beryllium, tantalum and cobalt.
>
> But it is not only nature that suffers from the extraction of high-demand critical raw materials.

[15] Michel Penke, *DW.com*, The toxic damage from mining rare elements, Apr. 13, 2021, https://www.dw.com/en/toxic-and-radioactive-the-damage-from-mining-rare-elements/a-57148185#:~:text=Securing%20just%20one%20ton%20of%20rare%20earth%20elements,Research%20Division%20of%20the%20German%20think%20tank%20SWP.

"It is a dirty, toxic, partly radioactive industry," Hilpert said. "China, for example, has never really cared about human rights when it comes to achieving production targets."

Dirty, toxic, radioactive: Working in the mining sector

One of the most extreme examples is Baotou, a Chinese city in Inner Mongolia, where rare earth mining poisoned surrounding farms and nearby villages, causing thousands of people to leave the area.

In 2012, British newspaper The Guardian described a toxic lake created in conjunction with rare earth mining as "a murky expanse of water, in which no fish or algae can survive. The shore is coated with a black crust, so thick you can walk on it. Into this huge, 10-square-kilometer [about 4-square-mile] tailings pond nearby factories discharge water loaded with chemicals used to process the 17 most sought after minerals in the world."

THE UNITED STATES IS THE GLOBAL LEADER IN OIL AND GAS PRODUCTION AND HAS HIGH ENVIRONMENTAL QUALITY

A recent study from the Institute for Energy Research[16] found that not only is the United States the global leader in oil and gas production, but the United States does so with very high environmental standards. The study found:

- For the 20 largest oil-producing countries outside the United States, the average EPI environmental score, weighted by liquid fuels production, is 39. When compared to the U.S. EPI

[16] David Kreutzer & Paige Lambermont, The Environmental Quality Index: Environmental Quality Weighted Oil And Gas Production, Feb. 2023, https://www.instituteforenergyresearch.org/wp-content/uploads/2023/02/IER-EQI-2023.pdf.

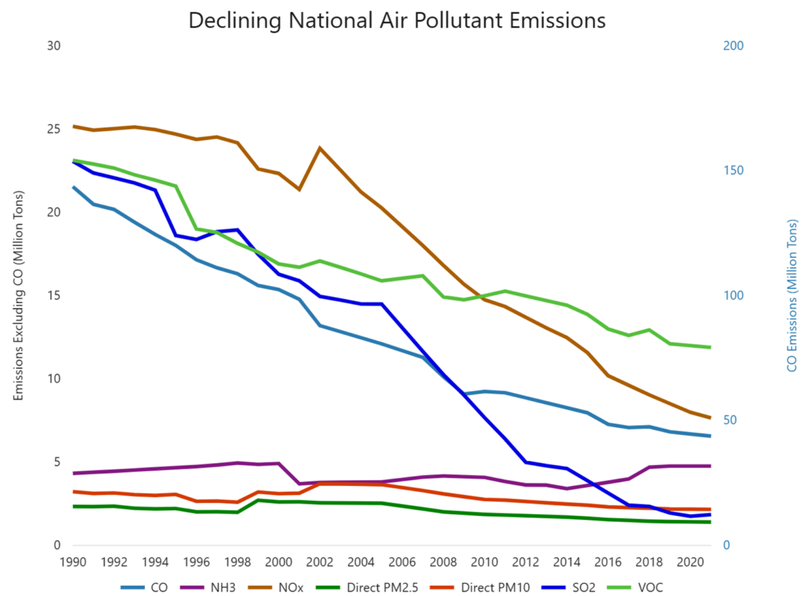
score of 51.1, it means the average barrel of non-U.S. petroleum is produced in a country with an environmental score that is 23.6% lower than that of the U.S.

- For the 20 largest non-U.S. natural gas producers, the average EPI environmental score weighted by production is only 38.6. So compared to the 51.1 EPI score of the U.S, the average bcf of natural gas is produced in a country with an environmental score that is 24.5% lower than that of the U.S.
- The United States, the world's largest producer of both oil and natural gas, is only outranked on environmental quality by 3 of the top 20 oil producers and 3 of the top gas producers. None of those countries produce even one-quarter of the volumes of oil or natural gas coming from the U.S. Indeed, all oil production from countries scoring higher on environmental quality amounts to only 35.7% of U.S. production, and that from gas-producing countries is only 33.4% of U.S. production. The sheer size of U.S. production combined with its excellent environmental standards means that U.S. production disproportionately reduces the environmental harms of oil and gas production on a global scale.
- U.S. production of crude oil and natural gas has increased over the last 40 years, while at the same time pollution and emissions have steadily and significantly declined across sources.
- Contrary to popular media characterizations, wealth created by energy development in free economies enhances environmental performance while making people's lives better.

CONCLUSION

The new energy economy the Biden administration is pushing for requires massive amounts of mineral and material resources. Much of these resources are currently produced in countries like China and the DRC, which have serious human rights and environmental problems. The United States has shown with

the shale revolution, that we can dramatically increase extractive industries and continue to improve our environment. For example, according to air quality data from EPA, pollution emissions in the United States continue to improve.[17]



The United States has vast mineral resources, but it is incredibly difficult to permit new mines in the United States today. To advance the energy economy the Biden administration is pushing for, they need to permit many, many new mines, as well as the processing facilities needed to make them useful. Our only operational rare earth mineral mine, for example, must export material to China to be processed to make it useable. In the United States, we can have high human rights standards, high environmental

[17] EPA, *Our Nation's Air: Trends through 2021*, https://gispub.epa.gov/air/trendsreport/2022/#home

standards, along with high production of mineral and energy resources. Producing energy and minerals in the United States helps build our energy security.

Mr. JOHNSON. Thank you, Mr. Simmons. And I appreciate all the witnesses for your statement. We will now begin questioning, and I recognize myself for 5 minutes.

Mr. Simmons, picking up right where you left off, does the United States currently have the critical mineral extraction and refining capacity to meet the Biden administration's climate goals on the timeline and the scale that is being proposed?

Mr. SIMMONS. The minerals are in the ground, there is no doubt about that, but there is no way to access them, especially with the Biden administration's policy towards mining.

Mr. JOHNSON. OK. So we don't. We do not have the mineral extraction and refining capacity in place right now.

So would it be accurate to say that, if we stay on the Biden administration's path, we will increasingly rely on this type of so-called artisanal mining in the Congo?

And I want to refer everyone to these posters again of the children that are forced into labor and the slave labor that is doing this work. Are we increasingly relying on this type of forced labor abuses in China and elsewhere?

Mr. SIMMONS. Yes, without a doubt.

Mr. JOHNSON. OK. Mr. Mills, you mentioned in your testimony that wind and solar have very low energy density and require 10 times more space to deliver the same amount of energy to our people as a hydrocarbon facility.

Furthermore, wind and solar are intermittent, nondispatchable energy sources that are unable to provide baseload power 24/7, since they actively depend on the wind blowing and the sun shining.

I want to go back and applaud our ranking member for pointing out the literally billions and billions of dollars of investments in these energy forms out of the Inflation Reduction Act. He called them investments. I call them irresponsible spending, because they are neither going to improve reliability and resilience of our energy grid nor are they going to improve the quality of life for the American people.

So, Mr. Mills, what would a drastic expansion of solar and wind projects mean for constituents like mine in the Midwest?

Mr. MILLS. Well, Mr. Chairman, we have the data, because a number of States have increased dramatically their use of wind and solar on grids. Germany has, other countries in Europe. And the track record there is unequivocal. The cost of residential electricity goes up, and it goes up rather dramatically. It has tripled in Germany, in Denmark and Sweden.

The overall ratio of every unit of increased wind and solar on a grid leads to an overall increase essentially 1-to-1 in a sort of percentage basis. In the United States in several service territories, we have seen a 300 percent increase in the residential cost of electricity.

Bear in mind this means that the wind and solar machines that are going on the grid are going on at a discount, because the subsidies are being paid by taxpayers elsewhere. And even with that, costs have gone up.

I will just briefly note the reason for that is operational.

Mr. JOHNSON. Right.

Mr. MILLS. When a wind turbine is blowing, the electricity is cheap, but the operational realities mean electricity gets more expensive.

Mr. JOHNSON. So, given what you just told us, does it make sense to raze millions of acres of arable farmland and Appalachian forests in favor of solar and wind farms? Would that have an adverse impact on the environment?

Mr. MILLS. Well, we used to have a very active environmental movement that was very unhappy about excess land use by civilization. So the question, to not be facetious, answers itself.

Mr. JOHNSON. Yes.

Mr. MILLS. We don't want to increase land use to deliver the same amount of energy. It is not environmentally sensible or green. We have to use land, but we should be trying to minimize land use.

Mr. JOHNSON. OK. Mr. Mills, continuing with you, global solar panel waste is projected to reach 78 million tons by 2050, with between 7.5 and 10 million tons generated in the United States alone.

Now, the last time this committee met, many of you will recall we discussed a number of politicians who vehemently opposed proper permitted disposal of roughly 40,000 tons of hazardous dirt.

I do wonder, if 40,000 tons is unacceptable, will the biggest renewables proponents commit to accept 10 million tons of hazardous, broken, retired solar panels at landfills in their congressional districts?

So it does beg the question, Mr. Mills: Does the United States have the existing landfill capacity to properly dispose of these retired solar panels?

Mr. MILLS. We have the land. It is a choice to use the land for those purposes. And I think there is a naivete about the quantity of land both for production and disposal.

The typical response, I should note, that is in everybody's head and proposed by the IEA and others is that we will recycle those materials instead of dispose of them. And it is technically possible to recycle a lot. It is extraordinarily expensive. And none of the models for future costs of wind, solar, and batteries account for real-world costs of recycling if that is mandated, which I suspect is what will happen.

Mr. JOHNSON. I yield back.

And I now yield to my colleague Mr. Tonko for his 5 minutes.

Mr. TONKO. Thank you, Mr. Chair.

Mr. Higgins, I want to make sure the record is clear about President Biden's policies in mandating a rush to clean energy. Is there a Federal policy that mandates that 100 percent or, for that matter, any percentage of our energy mix comes from wind and solar resources?

Mr. HIGGINS. No, Mr. Tonko, there is no such mandate.

Mr. TONKO. So am I correct in assuming that the recent increase in renewables has been driven by a mix of State policies, of electricity markets, and voluntary decisions being made by American businesses and consumers?

Mr. HIGGINS. That is right, including in response to the energy cost changes, that wind and solar can be much cheaper.

Mr. TONKO. And similarly, am I correct in stating that policies that seek to limit pollution from light-duty vehicles are technology

neutral? They are not mandating that 100 percent of future vehicles are electric, are they?

Mr. HIGGINS. That is correct.

Mr. TONKO. So if this is not mandated, can you explain for this subcommittee why auto makers are investing in facilities to manufacture new EVs and batteries here in the U.S., and are they responding to what they see as market and consumer trends?

Mr. HIGGINS. Yes, Representative Tonko, I think that is right. Electric vehicles are popular. Surveys have shown from Consumer Reports a 350 percent increase in consumer demand for battery electric vehicles in the last 2 years. And 70 percent of adults would consider buying or leasing an EV today, which means that there are now approximately 45 EV-ready buyers for every EV being manufactured.

And this is happening globally. And automakers know that, in order to remain competitive in the global economy, they need to make investments now to be ready to contest the investments that China has already been making and that our other allies, including Europe, are also interested in making to advance their electric vehicle industry.

Mr. TONKO. I do hear from constituents that they in many cases be on waiting lists and the like.

So in your testimony, you mentioned policy decisions made in the Inflation Reduction Act are driving workforce development and prevailing-wage jobs in clean energy.

Similarly, how are the voluntary incentives for EVs that were included in the Inflation Reduction Act intended to send a market signal to promote the domestic production of the entire EV supply chain?

Mr. HIGGINS. The investments in the Inflation Reduction Act and the Infrastructure Investment and Jobs Act work to invest across the entire supply chain for electric vehicles and batteries in particular.

Just to mention a few, there are grants, loans, and tax credits for investment in industrial capacity to extract critical minerals, to refine the critical minerals, to build battery cells, to assemble the cells into battery packs, to retool automotive facilities, to build new automotive facilities and to recycle batteries at the end of their life cycle. That is just the capacity.

The Inflation Reduction Act also has investments that support production at every one of those steps. IRA covers 10 percent of the costs of producing or processing critical minerals in the United States. IRA pays $35 per kilowatt hour for every battery cell produced in the United States. It provides $10 per kilowatt for every battery pack assembled in the United States. That alone is more than the difference in price between Chinese and U.S. battery manufacturing, according to Bloomberg New Energy Finance. It is also enough to put EVs and gas cars within price parity in the next 3 years.

On top of that, IRA will pay 30 percent of the costs of grid-scale battery deployment and an additional $3,750 for each EV built predominantly with domestic batteries and critical minerals.

So consumers across the world are interested in EVs and automakers want to build them, and IRA is making sure that at every

stage in the supply chain that every stage will have a home here in the United States.

Mr. TONKO. So, to be completely clear, many private businesses then are seeing what their consumers are going to want in the years ahead and are responding by positioning themselves to take full advantage of the available Federal incentives by investing in domestic manufacturing supply chains.

So, Mr. Chair, I appreciate that the clean energy transition will have its challenges. There are already major investments underway to reduce our dependence on volatile fossil fuel markets, lower cost for American consumers, create millions of good-paying jobs, and reduce pollution, and those investments are being led by the U.S. private sector.

So I hope we can work together on overcoming clean energy challenges in the name of U.S. global competitiveness rather than repealing incentives that are delivering hundreds of billions of jobs and job-creating investments all across our country.

With that, I thank you and yield back, Mr. Chair.

Mr. JOHNSON. The gentleman yields back.

The Chair now recognizes the chairwoman of the whole committee, Chair Rodgers, for 5 minutes for questions.

Mrs. RODGERS. Thank you, Mr. Chairman.

Mr. Mills, how green are wind, solar, and batteries when compared to traditional energy resources that power America's economy? And does China abide by the same environmental standards that we do?

Mr. MILLS. Well, Madam Chairwoman, we know that China does not abide by the same standards. And as we also know, it is relevant for the record the IEA has made a forecast of the CO_2 emissions reductions with respect to that one feature of environment that will arise under ideal conditions of fully spending all the IRA money and all the Infrastructure Act money. If all of it is spent as planned and expected, it reduces U.S. CO_2 emissions by a gigaton. For the record, China will increase its CO_2 emissions by that amount every 2 years for the next decade. So China's expansion in coal wipes out the next 10 years of U.S. CO_2 emissions reductions.

The green label, of course, is meant to refer to only carbon dioxide, as we all know. But green used to mean land use, toxic chemicals, air pollution of all kinds, and water pollution. In those metrics, there is nothing different about renewable machines, wind, solar, and battery, than any other kind of machines except they produce far more negative impacts on the environment, in aggregate, than producing the same amount of energy from hydrocarbon machines.

Mrs. RODGERS. Thank you.

Mr. Simmons, a group of us recently traveled to Europe, and we saw how similar rush-to-green policies harmed the security of European countries. Shutting down coal, nuclear, supporting a Nord Stream 2 Pipeline from Russia for their oil and natural gas, and then Russia weaponized that energy against them.

I don't want to see that happen in America, and I am concerned that the current approach by the Biden administration will, in their rush to green, strengthen China and weaken America's energy security.

As the former Assistant Secretary for DOE's Office of Energy Efficiency and Renewable Energy, you have firsthand experience with the deployment of renewables and batteries for electric vehicles and the electric grid.

What are you most concerned about with the Biden administration's timelines and targets to electrify and decarbon the economy? Do you believe that the administration has adequate framework to balance the environmental, human rights, and national security risk of climate-related policies?

Mr. SIMMONS. I am not aware that they have a framework that balances that. I mean, if you look at the statements from, say, Climate Envoy Kerry, I haven't seen any balancing that the administration has focused on.

To Ranking Member Tonko's point are these mandates, and generally they are not mandates technically, but they are de facto mandates when it comes to mandating massive amounts of EVs, because that is the only way you can meet the—it is the only way you can meet EPA's upcoming GHG regulations for vehicles.

And the problem is, is that those raw materials are currently dependent on Chinese supply chains, and not just like—we are not really talking about necessarily battery packs. We are talking about the lithium, the cobalt, the nickel, everything that goes into the battery packs. Those are all dependent on Chinese supply chain, and that will not change for years, no matter how many dollars are in the IRA. So I have serious concerns, because I don't see a real framework from the administration looking at all these issues.

Mrs. RODGERS. Thank you.

Mr. Nunes, I have heard from some car companies that the amount of raw materials in a large, fully electric car battery could be used to produce dozens of hybrid cars. If that is true, wouldn't hybrids reduce the battery supply chain's risk that all electric cars are subject to?

Dr. NUNES. Congresswoman, if you look at the total amount of minerals that are used in an electric vehicle battery pack, they are orders of magnitude above the volume of minerals you would need in a hybrid electric vehicle battery pack.

So the simple answer to your question is yes, you would be able to build out multiple hybrid electric vehicle batteries from a single EV battery.

Mrs. RODGERS. So wouldn't a hybrid vehicle be a better way to save money and reduce overall emissions?

Dr. NUNES. I think if you look at the numbers, a hybrid electric vehicle typically costs about 12 percent more than an internal combustion engine and emits about 25 percent less carbon dioxide. An EV typically costs you between 40 to 50 percent more than an internal combustion engine and is about 40 percent less polluting.

In terms of your dollar value, hybrid electric vehicles offer you the most bang for your buck when it comes to emissions reductions.

Mrs. RODGERS. So why isn't the administration encouraging hybrid?

Dr. NUNES. I am not authorized to speak on behalf of the administration.

Mrs. RODGERS. OK. I just thought I would ask. Anyone else?

Anyway, I will yield back. Thank you, Mr. Chairman.

Mr. JOYCE [presiding]. The gentlelady yields back. We now recognize the ranking member of the entire committee, Mr. Pallone from New Jersey.

Mr. PALLONE. Thank you, Mr. Chairman.

Later today, the House is expected to vote on the Default on America Act, which repeals a number of significant investments in our domestic clean energy industry enacted by the Inflation Reduction Act.

In the energy and environment space, this bill seeks to repeal programs designed to lower energy costs for American consumers with still tremendous homegrown clean energy job growth and would block critical investments in domestic manufacturing designed to onshore clean energy production. In my opinion, these misguided proposals play right into China's hands.

So, Mr. Higgins, I hope you can help Members understand each of these major deficiencies with the Default on America Act. First, would repealing the Inflation Reduction Act programs, like rebates for home efficiency upgrades or incentives for solar, wind, or zero-emission transportation technologies, lower energy costs for American families?

Mr. HIGGINS. No, Mr. Chairman. They would raise energy costs for American families.

Mr. PALLONE. Thank you for calling me Chairman, but I am the ranking member. But anyway, that is what I thought you would say.

So Republicans are claiming their proposals will reduce energy costs while voting to repeal critical energy cost-saving provisions that are already in law. That doesn't make sense to me.

So, again, Mr. Higgins, can you please speak to how the Inflation Reduction Act will strengthen domestic manufacturing of clean energy technology?

Mr. HIGGINS. Absolutely. So, as I mentioned in my last answer, there are investments up and down the battery supply chain, but the same is true in other parts of the supply chain for the clean energy economy.

There are incentives and requirements for any company who is taking the clean electricity tax credits to have increasing proportion of domestic content, including their steel, the manufactured components that go into the wind turbines. At the same time as we are creating that pool for new products, IRA is investing in new manufacturing capacity and retooling existing capacity and in specifically targeting investments to energy communities that need the jobs.

Mr. PALLONE. I agree that these policies in the Inflation Reduction Act directly lead to incredible benefits on the ground for Americans across the country, and, of course, these investments help keep us competitive on the global stage since China and other countries are already building the clean energy future. And, in fact, this was our intent with the bill, to try to, you know, make us more competitive with China.

But let me ask you this. Since the Inflation Reduction Act was enacted, there have been historic announcements in the clean en-

ergy sector, including more than 142,000 clean energy jobs, and it is projected to create 9 million in total.

And I have a report here by the Climate Power on IRA investments and jobs in districts all over the country, including many Republican districts.

So I would ask the chairman, I would ask unanimous consent to enter this into the record, if I could.

Mr. JOYCE. Yes, thank you.

[The information appears at the conclusion of the hearing.]

Mr. PALLONE. All right. Now, many of the jobs that we have mentioned in the Inflation Reduction Act come from incentives to onshore and reshore domestic manufacturing in the energy space.

So, Mr. Higgins, can you speak to the benefits of onshoring this work and how these benefits will result in more jobs and clean energy access, particularly in energy communities?

Mr. HIGGINS. One of the interesting features of the tax credits, including in the Inflation Reduction Act, is a 10 percent bonus credit for investments that happen in energy communities. And the definition of that includes anyplace with a brownfield site. It includes coal communities that have high unemployment. It includes any community that has a disproportionate amount of its employment coming from fossil fuels.

And these communities often see ups and downs in their employment, because fossil fuel markets, particularly with the fracking boom, can be volatile or unreliable. And so, by targeting investments in new clean energy construction and manufacturing in these parts of the country, we are going to be providing a pathway to a decade-long commitment to these communities' economic success.

And this is creating an opportunity for the United States to compete in the global clean energy economy of the 21st century. China has for decades understood really what we all understood, which is which technologies are going to be important in the clean energy economy. But, unlike us, they started investing in those decades ago. So we are playing catchup now to make sure that we can have the competitive American industry that we need for the next century.

Mr. PALLONE. Well, I think you just made the case why we should completely reject Republicans' rollbacks of the Inflation Reduction Act, but thank you so much.

I yield back, Mr. Chairman.

Mr. JOYCE. The gentleman yields.

The gentleman from Alabama, Mr. Palmer, is recognized.

Mr. PALMER. Thank you, Mr. Chairman.

I just want to make a point that apparently my colleagues across the aisle don't get. China's objective is not to save the planet from climate change. China's objective is to rule the planet as the sole superpower. And anyone who does not understand that I think contributes to the national security risk that we are facing with China.

Mr. Mills, is clean energy clean?

Mr. MILLS. By the definition of what we used to think broadly in environmental domains, no, the answer is no. It is no cleaner than, at best, any other form of energy.

Mr. PALMER. It potentially would be an environmental disaster, because of the mining requirement, refining requirement, by the way, which we don't do here. We have become 100 percent reliant on China for all of that. There is not a single smelter for rare earth elements in the Western Hemisphere that I know of. I think they are all in China except maybe one.

Mr. MILLS. Ninety percent of rare earth refining is in China. If you mine rare earths in America, you send them currently—and some are mined here—to China.

You know, it is worth pointing out for the record that the environmental impacts of energy are, of course, universal, right? I mean, we can't avoid that. These are machine issues.

But China has a dominance that was, as we know, planned for two decades publicly, but they don't dominate what the world uses for energy. Back to the 84 percent of all energy is hydrocarbon-based.

And the world spent 5 to 10 trillion dollars in the last 2 decades avoiding hydrocarbons, and we still only get 3 percent of all of our energy globally from wind and solar.

Mr. PALMER. I want to ask you another quick question, and I am not sure you know the answer to this. But approximately, it takes an enormous amount of cement and steel and plastic to build a wind turbine. It takes an enormous amount to build solar panels.

Are you aware that 50 percent of the world's steel production is from China, over 60 percent of the cement, over 30 percent of the plastics? And we have just been talking about rare earth elements. We are not even talking about the stuff that we don't do here. And you can't produce any of that without natural gas.

Mr. MILLS. You would need to use natural gas, coal, and oil to produce all those materials.

Mr. PALMER. So would you agree that this mad dash to eliminate all hydrocarbons, particularly natural gas, first of all, is, from a physics and engineering perspective, impossible but, just from a rational sense, insane?

Mr. MILLS. Well, it is actually physically impossible to do it to the scales and timeframes that are being imagined. And we have that from the IEA itself, which is pointing out that there is no path to eliminating use of oil, gas, and coal in minerals production and processing known for decades.

Mr. PALMER. Well, they also point out that, under no scenario, we will be at net zero by 2050.

Mr. MILLS. That is correct, sir. And Bill Gates testified in a public speech that, even if we did achieve net zero, it wouldn't change the climate modeling scenarios by a tiny fraction of a percent

Mr. PALMER. Yes. I want to talk about the other issues with renewables. And I am not against renewables. I just understand that we are not going to have a sustainable economy with the growth that we need for a country and the ability to help other economies, emerging economies grow with 100 percent renewables. It is not possible.

But I also point out that we need to be focused on next-gen nuclear, because we had a very good hearing last week, and I think we made some really good points.

But one of the problems with renewables, particularly in this case turbines, is their life cycle is only about 25 years, and you can't recycle the blades. And we have got some photos here of landfills in Wyoming and Texas where we are having to bury these things because we can't recycle them.

Would you consider that an environmental problem?

Mr. MILLS. I think massive waste production that you can't recycle is, by definition, an environmental problem. In theory, you could eventually recycle them, but that theory is still in the experimental stage. So right now, they are just trash.

Mr. PALMER. And enormously expensive. And we have a debt crisis that is an existential threat to our national security as well as the emergence of China as a superpower.

I also want to address this other issue of pollution over people and just remind my colleagues that my kids and, hopefully, my future grandkids breathe the same air that everybody else does. We drink the same water. We live on the same ground. And it is so disingenuous to use that kind of phraseology to further divide people. And, hopefully, people have enough common sense to realize that we all live on the same area. We are breathing the same air, drinking the same water.

And this idea that it somehow contributes or causes asthma, I just remind you that even the CDC says we don't know what causes asthma. And there are other things, most likely related to the economic conditions of individuals who are suffering from asthma, particularly kids, because of low household income, poor housing, things like that, that we can solve with a vibrant economy if we can get our debt crisis, our capital crisis that has now been created because of the debt, under control.

With that, Mr. Chairman, I yield back.

Mr. JOYCE. The gentleman yields.

The Chair now recognizes the gentlelady from Colorado, Ms. DeGette.

Ms. DEGETTE. Thank you so much, Mr. Chairman.

I would respectfully say to my colleague across the aisle, maybe your constituents don't live downwind from a refinery in an economically depressed neighborhood, like my kids do, and have a much higher percentage of asthma.

I would like to ask you some questions, Mr. Higgins, about some of these policies that we are talking about today. Because there seems to be this implication that we are having this coercive rush-to-green policies, but, in fact, what we are trying to do in the face of the climate crisis is play catchup for decades of inaction, denial, and lack of coordination.

And all of the experts that I have seen say that we have to slash our emissions and transition to clean energy as soon as possible. It is existential.

So what I want to ask you is, if we just drift along and don't do anything, are we going to have a further degradation of our environment?

Mr. HIGGINS. Yes, Congresswoman. Climate investments from IRA and IIJA are essential for giving us an opportunity to stabilize climate change.

Ms. DEGETTE. And do you think that—do the experts that you have reviewed, do they say that if we start to take aggressive steps that we are going to be able to at least begin to bend the curve on these extreme weather events and declined economic productivity that impact health?

Mr. HIGGINS. Yes, the science is very clear that every increment of emissions reduction is going to reduce the peak warming and the date at which we can achieve stable global temperatures.

Ms. DEGETTE. And what about the impact on developing countries? If we are able to have a clear progress, are we going to be able to have impact in the developing world?

Mr. HIGGINS. Yes. The developing world and poor parts of even the developed world are more exposed to the impacts of climate change. And they would be the first to benefit then from emissions reductions technologies that start to slow the pace of climate change and give us more time to adapt.

Ms. DEGETTE. Do we actually have—you heard some of your colleagues on the panel say that we can't possibly have any impact by 2050 and so why do it. Do you agree with that?

Mr. HIGGINS. No, I believe that is a false statement.

Ms. DEGETTE. Why do you believe that?

Mr. HIGGINS. Well, the International Panel on Climate Change jut put out their recent Synthesis Report, which builds on decades of science. And they were very clear that this problem of climate change is caused by primarily fossil fuel combustion, and it can be resolved by human action.

Ms. DEGETTE. Now, do we have the technology right now to get to zero percent carbon by 2050?

Mr. HIGGINS. We have the technology right now to substantially cut and to reach net-zero-greenhouse gasses by 2050. And it is important to note that the Inflation Reduction Act investments are not exclusively in any one technology. There are investments in nuclear, biofuels, carbon capture and sequestration in addition to wind and solar.

Ms. DEGETTE. Right. We are not mandating that we get to zero percent with wind and solar. Is that right?

Mr. HIGGINS. That is absolutely correct.

Ms. DEGETTE. It is source neutral.

Mr. HIGGINS. That is right.

Ms. DEGETTE. And that is what we are going to need to do to get to zero percent by 2050.

Mr. HIGGINS. That is right. In fact, the new tax credits changed the paradigm for the way our fiscal subsidies are produced so that they are not technology specific. By 2025, the Federal Tax Code will reward any technology that can be zero emission.

Ms. DEGETTE. And again, I want to ask, so if we are able to do that, to get to close to or at zero by 2050, the scientists believe that is actually going to have an impact?

Mr. HIGGINS. Yes. That would be—it would put us likely within range to constrain global warming to 1.5 degrees with limited overshoot, which is very important. And if we cannot reach net zero by mid-century, it is unlikely that we will be able to contain the pace of climate change this century.

Ms. DEGETTE. Now, I keep hearing my colleagues on the other side of the aisle talk about critical minerals. Frankly, we are all concerned about the human rights issues. So what do we need to do to try to get independent of some of those, the production in some of those countries?

Mr. HIGGINS. As many have already testified, China today refines the majority of the critical mineral supply in the world. It is their operations that are the principal driver for critical minerals mines throughout the world, including those with abhorrent labor abuses. And——

Ms. DEGETTE. So what do we need to do? I have got 10 seconds.

Mr. HIGGINS. The Inflation Reduction Act invests in creating an American supply chain and processing capacity. And we will be able to better leverage, with our democratic allies, a regime that we can control and enforce better human rights.

Ms. DEGETTE. Countries like Australia, right?

Mr. HIGGINS. Correct.

Ms. DEGETTE. Thank you. I yield back.

Mr. JOHNSON [presiding]. The gentlewoman yields back.

The Chair now recognizes Dr. Joyce from Pennsylvania for 5 minutes.

Mr. JOYCE. First, I want to thank Chairman Johnson and Ranking Member Tonko for holding today's hearing. Over the past few years, we have heard from the Biden administration preaching about the wonders of renewables. But, unfortunately, the rush to adopt green technology from wind and solar to electric vehicles and electric stoves has significant drawbacks for my constituents and hardworking families across the United States.

Our Nation has led the world in emission reduction, not because we have transitioned our energy generation to wind and solar but because we created new ways to harness the resources, the resources that are under the feet of my constituents.

Natural gas production from places like Pennsylvania has reclaimed American energy dominance while cutting our greenhouse emissions by 17 percent from 2005 to 2021, according to the EPA.

We cannot let Government policies, written with a misunderstanding of the real world, abandon the hard-earned advantages that our Nation has and directly will harm our constituents.

One example is the Department of Energy's proposed efficiency standards for distribution transformers. Utilities and electric co-ops in my district in Pennsylvania are already experiencing a critical shortage of grid components. To make matters worse, DOE's role would upend a fully domestic supply chain for the main steel component in distribution transformers to achieve an efficiency increase of just 0.29 percent, less than 1 percent. This rule would leave us reliant on foreign imports, create an even more acute supply crisis for critical grid components, and sacrifice family-sustaining jobs in Pennsylvania.

Another example of poorly conceived Government policy is the Biden administration's push for electric vehicle adoption. In my district, EVs simply cannot fulfill the needs of my constituents. They can't tow the distances that they are needed to tow. They can't maintain the charge at extreme temperatures or recharge fast enough to keep hardworking Pennsylvanians on the job.

That is why I introduced H.R. 1435, the Preserving Choice in Vehicle Purchases Act, to prevent the EPA Administrator from granting a waiver allowing California's ban on internal combustion engine sales by 2035. Although starting in California, once adopted, this regulation will spread across the Nation, disrupting the entire American auto market and ultimately limit what my constituents are able to buy.

President Biden has made it clear that he wants to force Americans to buy electric vehicles. This policy will harm working- and middle-class families by making cars more expensive and less capable. Only by taking Government's thumb off of the scale and letting the free market decide will Americans get the efficient and affordable transportation that they need and that they want.

My first question is for you, Dr. Nunes: The International Energy Administration projects that EV adoption at 15 percent by 2030, but President Biden is trying to mandate 67 percent adoption by 2032. Is it realistic to expect a 53 percent increase in this rate between 2030 and 2032, just in 2 years?

Dr. NUNES. My sense is that it would be challenging, to say the least. I also think it is important to distinguish between EV sales versus a total number of—you know, there is a lot of focus on how many EVs we are actually selling versus looking at what the propulsion profile is of the national fleet.

If you look at markets like Norway—which is something we hear quite a lot about—Norway sells a lot of electric cars. At the same time that you see increases in the number of electric cars, you are also seeing an increase in the total number of cars on the road, and that is not a good thing.

What that suggests is that the majority of people are buying electric cars as second or third vehicles. They are not trading in their gasoline-powered vehicles.

Mr. JOYCE. But isn't that economically challenging for the middle- and the working-class Americans to be able to afford a second or third vehicle? Is that even plausible?

Dr. NUNES. Well, I think if you look at the distribution of who actually owns electric cars, they are skewed towards high-income earners.

Mr. JOYCE. And that skew is very concerning for someone who represents working-class people throughout Pennsylvania.

Are Americans, particularly families, ready to give up their primary, their workhorse car with an internal combustion engine for an EV? Those who can only afford one EV, one vehicle, are they going to turn that over?

Dr. NUNES. I think that in order for an electric vehicle to become the de facto choice for middle- and low-income Americans, these vehicles would need to boost significantly larger range and interior space requirements.

Mr. JOYCE. Which they don't have right now. And in your earlier testimony, you said they cost between 40 and 50 percent more. These aren't costs that my constituents can afford right know.

Dr. Nunes, since 2005, auto sales have fluctuated. Do you feel that the current regulatory environment is going to be able to produce the EVs that are necessary?

Dr. NUNES. I think that, while there is, you know, considerable reason for optimism when it comes to producing vehicles, there would be significant challenges associated with meeting the EPA's de facto emission standards.

Mr. JOYCE. I think this committee recognizes those challenges. My time has expired. I thank you for the candid conversation.

And, Mr. Chairman, I yield.

Mr. JOHNSON. The gentleman's time has expired.

The Chair now recognizes the gentlewoman Ms. Schakowsky for 5 minutes.

Ms. SCHAKOWSKY. Thank you, Mr. Chairman.

So today we are likely to see a vote on what Democrats are calling the Default on America Act, which, among other things, I would say, despite my colleagues' objection to that, that puts politics over people, which has really been the tradition in the United States, that people who breathe air in certain communities are much more likely to get sick, and those more polluting places are often put into low-income communities.

And one of the things that this legislation would do is to eliminate the Inflation Reduction Act, which does actually have in it the High Efficiency Electric Home Rebate Grant Program. And I wanted to talk to you about that, Mr. Higgins.

What would be the consequence, then, if that program would be eliminated, both to private-sector investors and, of course, to everyday consumers who have seen or will see a decrease in their energy costs?

Mr. HIGGINS. Thank you, Representative. Yes, the Home Electrification Rebates Program is I think going to be an excellent program that offers low-income households up to 100 percent of the costs of replacing their fossil fuel furnace or gas stove, if they choose, with a high-efficiency electric alternative. And that is one of the many ways that we can make sure we are reaching every household.

The bill also includes tax credits for heat pumps for higher-income households. It includes training for contractors. It includes manufacturing support for companies to produce the heat pumps. And this way we are approaching the problem of how do you improve indoor air quality and reduce the fossil fuel demand of the housing sector by addressing all of the elements of the supply chain and the consumer experience.

Ms. SCHAKOWSKY. Thank you for that. The IRA also includes tax credits to encourage workforce development, apprenticeship programs and other things to expand the workforce.

I would also note that right now 650,000 unfilled jobs are out there right now. And so what can we do to make sure that we expand the workforce, helping workers and certainly helping us address the climate?

Mr. HIGGINS. Thank you. Yes, the Inflation Reduction Act is both driving gains in job growth in clean energy industries but also improving job quality by, as you mentioned, tying incentives across eight different tax credits to prevailing wage requirements and apprenticeship requirements. And this will support the quality of the job as well as train the workers that we need.

There is also a new advisory board in the Infrastructure Investment and Jobs Act that is meant to identify places where there are skills gaps. And that could be an area for Congress to focus on over the next decade and making sure that we will have the highly skilled technical labor that we need to build the clean energy economy.

Ms. SCHAKOWSKY. Can you talk a little bit more about training programs? We know that there are a lot of people who need to work. There is the need for the workers. What are we going to do to train the workers to be there?

Mr. HIGGINS. One of the interesting aspects of the Inflation Reduction Act is that it includes funding for disadvantaged communities specifically to make sure that they have training opportunities for taking advantage of the investments that will be happening in their communities.

So through the equitable and—Climate Justice Block Grants program as well as through Greenhouse Gas Reduction Fund, there can be opportunities to support training directly.

I also think that there's room for more intervention of Congress personally. There were proposals in earlier processes, including the House-passed version of Build Back Better, that didn't ultimately be enacted. I think these types of investments and other interventions would be a very helpful way to make sure that we are developing the workforce that we need to remain competitive.

Ms. SCHAKOWSKY. Thank you so much. I yield back.

Mr. JOHNSON. The gentlelady yields back.

The Chair now recognizes Mr. Allen for 5 minutes.

Mr. ALLEN. Thank you, Mr. Chairman.

And, you know, I don't know where asthma comes from. I happened to be born with it, so—but I have dealt with it for a long, long time.

And yes, this important hearing, you know, the thing that we are not doing is nobody has given me a number of what it is going to cost to meet all these goals. In other words, how much are the American people going to have to sacrifice?

Now, we lead the world in reduction of carbon emissions, there is no question about that, and overwhelmingly lead the world. We have spent a lot of treasure to the extent with $31.5 trillion and growing every second debt in this country.

The markets are very volatile right now, the financial markets, because of this Government spending and because of this debt. In fact, you are seeing chairmen of major financial institutions in this country say that, if you don't get your fiscal house in order, that is the greatest existential threat to this country, because if we become a Third World country, yes, we might be clean but, you know, we won't be the country we are. And debt will do that.

You know, the potential threats to our national security we have talked about with these new policies are not fully understood, and I hope that today we can learn more about them.

Right now there is a push towards transitioning our energy to be dependent solely on renewables. And, of course, personally I am from an all-in approach. We need to be energy dominant again.

The reality is that many of these favored technologies require critical materials that we are relying on from other countries, pre-

dominantly China and others whose mining industries are largely controlled by the CCP. We should not be dependent on our adversaries for these critical materials.

If we are going to dramatically increase deployment of green technologies and electric vehicles, we must look at domestic remedies. I have not heard one remedy here today to do that. Nothing is being done to that. We can't get permits to mine today.

Mr. Mills, you noted that the United States is 100 percent reliant on imports of 17 critical minerals and heavily dependent on other countries for 28 of the 50 critical minerals identified by the United States Geological Survey. China specifically is the top producer for most of those critical materials.

What are the national security risks associated with relying almost entirely on critical mineral inputs from other countries, predominantly China?

Mr. MILLS. Well, Congressman, as you well know, the dependence on other countries for things that are critical is a geopolitical risk by definition. With all due respect to the Congress of the United States, we are now fully 70 years, 70 years into hearings about critical mineral dependencies. It began shortly after World War I, ironically, escalated after World War II, and for the last 20 years or 30 years, in my experience with the Congress, there have been dozens of studies and reports, hearings, legislations dedicated to solving the critical mineral problems.

It is only solved one way. It is environmental regulations have to be modified to encourage mining and refining of minerals. That has never been done yet. We have done the opposite. We have increased our strategic dependencies.

So as you say, sir, we get 100 percent of 17 critical minerals through imports. Another 20 we import about 50 to 80 percent of what our needs are, and we will increase those needs by orders of magnitude with these plans to build assembly plants here, not mines.

Mr. ALLEN. Right. And, Mr. Simmons, what can we do to ensure that we are not relying on China for critical mineral inputs?

Mr. SIMMONS. Well, what that means is a massive increase in the amount of mining in the United States. That means that new mines actually get permitted. There is one new mine, to my knowledge, which is Thacker Pass in Nevada, that is a lithium mine. The Biden administration deserves credit—let's give them kudos—that that is now moving forward. That is fantastic, but we need much, much more. We need 42 times—the world needs 42 times as much lithium as we are currently producing today. That is going to come from a lot of different places.

Mr. ALLEN. And are we getting significant price fluctuations as well as far as trying to move in this direction?

Mr. SIMMONS. There is—I mean, we have had all kinds of price fluctuations, but overall we have seen price increases, a lot of energy inflation over the past few years, and that is only going to get worse unless we have more production.

Mr. ALLEN. Yes. And, of course, the war on fossil fuel has created tremendous input costs to every business, which is affecting our ability to grow our economy.

Thank you so much.

And I yield back.

Mr. JOHNSON. The gentleman yields back.

The Chair now recognizes my friend and colleague Mr. Ruiz for his 5 minutes of questions.

Mr. RUIZ. Thank you.

As I pull up my questions here, I want to give a very special shout-out to constituents, school board members from Imperial Valley in Eastern Riverside County for being here.

Mr. JOHNSON. Mr. Ruiz, turn your microphone around.

There you go.

Mr. RUIZ. And I want to thank you, Mr. Chairman, for holding this hearing.

My district, California's 25th District, produces the most renewable energy on Federal land in the Nation. And I also must say that climate change is real. Pollution is real. And it affects the underserved, marginalized, underresourced communities more than it does the others.

And there are challenges to shifting to a clean energy future, but I see them as opportunities, opportunities to expand the positive impacts of clean energy. I see them as opportunities that recent legislation has provided to help us overcome these challenges with solutions.

As it has been mentioned by me in numerous committee hearings, litium batteries are a critical component of electric vehicles. But they are also an obvious solution to securing our clean energy future, while also providing the grid reliability that we need. Unlocking the potential that lithium batteries have to offer in a safe and responsible way will have an enormous impact on our national security, economy, and energy independence.

In my district, the Salton Sea region in the Imperial Valley, we have a massive supply of raw materials that can power our clean energy future. The Salton Sea area has the fifth largest deposit of lithium in the world, and it has the potential to supply the lithium needed not only for electric vehicles but also the batteries that can make our electric grids resilient.

We speak about supply chains. Extracting lithium, producing batteries that benefit the people in the district is a good supply chain. Taking the time to invest in responsible methods of extracting lithium is critical to the well-being of our local communities.

Mr. Higgins, could you speak to why investing in high environmental standards for domestic mining or extraction is necessary to ensure the safety of our communities and how it will strengthen our supply chains in the long term?

Mr. HIGGINS. Absolutely. Thank you, Representative Ruiz.

The Inflation Reduction Act makes the process of finding mining opportunities that actually win support of local communities easier, in my opinion, by supporting 10 percent of the costs of extracting lithium, by providing a billion dollars for properly staffing the Federal Government to conduct environmental reviews. And the Salton Sea, in particular, is of interest because it potentially provides opportunities to resolve multiple problems at once, including the toxic dust that is coming off of the Salton Sea. And the trick will be, as you have articulated, doing this in a way that actually benefits the communities.

And approaching this in a thoughtful way that wins the support of local communities that considers the water impacts and evaluates all of the issues is really the only path forward to making sure that the critical mineral extraction here in the United States is different from the critical mineral extraction we have heard concerns about across the world.

We are proud of our labor standards. We are proud of our environmental standards. We can address these challenges all at the same time.

Mr. RUIZ. Thank you.

Indeed the Inflation Reduction Act passed into law last year is a critical first step in the shift towards clean energy, and we are already beginning to see those investments produce results in the form of jobs and health benefits. Hundreds of thousands of well-paying, long-term clean energy jobs have already been created.

In my district the Crimson Energy Storage in Blythe is currently the second largest energy storage project in the world, constructed by union labor, including the International Brotherhood of Electrical Workers, IBEW, powering vital medical equipment, electric vehicles, and so much more.

Additionally, studies have shown the Inflation Reduction Act is not only good for our constituents' wallets but also good for their health.

So, Mr. Higgins, can you elaborate on the health benefits specifically for low-income communities and communities of color as a result of the Inflation Reduction Act?

Mr. HIGGINS. Now, harmful air pollution is disproportionately concentrated in Black and Brown communities. Of the 13 million people of color who live in areas with failing grades for ozone and particulate pollution, over 9 million are Hispanic in this country. There are more than 1.8 million Latinos who live just within a half a mile of high-emitting industrial facilities and oil refineries.

So the burdens of the fossil fuel economy are not evenly distributed across our country.

Mr. RUIZ. It won't. They are not. And, in fact, the medical literature and recent research shows that individuals living near high-polluted or in high-polluted cities and areas live on average 10 years less than if you lived in an area that didn't suffer from high pollution.

And as an emergency physician, I can say there are countries faced with a climate crisis that is affecting the well-being of our constituents, and we must offer solutions, not just continuing to give them the same outdated medicine that is doing more harm than good. We need to put people above politics and take care of people.

Thank you.

Mr. JOHNSON. The gentleman yields back.

The Chair now recognizes the gentleman from Ohio, Mr. Balderson, for 5 minutes.

Mr. BALDERSON. Thank you, Chairman Johnson. I appreciate your time.

Thank you, panel, for being here today.

Mr. Simmons, in your testimony you emphasize that the sheer size of U.S. oil and natural gas production, combined with its excel-

lent environmental standards, means that U.S. production disproportionately reduces the environmental harms of oil and gas production on a global scale.

The Biden administration has taken multiple actions to curtail oil and gas production in the United States and instead expand renewable energy projects such as solar and wind. If the United States were to transition entirely to renewable energy sources, what would be the impact on global emissions?

Mr. SIMMONS. I don't think I can do that calculation in my head. That would be—that would be difficult.

The question is, you know, the United States has a very good environmental track record. We have dramatically increased our oil and gas production and continue to improve the environment, lower overall criteria air pollutants, as well as lower carbon dioxide emissions. We have seen that with higher production.

So when that gets shifted overseas, it means higher emissions overseas of pollution even though there would be less, you know, production of oil and natural gas here in the United States.

Mr. BALDERSON. OK. Followup for you then. Currently electric vehicles account for just 1 percent of the 250 million vehicles, SUVs, and light-duty trucks on the road in America.

In addition to the major concerns we have outlined with sourcing the critical minerals needed to produce these vehicles, I want to discuss the national security risk associated with the strain that will be placed on the electrical grid.

A recent PGM report found their service area, which includes my district, is facing an increase where the pace of retirement to the closure of generation resources could well outpace the replacement of that generation with new renewable sources. The report notes this could force the PGM region to fall below the level of reserves needed to maintain reliability by 2030.

Do you have concerns with the increased demand on the electrical grid if the EPA's vehicle emission standards proposal which would force electric vehicles to account for 67 percent of new light-duty vehicle sales by 2032 were to go into effect?

Mr. SIMMONS. Certainly. You know, when I was at the Department of Energy, we had this conversation, and I talked with the staff and asked them, OK, like with this dramatic increase, with a dramatic increase in EV, what happens to the grid? And the answer was, well, we have built that much capacity, we have built that much of the grid before, we can do it again, which is certainly true.

But that was certainly true in a regulatory environment of the Seventies, of the Eighties, not necessarily in today's regulatory environment where the Biden administration just signed off on TransWest Express, a long-distance transmission line.

It took 15 years, 15 years to permit that. That is ridiculous by any standard, and it also means that there is just no way that the grid can handle that kind of increase.

Mr. BALDERSON. Well, you have kind of touched on it a little bit, but the national security risk of losing the greater reliability also.

Mr. SIMMONS. Oh, certainly, certainly. I mean, any—one of the reasons that we have strong national security is because we have a strong energy economy. We have incredibly reliable energy here

in the United States. When that goes down, that harms the economy, harms the national security.

Mr. BALDERSON. Amen.

Mr. Chairman, I yield back my remaining time to you.

Mr. JOHNSON. Will the gentleman yield?

Mr. BALDERSON. Yes, sir.

Mr. JOHNSON. I thank the gentleman for yielding.

Mr. Mills, I want to go back to you to wrap up a couple of questions that I didn't get to earlier.

You had mentioned in your testimony when you consider all of the talk of society reusing and recycling. Can you explain how low-energy dense renewables and electrification of the economy could increase the material in landfills?

Mr. MILLS. Well, Mr. Chairman, it distills to a simple physics fact. The low density of wind and sun, the amount of energy you get per square mile per machine, translates into roughly a tenfold increase in land use but, more critically, a threefold increase in machine use and then roughly a 10- to 50-fold increase in——

Mr. JOHNSON. So there is a lot of that material?

Mr. MILLS. A lot of material. And, eventually, it is recyclable in principle, but as the IEA has pointed out, the build-out phase for the next 20 years of the proposed energy transition will not produce materials available for recycling because they are not worn out yet.

So we are going to have to have a massive expansion in global mining. The mining is not going to happen here. Our standards have driven the mines into Africa, into Asia, into South America.

And I just want to make a point for the record. I too care about the poor neighborhoods. What we are doing is exporting our pollution that we caused by our mandates in spending to other nations where people are affirmatively poorer and are less able to defend themselves from the predations of the kinds of mining that is done predominantly by Chinese-owned firms.

Mr. JOHNSON. Got you.

Assuming these levels of increased waste will grow exponentially, do you envision permitting new landfill capacity for this kind of waste to be any easier or quicker?

Mr. MILLS. Well, this is another category where we know the question——

Mr. JOHNSON. Kind of a rhetorical question because that is one we have to answer, right?

Mr. MILLS. Congress and the States. Regulatory reform has not come to general environmental domains, which will dictate both construction mining, manufacturing permitting, refining, and waste disposal.

Mr. JOHNSON. Got you.

OK. I yield back to Mr. Balderson, and Balderson yields back.

I now recognize the gentlelady, my colleague Ms. Barragán from California, for 5 minutes.

I am sorry. Mr. Sarbanes, I did not see you down there. I apologize.

I recognize Mr. Sarbanes for 5 minutes.

Mr. SARBANES. Thanks very much. Sorry about that.

Mr. JOHNSON. You were stealthy.

Mr. SARBANES. I was stealthy.

So I have to say I am a little bewildered by why some of my colleagues are so concerned at the pace at which we are trying to incentivize and adopt these green technologies. I mean, certainly the public appreciates us moving quickly and deliberately in that direction. The majority of Americans agree that climate change needs to be addressed now—not 10 years from now or 100 years from now, but now.

And Democrats and the Biden administration have worked very hard to respond to that, to the public's desire to expediently address climate change, and that included our passage of the historic Inflation Reduction Act in the last Congress.

The bill, as we have been saying, recognizes that America can be a leader in our global green energy transition, and together with the bipartisan Infrastructure Investment and Jobs Act that we passed and President Biden's nine Executive orders on climate and interagency efforts to strengthen energy and environmental regulations, it really sets us up well to meet this moment, I believe.

These are successes that are going to create new jobs. They are going to strengthen our domestic clean energy production. They are going to make meaningful advances in addressing climate change.

So, Mr. Higgins, you have spoken to it already. I would like you to come back and maybe put a punctuation mark, if you could, on what the climate implications are of the clean energy transition that the Democrats and the Biden administration are supporting through actions like investments in the Inflation Reduction Act.

Mr. HIGGINS. Thank you, Representative Sarbanes.

The climate investments from the Inflation Reduction Act, coupled with the Infrastructure Investment and Jobs Act, are projected by themselves to reduce U.S. greenhouse gas emissions up to 42 percent below 2005 levels by 2030, which is great. It is not quite enough, though, by themselves. What is important is that these investments are also enabling further action. They are changing the economics of clean energy. They are changing their affordability for households. They are supporting planning by the States. And together with the full suite of Federal Executive actions and State actions, they put—these investments put within reach the 50 percent goal that President Biden has set.

They also changed the economics and the politics of global diplomacy on clean energy, and this makes it possible to push the whole world forward to meet the greenhouse gas emission reductions that we need to have a shot at stabilizing global temperatures at 1.5 degrees Celsius.

Mr. SARBANES. I appreciate that.

I have to say when we passed that Inflation Reduction Act, it was the first time in a long time that I did not feel powerless or feel that we were powerless in the face of climate change coming at us. There is a path forward now, and hopefully we will get there in time before this sort of tipping point escapes us for good.

But these are dramatic changes that can bring us to a new place and, I think, have given many people a sense of hope instead of despair in the face of what we are seeing with a warming planet.

So while Democrats and the Biden administration are working to build on the successes of last Congress, doing that very delib-

erately—and I commend the administration for those efforts—some of my colleagues have been suggesting that we slow the progress down, that we revert back to responding not to the public's desires but, unfortunately, to some of the wealthy special interests of the oil and gas lobby, which has just had an incredible impact, chokehold, stranglehold on our policy when it comes to energy for decades and decades in a way that I think really compromised our Nation and its prosperity, frankly.

Mr. Higgins, again, can you explain how our recent actions to quickly, decisively address the climate crisis can address Americans' pressing environmental and economic concerns and have benefits that simply can't be matched at all by the proposed rollbacks that we saw in the energy bill that the Republicans brought to the floor or even a slower, more piecemeal approach than that?

Mr. HIGGINS. I think one of the great insights of the investment-led approach here is that climate action is not divorced from people's lived experience, nor is it something that happens just to future generations. And investing to make clean energy more affordable and available brings benefits to people in their everyday lives today, and that means saving 4,500 lives by 2030 from reduced air pollution. It means cutting household energy costs. It means creating already more than 140,000 jobs.

These are benefits that people will understand and experience, and it will—not only are the benefits worthwhile themselves, it will also build, I think, a better understanding of why addressing climate change is beneficial today and tomorrow.

Mr. SARBANES. Thanks very much.

I yield back, Mr. Chairman.

Mr. JOHNSON. The gentleman yields back.

The Chair now recognizes the gentlewoman from Iowa, Mariannette Miller-Meeks, for 5 minutes.

Mrs. MILLER-MEEKS. Thank you, Mr. Chair.

And I am going to start out today by actually lauding renewables, but I also want to acknowledge that sometimes we forget, and especially this administration, that renewables are more than just wind and solar.

My friend from the great State of Utah, Mr. Curtis, has some of the most abundant geothermal resources in the world. Like much of the Pacific Northwest, Chairwoman Rodgers has abundant hydropower in the 5th District of Washington State. And in Iowa, the corn State, which is an energy State, we are proud to have abundant ethanol and biodiesel.

Ethanol's use is widespread. More than 98 percent of gasoline in the U.S. contains some ethanol and is an option for low-carbon liquid fuels. In 2022, ethanol supported more than 57,000 jobs across Iowa, generated $3.5 billion of income for Iowans and accounted for nearly $7.2 billion of the State's economy and is, in fact, a renewable energy source. And if we don't grow corn in Iowa or the United States, it will be grown in Brazil or in South America, and they will cut down rain forests in order to plant more corn.

So, Dr. Nunes, like many of my Republican colleagues, I have concerns about the war President Biden has waged on liquid fuels. There are approximately 300 million passenger vehicles in the United States. That does not include logistical transport.

And for a single 100-mile charge for an electric vehicle, that is 30 kilowatt hours. Do the math on how much energy it would take to get a single 100-mile charge and if we could, in fact, do that.

The Biden administration's recent proposals, including its set proposal, which creates a new and statutorily unauthorized program to incorporate electric vehicles into the renewable fuel standard program, as well as its market-commandeering standards for light- and medium-drive vehicles, are a deliberate attempt to prop up electric vehicles at the expense of American consumers and Iowa ethanol. And I say this having driven a Honda Civic hybrid for 20 years, two of them.

How will these proposals increase costs for American families?

Dr. NUNES. Thank you for the question, Congresswoman.

I think if you look at the EPA's own numbers regarding the improvements in fuel economy that you would need to achieve to comply with the regulatory standards, we are talking, at least for internal combustion engines, about thousands of dollars. In the absence of selling electric vehicles, the price of conventional vehicles would, at a minimum, go up by about $2,000, at a minimum.

You could presumably sell electric vehicles to comply with the standard. However, here two challenges persist: The economics of building electric cars are challenging, to say the least. And even when you sell cars at $50,000 or $60,000, we have numerous OEMs that don't make profit off those vehicles.

Mrs. MILLER-MEEKS. And they are powered by what?

Dr. NUNES. Well, of course, it would depend on which State you live in. But, you know, by and large, it depends on the cleanliness of the grid—some coal, some gas, some renewables.

Mrs. MILLER-MEEKS. So, Mr. Simmons, the International Energy Agency estimated that the demand for lithium will increase by 43 times in the next 20 years, but the United States produces less than 2 percent of the global lithium supply.

And because my time is running out, have all of you heard of Blood Diamonds?

OK. Well, there is another analogy now, and that is Cobalt Red. And, you know, the climate-friendly—I beg to differ with one of the witnesses—of mining for cobalt, mining for rare earth is anything but environmentally friendly and also not labor friendly.

Does the United States have reserves, Mr. Simmons, to meet the expected lithium demand?

Mr. SIMMONS. We don't necessarily have enough to meet the global demand. We have a decent amount of reserves in places such as Rhyolite Ridge, Thacker Pass. We have large amounts of lithium reserves. The question is being able to access those reserves and whether the Biden administration will continue to stand in the way.

Mrs. MILLER-MEEKS. And is solely relying on allies to make up production and refining deficits a sustainable long-term strategy? And is it environmentally and labor friendly?

Mr. SIMMONS. I mean, when the United States has some of the best environmental and labor standards in the world, anytime we are exporting that, we are exporting lower environmental, lower labor standards.

Mrs. MILLER-MEEKS. Thank you very much.

Mr. Chair, I yield back my time.

Mr. JOHNSON. The gentlelady yields back.

The Chair now recognizes the gentlewoman from California, Ms. Barragán, for 5 minutes.

Ms. BARRAGÁN. Thank you, Mr. Chair. Thank you for having this.

Thank you to our witnesses for being here.

I think, you know, it is—I don't disagree that there should be a conversation about challenges that we need to face to be able to transition to a 100 percent clean energy economy, but I don't think that we should also just say, "Well, it is too much of a challenge, so let's just not do anything and let's have no action on climate or environmental justice."

And I think that is why we saw President Biden and Democrats in Congress pass bills like the infrastructure law and the Inflation Reduction Act to bring clean energy manufacturing jobs to America and to invest in things like batteries and recycling.

So I think that there are solutions that we can work on, but just to say, "Oh, we are just not going to do this because it is too hard" is not the way to go.

There has been a lot of talk today about national security. I want to remind folks that the U.S. defense and intelligence leaders agree that climate change is a national security risk. It's a threat to the U.S. national security. It is not a future threat. It is a threat that is happening today. And climate change is affecting global stability, military readiness, creating humanitarian crises, and is increasing the risk of war.

So if we want to talk about national security, we need to talk about it in the greater sense as well that climate change is posing.

Today, as I was preparing for the hearing, I was repeating—reviewing the Republican memo that claims that clean energy technologies are being forced on Americans. They are being forced on Americans.

What is being forced on Americans in my district and many other districts is things like urban oil drilling, things that have forced my constituents to live next to homes where they have pump jacks, where they are having air pollution, where they are suffering health impacts. And in many parts of our country, fossil fuel extraction and infrastructure continue to pollute low-income communities and communities of color.

Mr. Higgins, is clean energy being forced on environmental communities, or are we choosing to install solar panels and transition to zero emissions because its better for our health and our environment?

Mr. HIGGINS. Thank you, Representative Barragán.

Yes, clean electricity and other points of energy are better for our health and environment, and the investments offered in the Inflation Reduction Act are estimated to save up to 4,500 lives by the end of the decade and avoid nearly 120,000 asthma attacks annually.

This is—as you noted, these pollution components are not borne equally across the country. They are concentrated in communities of color and low-income communities. And the investments in the Inflation Reduction Act make it possible for those communities to

choose a different path. It is not a mandate. Nothing is being forced, but we are seeing how investments can make ever greater opportunities for clean energy available to the United States.

Ms. BARRAGÁN. Thank you.

The rights of foreign workers mining critical minerals is a serious issue and one that House Democrats want to address, but my Republican colleagues in this committee were less concerned about worker safety just a month ago when they passed a bill that exempted refineries that used highly toxic hydrofluoric acid from doing a hazard assessment or an assessment of safer technology options.

The United Steelworkers wrote this committee in opposition to this reckless bill, and their concerns were dismissed. While Republicans raise worker safety issues only when it suits their argument, Democrats are leading the way with solutions to create good-paying clean-energy jobs that uplift communities.

Mr. Higgins, how does the Inflation Reduction Act move us toward more responsible and sustainable energy jobs and energy supply chains?

Mr. HIGGINS. I am very excited about the first-time-ever idea in the Inflation Reduction Act, TEI, clean energy incentives, to requirements for apprenticeship programs and prevailing wages. This is going to make sure that the job quality of the clean energy economy is much higher and is going to provide real job communities for whole careers for people.

Ms. BARRAGÁN. All right. Thank you.

With that, Mr. Chair, I will yield back.

Mr. JOHNSON. The gentlelady yields back.

The Chair now recognizes the gentleman from Georgia, Mr. Carter, for 5 minutes.

Mr. CARTER. Thank you, Mr. Chairman.

And thank all of you for being here. This is an extremely important subject.

You know, I too believe that there is a rush to green. Now, let me preface my remarks by saying that I believe in climate change. I believe it is real. I do believe it is cyclical.

I have taken an active role in this discussion. I have advocated to be on the Select Committee for Climate Change last session. I was on that committee, and I am Chair—or Cochair of the Roosevelt Conservation Caucus. I am a member of the Conservative Climate Caucus. I have traveled to Europe with the Conservative Climate Caucus to learn as much as I can about this issue.

But one thing that I get frustrated with is that I don't feel like that we often look at the full cycle, and I always want to make that motion whenever I am describing it, because it is a cycle.

And we can take more important parts of that cycle, particularly when it is over with. And what do you do with the lithium ion batteries after it is over with? What do you do with the windmills and the blades after it is over with, and all of this stuff?

And I will be quite honest with you, I have biomass in my—and I represent south Georgia. I have a lot of timber, a lot of forestry, and biomass is something I am very interested in. I get it. I understand how people would think, "Well, you are burning something.

How can that be good?" But if you look at the full cycle, you will see that our forests serve as carbon sinks.

And it is carbon neutral by the end of the full cycle, and people just—that is what really frustrates me about this.

In our State of Georgia, we are doing our part. We are in the top 10 now in solar energy. We have got nuclear reactors that are fixing to come online, the first in over—in many decades that have come online in this country. And we have got—in my district, the largest economic development project in the history of our State is being built there by Hyundai, an EV plant, a $5.5 billion investment that is going to create over 8,100 jobs. We are excited about that. We have got a battery plant. SK batteries is coming there at that time.

But, again, I am concerned about the total cycle, the full cycle, because I don't think people look at it, and I get frustrated because, as you all know, China puts out more hydrocarbons than the entire world combined, and they are the worst polluter out there. And yet, people always want to point towards us. Here in the United States in the last decade we have decreased our carbon emissions more than the next 12 countries combined while still growing our economy. And I do believe in an all-of-the-above type energy strategy. I believe that fossil fuel is a natural gas.

And you all all know this, so I am just talking to myself here, because this is a preacher preaching to the choir. I get it.

Mr. Mills, I want to ask you a question. As of today, only 5 percent—5 percent—of lithium ion batteries for electric vehicles are recycled, compared to 99.3 percent of lead acid batteries for traditional gas-powered vehicles.

Since electric vehicles rely on lithium ion batteries—which are considered hazardous waste, by the way—what is the best way for us to address the end-of-the-life disposal issues with electric vehicles?

Mr. MILLS. Well, that is the—there is no easy answer to that because batteries are mechanically and electrically complex machines. Each one weighs about a thousand pounds, has thousands of components, chemicals, electronic pieces, cooling systems. Though they are typically dismantled by hand, it takes 1 to 2 days for one technician to transmission a single lithium ion battery. It is not just chemically hazardous, it is electrically hazardous.

And then you could technically recycle them, in all the studies that have been done to show that you can eventually get there. It would be very expensive. There is no path to cheap recycling of lithium ion batteries. There is technically a path for us to get there, but they won't be available for recycling until cars wear out.

Mr. CARTER. What about the blades on windmills?

Mr. MILLS. There is no path now. There has been one announcement that recycle resins made for batteries—for wind turbine blades. For now, they are trash.

Mr. CARTER. OK. You get what I am getting at, though?

Mr. MILLS. Yes.

Mr. CARTER. The full cycle, it is just we don't look at that.

I want to shift real quick. Mr. Simmons, you mentioned that one solution to the human rights issues that we know happens, like in Congo where we are getting some of these critical minerals, is to

increase critical mineral production and refinery in the United States.

How can such an expansion occur under the Biden administration's current policies?

Mr. SIMMONS. Under current policies, it can't.

Mr. CARTER. Exactly. Again, folks, we have got to look at the total picture here. We have got to look at the full cycle. I know it doesn't do me any good to keep doing this, but I am just telling you, we are not looking at it from its totality.

Mr. Chairman—and if you all ever want to see time fly, come here and get 5 minutes, and you will see time fly. Thank you all.

And I yield back.

Mr. JOHNSON. I thank the gentleman for yielding back.

The Chair now recognizes Mr. Crenshaw for 5 minutes.

Mr. CRENSHAW. Thank you, Mr. Chair.

Thank you all for being here.

So the title of this hearing is "Exposing the Environmental, Human Rights, and National Security Risks of the Biden Administration's Rush to Green Policies." It is an important title. I want to unpack that for a second.

Environmental risks. Mr. Mills, you have got some great data in your testimony. You talked about the amount of material excavation needed for the equivalent amount of energy for quote/unquote "green energy" versus your more standard, reliable energy sources such as natural gas. It also goes into the amount of land needed, hundreds of times more land space needed for the equivalent amount of energy compared to traditional energy sources that actually turn on when you need them.

So talking about environmental risks, that part of the conversation just gets ignored, which is why I am glad we are doing this hearing to expose that.

Human rights. A basic human right might be to turn the air-conditioning on when it is really hot, to be able to turn the heat on when it is really cold. Energy security should be a basic human right, at least in modern times, a basic human right. It hasn't been for thousands of years.

We finally made it one, and now we want to destroy it all and claim that the energy sources that have given us all of the modern amenities that we have today are to blame for—and are racist and are hurting people of color and hurting the disenfranchised.

Now, what will hurt the poor, what will hurt people of color, what will hurt the disenfranchised in our country would be energy insecurity. That will actually hurt them.

And we can see the results. I mean, look at California and its rush to green energy. Seventy percent higher costs for their energy than the rest of the country. I wonder how the poor feel about that.

In Germany, in their rush to get rid of their nuclear plants and basically deindustrialize, they have 300 percent higher energy costs. They have had to resort to burning coal and wood, which has far more carbon emissions.

So I will add that to the environmental destruction of rushing to green energy. It actually has the potential, as we see in Germany, of increasing carbon emissions. That is what is actually happening.

And national security risks. Well, if you—if the lights don't turn on, that is, obviously, a national security risk. I don't think I need to flesh that out too much.

Mr. Mills, maybe I will start with some of your really interesting data points that you have in your testimony. I like this one: "Analyses show that manufacturing a single battery, one capable of holding energy that is equivalent to one barrel of oil, entails processes that use the energy equivalent of 100 barrels of oil."

Do you want to comment on that and then some of the other data points that you have as far as materials needed, land space needed, things like this, that show that the input for these types of power production types are not what people say?

Mr. MILLS. Thank you, Congressman.

One of the things that is ignored generally in the debate—but the IEA should be commended for publishing excellent studies on this, as has the World Bank and many other international organizations—the underlying infrastructures required to make the minerals and materials and transport them are all hydrocarbon-based coal, oil, and gas.

The industries themselves that produce minerals consume 40 percent of all of the world's industrial energy. And there is no path to replace coal, oil, and gas at scale globally in the industrial sector. What that means is, when you produce the electric car, you are consuming oil and gas and coal before the car is delivered to your driveway, and therefore you are causing CO_2 emissions. We actually don't have a good number to know exactly how much it is. We know what the range is.

And I will commend Volkswagen and Volvo for publishing studies that illuminate that. And they point out that, when you take that into account, you radically reduce the ostensible, you know, dramatic reduction in CO_2 emissions. And, in fact, in some cases, as they pointed out, you can wipe out all the CO_2 emissions for not burning gasoline.

So when I was in Norway recently, which buys the most electric cars per capita at the moment, they pointed out that everybody bought a Tesla—a lot of Teslas, they are very popular there, nice car, well made, beautiful engineering—what you have already done is exported somewhere between 15 to 20 tons of CO_2 when you buy that one car. And you do cut CO_2 emissions as you drive the vehicle on that hydropower grid. If you drive it on an American grid or a German grid or a British grid, you reduce the CO_2 emissions eventually, but only by about 15 to 20 percent.

So it is ignored in the emissions calculations. It is ignored in the geopolitics. It is also ignored in the cost calculations, because the increased cost of hydrocarbons increases the cost of solar power.

Mr. CRENSHAW. And that is what we are talking about.

In my last 10 seconds, I will say, look, everything we are referring to here is a cost-benefit analysis. What is the benefit you are getting for the cost that you are incurring on people who can probably afford to pay it the least?

So that is what this discussion is about. That is why Republicans push for nuclear energy, right? It is reliable, and it is clean. We push for natural gas exports because it is reliable, it has an actual chance of displacing foreign coal, and an actual chance of reducing

carbon emissions globally in a very massive way. And we should be exporting more of it and encouraging more of it, not less of it.

And I yield back. Thank you.

Mr. JOHNSON. The gentleman yields back.

The Chair now recognizes the gentlelady from Michigan, Mrs. Dingell for 5 minutes.

Mrs. DINGELL. Thank you, Mr. Chairman.

Here is a reality: The climate crisis is real, and it is going to impact every aspect of our daily lives. The longer we wait to address this threat, the more expensive and complex it is going to become to mitigate it.

So I am listening to all of my colleagues, and when you just talk about—I am going totally off script here. But when you talk about how much it costs now, but we have got to invest in alternative ways, so it eliminates both the cost and the amount of carbon emissions.

I am a car girl. I care about the auto industry. I am going to talk about the auto industry today, and I am going to tell you, I am participating in this hearing as a Democrat from Ann Arbor who did not support the Green New Deal because it was important to bring everybody to the table, and I went through sheer, unadulterated hell as I worked to bring everybody together. But, as Mr. Higgins knows, I did bring everybody together. And making sure that the auto industry stays competitive and its workforce is protected is an intense priority for me, so that is what I am going to focus on.

But we are already behind other countries, and that is a problem. China is beating us at technology. The last quarter in Europe, the alternative population—propulsion vehicles beat the sales of internal combustion engines. We are a global—we are competing in a global marketplace. I want to see American innovation and technology selling in the world and selling here, and that is the reality that we are competing with.

It is an economic security issue, it is an energy security issue, and it is a national security issue. And as I have these discussions, there isn't anybody up here that doesn't know—somebody said the cheapest car is $70,000. The OEMs—and the other companies are too—are working as we go into mass production to make those vehicles. When I was with the President at the Detroit Auto Show, Mary Barra, the CEO of GM, showed a vehicle that will be 20-some thousand dollars, which is what the cost of an ICE is. The other companies are going to bring those costs down as we go into more production.

But, as we all know, the U.S. transportation sector accounts for roughly 30 percent of our greenhouse gas emissions. If we are to meet our climate goals, we have to rapidly shift to either electric vehicles or another—I am not against hydrogen or other powered vehicles, and I say that to everybody when we are talking about it.

And as Mr. Higgins knows, we brought—we didn't include the OEMs. We brought the environmentalists and the labor units together to talk about where we needed to go. People could sense that it was doable and we should target—target—50 percent sales of vehicles by the year 2030.

If you talk to GM and Ford—they are very much competing with each other too—they know that if they are going to compete in an international marketplace, they have to do this because they want to sell their vehicles not only here but around the world. And China is beating us.

And I am already out of time.

Mr. Higgins, I want to ask you, if we sit back and do nothing to prepare and support this growing industry, what do we risk? What will our auto industry look like 20 years from now if we don't support the EV industry or transition to other vehicles and support our workers through this critical transition?

Mr. HIGGINS. Thank you for your leadership on these issues, Representative Dingell. And I think what you were able to contribute to with the Inflation Reduction Act has completely flipped the paradigm for investment in the auto industry.

The United States automakers were behind on EVs. China has invested for decades in consolidating manufacturing capacity for advanced technologies, including the batteries and the cars themselves, and the automakers in the United States were not prepared to compete. But with the investments included in the Inflation Reduction Act, it is now possible to invest in everything from the critical minerals, to the batteries themselves, to the vehicles and make it so that of the 32 vehicles that are now eligible for the tax credit, the overwhelming majority are produced American brands.

Mr. JOHNSON. I think the gentlelady yielded back.

The Chair now recognizes the gentleman from Idaho, Mr. Fulcher, for 5 minutes.

Mr. FULCHER. Thank you, Mr. Chairman.

And thank you to those of you on the panel for coming and speaking today.

Mr. Chairman, as you know, we have sometimes got dueling committees, but the content of the testimony has been very, very good, and I am very thankful you are willing to do this.

Mr. Simmons, I wanted to just point out a couple of things and then just talk to you for a minute.

Idaho has got the largest deposit of antimony in the world that is not under Chinese control. And, of course, that is used in key defense and clean energy technologies. And right now antimony partially comes from—as processed in China as well as Russia. And both antimony and cobalt are listed as materials of interest by the Defense Logistics Agency, and DoD has concerns about the stockpile of antimony that is running out in the near future leading to potential ammunition shortages.

I know you have touched on this, but just for the record and for part of this dialogue, Mr. Simmons, could you share what are the national security benefits of buying locally produced critical minerals domestically or in allied countries with reliable partners?

Mr. SIMMONS. Sure. There are—with so many of the minerals that have been identified as critical minerals by the USGS, one of the aspects of whether or not those minerals are used for defense purposes, many of them are, and whenever we have—and it is critically important that we get those from trusted partners. Unfortunately, for many, we don't, which means that if there is conflict

that we will be unable to obtain those resources of the quantities that we need.

And, especially, we will not be able to obtain them in any, like, economically significant quantities. You maybe could—you know, DoD can have stockpiles of certain things for their purposes. But in terms of the economy as a whole, we will not have access to a whole bunch of critical resources.

Mr. FULCHER. Well, we are in a struggle in my State of trying to get access to some of that. The good news is, I guess, we have got it. The bad news is we are fighting ourselves to be able to get responsible access to it.

So thank you for your comments, and we will be potentially accessing your expertise in this battle as we move forward.

I am going to shift to Mr. Mills.

Mr. Mills, I am from the Pacific Northwest. Thank you for your testimony. In our part of the country, we are experiencing a significant amount of growth, and the need for more power is very, very evident. As you pointed out in your testimony, not all power is created the same, if you will. If we are talking solar and wind, it is roughly 3,400 megawatts per year. If it is natural gas, it is only 800 megawatts per year. And that is that density that I think I heard you talk about.

Northwest Power Council said replacing 3,400 average megawatts of existing hydropower and nuclear would require 5,500 megawatts of new wind and solar as well as 2,000 megawatts of natural gas.

Again, I know you have touched on this, but for the sake of our conversation, why are we doing what we are doing? Why the drive towards this low-density energy sources?

Mr. MILLS. Well, that is a political and psychological question as opposed to an engineering and physics question. But we all know the answer is that the pursuit of avoiding hydrocarbons, lowering carbon dioxide emissions, is what this is all about, but the consequence of that is ignoring the hydrocarbon use and carbon dioxide emissions in the total fuel cycle, also ignoring the scale of infrastructure required, not just land use, but we are on a path to try and replicate Germany.

Germany did not eliminate is original grid. What they did is they doubled the size of the grid over the last 20 years. Even if it was electric, consumption only went up 10 percent. That is, in a nutshell, why they have had very little carbon dioxide emission savings, but have seen their electric costs for consumers triple.

This is the path that we want to emulate, which I think is a bad path. It is not an observation about political objectives. It is an observation about economic consequences.

Mr. FULCHER. That is, unfortunately, the reality. And I thank you for your expertise in sharing that.

Just as a matter of record on our side, we have got a wealth of hydro, geothermal, and nuclear available. It is just the question is, are we going to commonsense utilize that.

So, Mr. Chairman, I yield back.

Mr. JOHNSON. The gentleman yields back.

And now I would like to take a moment of personal privilege before I go to our next questioner and recognize some high school students from Shadyside, Ohio.

Thank you all for being in our Nation's Capital today. Thanks for coming down to the hearing.

And with that, the Chair now recognizes the gentlelady from Florida, Ms. Castor, for 5 minutes.

Ms. CASTOR. Well, thank you, Mr. Chairman.

Thank you to our witnesses for being here today.

You know, Washington is a really strange place because on the day that the House will vote on the Republicans' Default on America Act, a bill that clearly will increase energy and electric bills for American families and businesses, my Republican colleagues are, once again, boosting corporations that have been responsible for fueling inflation and gouging consumers.

We are not going to allow them to raise costs on Americans families by repealing the Inflation Reduction Act so that fossil fuel companies can continue to pollute and wreak havoc, and I will give you an example.

The Florida Utility Service Commission just last month approved huge price spikes on Floridians. In my neck of the woods, Tampa Electric Company customers can expect their energy bills to increase by about 10 percent starting this month. The average customer's bill will have risen 62 percent from 2019, from $99.53 to $161.13. Duke Energy got a 15 percent increase. FP&L, Florida Power & Light, 10 percent. Ouch.

Why? Because they rely on gas overwhelming. Seventy-five percent of electricity production in the so-called Sunshine State comes from gas.

So the Inflation Reduction Act is really giving us hope right now. We are the Sunshine State, and we should be a leader in lower-cost solar power. But the IRA now is just starting to work and lower costs. Clean energy, solar technology, EVs, cars, and trucks are creating a lot of made-in-America jobs too.

Mr. Higgins, you highlighted this in your testimony. Since the enactment of the Inflation Reduction Act, we have seen the creation of over 142,000 jobs and over $240 billion in new investment in American communities. And then when we are talking about China—a lot of that has been a topic of conversation here today—it makes no sense for Republicans to roll back critical new policies that help domestically or allied-sourced critical minerals for batteries, domestic battery manufacturing, and solar and wind energy production. China still holds most of the world's capacity for litium ion battery sales, with nearly 75 percent being manufactured in China.

So the House Republicans rush to reverse these key mechanisms in the Inflation Reduction Act to end reliance on supply chains originating in China. It just doesn't make any sense.

And, Mr. Higgins, you have highlighted all of these private-sector investments now. We are just getting started. Talk a little bit about the announced construction of domestic solar manufacturing facilities. I am very interested, coming from the Sunshine State, in domestic manufacturing capacity. What does that mean for us?

Mr. HIGGINS. Thank you, Representative Castor.

The story of solar manufacturing in the United States is actually an interesting one because this is a technology that really largely originated here, including support from the National Labs, but we lost the manufacturing capacity advantage to China because of their subsidies. But now for the first time, with the Inflation Reduction Act, investments in new manufacturing capacity as well as the incentives for energy deployment to achieve ever higher levels of domestic content are going to change the paradigm. And they are already leading to new manufacturing facilities for wind turbines and for solar panels as well as for batteries and cars, as you mentioned. And bringing those industries here to the United States allows us better control over the supply chain issues that have been addressed at today's hearing and equips the United States to compete on the global energy economy of the 21st century.

Ms. CASTOR. So if Republicans are successful in passing their Default on America Act, and then they have another attempt at the end of the week to undo the Biden administration's 2-year pause on new solar tariffs, what does that mean for jobs in this sector?

Mr. HIGGINS. So there will be up to a million jobs created, thanks to the investments in the Inflation Reduction Act, by 2030. But that already has led to over 140,000 jobs already happening just in the last year. And repealing——

Ms. CASTOR. Well, these companies—yes, repealing, what does that—go ahead.

Mr. HIGGINS. Right. Repealing the Inflation Reduction Act would not only raise household energy costs and worsen air pollution, it would pull the rug out from underneath these jobs. And it would mean that more than $240 billion in private investment that has already happened making America competitive with China would be lost. It would play right into China's hands. And, in my opinion, it would be a devastating and unacceptable mistake to repeal and revoke these investments in the American economy just as we are getting started.

Ms. CASTOR. It is downright un-American. I think we need to stick on the patriotic course and keep the Inflation Reduction Act working for American families and businesses.

Thanks so much.

Mr. JOHNSON. The gentlewoman yields back.

The Chair now recognizes the gentleman from Michigan, Mr. Walberg, for 5 minutes.

Mr. WALBERG. Thank you, Mr. Chairman. And thanks for allowing me to waive on today to this hearing.

And thanks to the panel for being here.

I also—I wish my sister from Michigan were still here. She would be not surprised to hear that I agreed with her on some things and disagreed with her on other things. Coming from the motor—I still call it the motor capital of the world, Michigan, we are concerned about energy. We are concerned about innovation. We are concerned about jobs.

And let me quickly state anything that has been said about the IRA is all picking out of the air. It hasn't been fully implemented yet, thank God. Maybe we can turn it back and we could go the right direction in the process.

Michigan is made up of autoworkers. Automakers have a great history of innovating to meet consumer demand and market trends, and that includes innovation around electric vehicles. Nobody is against electric vehicles if they work and if the consumer wants them.

But recently there has been a dramatic and forced—and that is part of the IRA—shift toward only EVs. And, sadly, some of our American nameplates have hunkered down and said, "We don't see any hope. The Government is going that way, so we are going to do it whether it makes sense or not." Unions have sold out their members, and we know for a fact that they are going to lose jobs.

Just talking with a dealer on Monday, he told me that, for a fact, the only reason the auto industry or the manufacturers are going forward with their arm behind their back is the fact that it looks like the writing on the wall and they have got to do it, hunker down, unless somebody with some common sense says, "Wait a second. Let's let the engineers and let's let the consumers decide what they want and what they need."

We have cleaned up significantly our world. What we do here will just put us behind other polluters that aren't going to clean up their world, like China, and common sense says that is not a good direction.

Consumers aren't asking for it. Six percent, as of most recent reports, of car sales have been electric, and most of those have been only, as we have talked about today, for second and third cars. They are not for the necessary transportation they have beyond what they are doing day-to-day work. And for the middle-income person, that is not their car of choice.

Dr. Nunes, you have said, and all indications suggest, that EVs will need substantially greater range at significantly lower costs before most American consumers will adopt them as their primary vehicle. The most popular selling vehicles in America today are SUVs and trucks. Just come to my district that crosses from Lake Michigan to Lake Erie, and you will see that.

Do the EVs on the market today meet the size and range needs of American consumers?

Dr. NUNES. They do not, Congressman. We estimate that the price of EVs would need to go down by about 10 to 15 thousand dollars, while at the same time the range would need to go up by approximately 50 percent.

Mr. WALBERG. So they are for wealthier buyers at this point in time.

Dr. NUNES. All the current indications suggest that they cater to upper-income Americans.

Mr. WALBERG. Will greater production of EVs necessarily lead to lower costs?

Dr. NUNES. Historically, the idea behind increasing production volume has been that, if you increase production, prices invariably drop. That is not what we are currently seeing on the market. What we are seeing is an increase in price in inflation-adjusted dollars over time.

Mr. WALBERG. Let me ask another set of questions, Dr. Nunes. Just yesterday, GM announced that it would end production of the

Chevy Bolt, arguably an electric vehicle considered to be the cheapest EV available in the United States today.

In your testimony, you mention that the number of miles driven with an EV significantly influences any emissions advantage over gas-powered cars. If a wealthy family purchases an EV—it won't be a Bolt now but an EV as a second or third car—how many miles would it have to be driven to reach parity with an internal combustion engine, in terms of a carbon footprint?

Dr. NUNES. Depending on whether or not the vehicle is purchased as a second car or is used to replace a second car, you may need to hold onto that vehicle for upwards of 10 years.

Mr. WALBERG. And upwards of 10 years, then I would suggest, from what I have heard, that the resale value of that car, specifically in concerns about the battery and the cost of replacing a battery—and shortly after 10 years, that could be likely—could that be a significant inhibitor for anyone wanting to purchase an EV and then turning it over to their kids following that?

Dr. NUNES. It very well might. You know, as the Congresswoman mentioned earlier, that, you know, we have cheap cars on the market, cheap EVs on the market. We certainly do.

In 2022, the cheapest EV on the market cost about $27,000. It is important to remember that there were just 12,000 units sold out of over 700,000 EVs.

Mr. WALBERG. And the battery replacement—I guess my time has run out. So, Mr. Chairman, thank you and thank you for the panel.

Mr. JOHNSON. The gentleman yields back.

The Chair now recognizes the gentleman from Texas, Mr. Pfluger, for 5 minutes.

Mr. PFLUGER. Thank you, Mr. Chairman. And I appreciate your leadership in this very, very important topic. And thank you all for your time today.

I will get right to it. My concern is that we are throwing away the resources that this country has been so abundantly blessed with, that we are not just enriching the Chinese Communist Party but that we are also adding to the human rights violations in places like the Democratic Republic of the Congo, which I am sure has been discussed already today here.

After reading Cobalt Red, you know, how do we have policies that are ignoring the resources that we have here? In the name of something that should be good, we ignore doing what we are supposed to be doing here.

So, Mr. Simmons, I will start with you. And just talking about the Institute for Energy Research's newest paper, "The Economic and Strategic Importance of Domestic Mineral Production," which I think provides a realistic analysis of the challenge transitioning rapidly toward critical mineral-intensive technologies, and it touches on how the administration is working hard to incentivize or actually force electrification.

Mining companies are not increasing investment levels that would be needed to meet the projected demand, especially here. So what policies, if enacted right now today, would get us to the point where we don't hand the Chinese Communist Party these major wins and we do it here near-shoring for that mining?

Mr. SIMMONS. We need massive permitting reform. H.R. 1 was a good step in that direction, but we need far more to be able to require that the administration, you know, permits new mines in the United States.

It is incredibly—like, these are very capital-intensive projects. And the regulatory risk is such that it is, like, very long timelines. That needs to be shortened if we are going to be producing the minerals that we need here in the United States instead of continuing to import them, especially from places like China.

Mr. PFLUGER. I mean, the quantity of critical minerals that is needed in an electric vehicle is massively different than in these devices, than we have seen in tablets.

So, Mr. Mills, Secretary Granholm recently talked about the fact that the U.S. can learn from China and what they are doing when it comes to clean energy technologies, which I was blown away at.

Is China the standard for green energy?

Mr. MILLS. We are the standard for building the infrastructure to export the critical minerals for green energy machines to the rest of the world. They are net importers, you know, I am sure, Congressman, of gasoline and oil, which fuel our economy.

It is a hydrocarbon-based economy. And manufacturing, assembling cells, battery cells, and battery packs in America, assembling solar panels in America doesn't change the fact that today, for a very long time, probably at least a decade or more, the solar modules themselves are fabricated on coal grids in China, 90 percent of the world's solar modules, because it is a very energy-intensive process to turn sand into silica and from there into a PV cell. The same is true for the chemicals.

So what we are doing is building a dependency in the supply chain on China and not—despite the incentives in the act, there is zero evidence that it is resulting in a rush to mine not only in America but globally.

The global mining industry's total investments to produce the minerals needed has been declining for years and is still declining and, according to the latest data, will be one-tenth of what is needed to fuel our ambitions over the next decade.

It takes an average of 16 years to open a mine. Sixteen years is easy arithmetic to do from today. And those mines are not being opened en masse. The mining industry is consolidating, not investing in new production. I think they know something, would be my guess.

Mr. PFLUGER. What I am hearing each of you say is that this rush to electrification not only is unrealistic, but it is also emboldening places like China, where if you really look at the life cycle of emissions of an electric vehicle, they are actually way worse than anything else that we actually have right now.

Mr. MILLS. Absolutely correct. It is also emboldening countries like Chile to announce they want to form nationalized lithium industries and form a lithium cartel in South America, which will have pricing power over lithium greater than OPEC's pricing power on oil.

Mr. PFLUGER. What will this dependency do to our national security, any of you?

Mr. MILLS. Well, it is not good, let's just say. And it is hard to actually predict the specific, because they are reshuffling our resource dependencies. And most of the resource dependency shuffling is going to nations that are not our friends. Some of it is going to Canada, my homeland. Some of it is going to Australia, which is good, and good for them. But most of it is going to unfriendly places.

Mr. PFLUGER. Mr. Chairman, once again, thank you for holding this hearing. It is very important that we maintain the resources we have, that we actually look at something that is sustainable, and this is completely unsustainable.

I yield back.

Mr. JOHNSON. The gentleman yields back.

Seeing that there are no other Members to ask questions, I ask unanimous consent to insert in the record the documents included in the staff hearing documents list. Without objection, that will be the order.

And I remind Members that they have 10 business days to submit questions for the record, and I ask the witnesses to respond to the questions promptly.

I want to thank our witnesses for being here today. You have all been very informative. Thank you.

Members should submit their questions by the close of business on May 10th.

Without objection, the subcommittee is adjourned.

[Whereupon, at 1:07 p.m., the subcommittee was adjourned.]

[Material submitted for inclusion in the record follows:]

U.S. House Committee on Energy and Commerce
Subcommittee on Environment, Manufacturing, and Critical Materials
"Exposing the Environmental, Human Rights, and National Security Risks of the Biden Administration's Rush to Green Policies"
[April 26, 2023]

Documents for the record

At the conclusion of the meeting, the Chair asked and was given unanimous consent to include the following documents into the record:

1. Report from the Institute for Energy Research entitled, "The Economic and Strategic Importance of Domestic Mineral Production" April 24, 2023, submitted by the Majority.
2. Article from The Harvard Gazette entitled, "Benita Kayembe takes hard look at hidden human cost of electric cars" April 25, 2023, submitted by the Majority.
3. Article from Harvard Business Review entitled, "The Dark Side of Solar Power" June 18, 2021, submitted by the Majority.
4. National Mining Association "2023 Mining Facts" April 2023, submitted by the Majority.
5. An article from Rewiring America entitled, "Electrification won't break the grid, it will make it smarter" Submitted by the Minority.
6. An article from Rewiring America entitled, "Exporting oil and gas does not create energy independence, electrification does." Submitted by the Minority.
7. A report from the Union of Concerned Scientists entitled, "Driving Cleaner: Electric Cars and Pickups Beat Gasoline on Lifetime Global Warming Emissions." Submitted by the Minority.
8. A blog from the Union of Concerned Scientists entitled, "Today's Electric Vehicles Can Greatly Reduce Emissions From Driving." Submitted by the Minority.
9. A blog from the Union of Concerned Scientists entitled, "Are There Enough Materials to Manufacture All the Electric Vehicles Needed?" Submitted by the Minority.
10. A blog from the Union of Concerned Scientists entitled, "How Much Land Would it Require to Get Most of Our Electricity from Wind and Solar?" Submitted by the Minority.
11. A blog from the Union of Concerned Scientists entitled, "Challenges and Opportunities in Mining Materials for Energy Storage Lithium-ion Batteries." Submitted by the Minority.
12. A blog from the Union of Concerned Scientists entitled, "What Happens to Wind Turbine Blades at the End of Their Life Cycle." Submitted by the Minority.
13. A blog from the Union of Concerned Scientists entitled, "Solar Panels Should Be Reused and Recycled. Here's How." Submitted by the Minority.
14. A fact sheet from Earthjustice entitled, "Building a Sustainable Mineral Supply Chain For a Clean Energy Economy." Submitted by the Minority.
15. A fact sheet from Zero Emission Transportation Association entitled, "Electric Vehicle Factsheet." Submitted by the Minority.

16. A report from Climate Power entitled, "Clean Energy Boom." Submitted by the Minority.
17. A report from Climate Power entitled, "The Clean Energy Boom in House Republican Districts," submitted by Ranking Member Frank Pallone, Jr.
18. A Politico article entitled, "Big Winners from Biden's Climate Law: Republicans Who Voted Against It." Submitted by the Minority.
19. An article from CleanTechnica entitled, "Want to Electrify Everything? Train More Electricians—Quickly" Submitted by the Minority.
20. A report from Rewiring America entitled, "Mobilizing for a Zero Carbon America: A Jobs and Employment Study Report." Submitted by the Minority.
21. A blog from the Union of Concerned Scientists entitled, "Are EV Batteries Recyclable?" Submitted by the Minority.
22. A blog from the Union of Concerned Scientists entitled, "Battery State of Health—What is it? Why is it Important?" Submitted by the Minority.
23. A blog from the Union of Concerned Scientists entitled, "California's Progress Toward Recycling Policy for EV Batteries." Submitted by the Minority.
24. A blog from the Union of Concerned Scientists entitled, "What Can We Learn From the EU Battery Law?" Submitted by the Minority.
25. A blog from the Union of Concerned Scientists entitled, "Guiding Principles for EV Battery Recycling Policy." Submitted by the Minority.
26. A blog from the Union of Concerned Scientists entitled, "Why Do We Need EV Battery Recycling Policy?" Submitted by the Minority.
27. A blog from the Union of Concerned Scientists entitled, "Why New DOE Battery Recycling and Repurposing Investments Are Crucial to the Future of EVs." Submitted by the Minority.

The Harvard Gazette

CAMPUS & COMMUNITY

Benita Kayembe takes hard look at hidden human cost of electric cars

"My parents said the biggest thing you can give to yourself is education, so I did everything I could to go to school," said Benita Kayembe, who at 19 moved from the DRC to California, despite knowing no English.

Kris Snibbe/Harvard Staff Photographer

Chan graduate's research focuses on deadly risks, exploitation faced by workers who mine key component of lithium-ion batteries in Republic of the Congo

Alvin Powell
Harvard Staff Writer
April 25, 2023

This story is part of a series of graduate profiles ahead of Commencement ceremonies.

For Benita Kayembe, global health ties together different threads of her life.

She grew up in the Democratic Republic of the Congo's Katanga Province, a region known for mining everything from copper and uranium to diamonds and cobalt — a key ingredient of lithium-ion batteries, which power the electric cars that many hope will soon supplant gasoline vehicles globally.

Though mines are an important part of the local economy, she said she grew up unaware of their prominence. But she knew health care was important. Her late father was a nurse who worked in a major mining company hospital, Gecamines Clinic. He also advocated for local people and started a small clinic in their town to meet unmet health needs. There she came to understand the importance of quality healthcare.

"He was a motivation for me," Kayembe said, "working at Gecamines, being involved in politics, and having a health care center. I saw people dying for no reason. The deaths of many people could have been prevented."

Kayembe, who is graduating this spring with a master's of science degree in global health and population from the Harvard T.H. Chan School of Public Health, took a winding road to Harvard. Despite knowing no English, at age 19 she moved from the DRC to California in 2013 for a chance at greater educational opportunities.

She stayed with family there and, with her parents' words on the importance of education firmly in mind, she took courses in English at a local job-training nonprofit and then moved on to economics at Cañada College, a public community college in Silicon Valley, earning an associate's degree.

She transferred to Cornell University and set her sights on international development, earning two bachelor's degrees by the time she graduated in 2020, in development sociology and in international agriculture and rural development. Along the way, she worked: as a server for a catering company, as a mentor to other community college students, and as a consultant, living in Phoenix and Seattle for a year after Cornell before deciding it was time to keep moving toward her dream.

"I knew that I wanted to pursue education because that was instilled in me," Kayembe said. "My parents said the biggest thing you can give to yourself is education, so I did everything I could to go to school."

It was at Cornell that Kayembe took her first global health course, which she felt finally provided an umbrella under which she could bring together the different threads of her studies and experiences.

"When I took my first introduction to global health, I knew that was what I would do," Kayembe said. "Global health gave me a different perspective on things I already experienced in my life, living in DRC and

in California, seeing how education impacts health, economics impacts policy, and global health is at the intersection of everything."

For the last two years, Kayembe has been studying global health at the Harvard Chan School and says the people she's met and the subjects she's explored have helped her understand the forces that shape the health of people around the world and how those forces interact to affect lives.

She's the president of the Harvard Africa Health Forum, founded a podcast dedicated to diverse voices in global health, and was a panelist at the Prince Mahidol Award Conference in Thailand, where she presented the results of research last summer that took her back to DRC for the first time in a decade.

She was happy to visit family while she was there, but the focus of that trip was the independent cobalt miners who operate outside of the operations of large companies. This informal sector is made up of tens of thousands of workers — including between 10,000 and 17,000 children — and accounts for about 20 percent of DRC's cobalt production.

The nation's cobalt industry, which produces about 70 percent of the global supply, has drawn more attention in recent years as demand for the mineral has increased. It is, after all, a key component in the batteries that power a variety of popular consumer products, including computers, cellphones, and electric vehicles. But analysts say a significant part of the demand is because of surging electric car sales amid rising signs of climate change.

Miners toil with little protection, and the work is hazardous. According to media reports, in 2019, 43 informal miners were killed in the DRC when a copper and cobalt mine collapsed; in 2020, 50 were killed after a gold mine shaft collapsed; in 2021, 12 died in a landslide at an informal gold mine; and in March 2023, two miners died in a collapse at one mine, while nearby, nine others were rescued after two days underground when the mine they were working in collapsed after heavy rain.

Spoils from mining can also be toxic. In 2021, 12 people were killed and 4,500 sickened when toxic metals from a diamond mine in Angola spilled into the Kasai River and flowed into DRC.

Kayembe, supported by a Rose Service Learning Fellowship, worked on the project in collaboration with Tony Kitenge at the Institut Supérieur des Techniques Médicales de Lubumbashi, who assisted her in getting access to the miners and the sites.

When she sat down with people and asked about their lives, Kayembe said she was surprised at how willing they were to share their experiences working all day to extract the ore from which cobalt can be separated.

During the 45 or so interviews she conducted, she learned that these miners are pushed into the work by economic pressures and subject to exploitation by systemic corruption. They often work with rudimentary tools or bare hands; they have no protective equipment; and the work is sometimes done by families. She saw kids as young as 5 cleaning off the minerals their mothers found. The mining sites had no schools, healthcare centers, or even facilities as rudimentary as toilets nearby.

"I grew up in Katanga six hours from a cobalt mine," Kayembe said. "I grew up in a family in a community shielded from other realities."

Jesse Bump, executive director of the Takemi Program in International Health at the Chan School and lecturer on global health policy, advised Kayembe on the project, encouraging her to forge ahead on work that he said "illuminates a vast universe of harm."

Bump praised the breadth of experience and scholarship that Kayembe can bring to bear and said all of that gives her the opportunity to do meaningful work in places where health ills are significant yet often missed because of inaccessibility and cultural and language barriers. To Kayembe, he said, those are no barriers at all.

"As a Congolese citizen," Bump said, "she has a life experience that goes to the core of what we're studying in global health: What are the causes of inequality? What are the skills you need to interrogate that?

"Much of what we do in global health is predicated on the reality that health is personal, and yet to confront that on a global scale often requires a tool kit that is somewhat reductionist: We do a lot of counting and calculating and then make assumptions based on our best estimates and surveys about what things must be like and what might be needed.

"But Benita can shortcut that in the Congo because she speaks the languages, knows the culture, and illuminates a set of dynamics that would resist interrogation by methods that are much more common here. What you have in her work is exactly the kind of work we should be doing, and exactly the kind of person who should be doing it."

And Kayembe plans on continuing. She's certain she wants her work to benefit people in disadvantaged communities in the DRC, though she confesses she's not certain what that means for the months and years after graduation. She expects to work for a time and is already considering whether a Ph.D. program might be the right next step. What she's sure of is that the need for artisanal miners will only grow as the world charges forward with electrification. She also knows she doesn't want them to be an afterthought in the push for a more sustainable planet.

"I might be enjoying an electric car," Kayembe said, "but somewhere someone is dying."

Harvard
Business
Review

Sustainable Business Practices

The Dark Side of Solar Power

by Atalay Atasu, Serasu Duran, and Luk N. Van Wassenhove

June 18, 2021

HollenderX2/Getty Images

Summary. Solar energy is a rapidly growing market, which should be good news for the environment. Unfortunately there's a catch. The replacement rate of solar panels is faster than expected and given the current very high recycling... **more**

It's sunny times for solar power. In the U.S., home installations of solar panels have fully rebounded from the Covid slump, with analysts predicting more than 19 gigawatts of total capacity installed, compared to 13 gigawatts at the close of 2019. Over the next 10 years, that number may quadruple, according to industry

research data. And that's not even taking into consideration the further impact of possible new regulations and incentives launched by the green-friendly Biden administration.

Solar's pandemic-proof performance is due in large part to the Solar Investment Tax Credit, which defrays 26% of solar-related expenses for all residential and commercial customers (just down from 30% during 2006–2019). After 2023, the tax credit will step down to a permanent 10% for commercial installers and will disappear entirely for home buyers. Therefore, sales of solar will probably burn even hotter in the coming months, as buyers race to cash in while they still can.

Tax subsidies are not the only reason for the solar explosion. The conversion efficiency of panels has improved by as much as 0.5% each year for the last 10 years, even as production costs (and thus prices) have sharply declined, thanks to several waves of manufacturing innovation mostly driven by industry-dominant Chinese panel producers. For the end consumer, this amounts to far lower up-front costs per kilowatt of energy generated.

This is all great news, not just for the industry but also for anyone who acknowledges the need to transition from fossil fuels to renewable energy for the sake of our planet's future. But there's a massive caveat that very few are talking about.

Panels, Panels Everywhere

Economic incentives are rapidly aligning to encourage customers to trade their existing panels for newer, cheaper, more efficient models. In an industry where circularity solutions such as recycling remain woefully inadequate, the sheer volume of discarded panels will soon pose a risk of existentially damaging proportions.

To be sure, this is not the story one gets from official industry and government sources. The International Renewable Energy Agency (IRENA)'s official projections assert that "large amounts

of annual waste are anticipated by the early 2030s" and could total 78 million tonnes by the year 2050. That's a staggering amount, undoubtedly. But with so many years to prepare, it describes a billion-dollar opportunity for recapture of valuable materials rather than a dire threat. The threat is hidden by the fact that IRENA's predictions are premised upon customers keeping their panels in place for the entirety of their 30-year life cycle. They do not account for the possibility of widespread early replacement.

Our research does. Using real U.S. data, we modeled the incentives affecting consumers' decisions whether to replace under various scenarios. We surmised that three variables were particularly salient in determining replacement decisions: installation price, compensation rate (i.e., the going rate for solar energy sold to the grid), and module efficiency. If the cost of trading up is low enough, and the efficiency and compensation rate are high enough, we posit that rational consumers will make the switch, regardless of whether their existing panels have lived out a full 30 years.

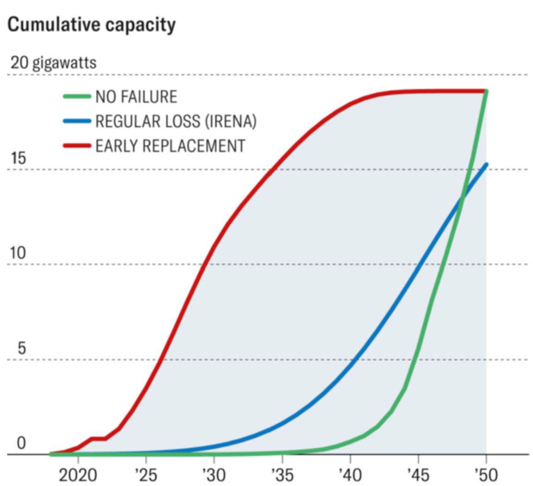
As an example, consider a hypothetical consumer (call her "Ms. Brown") living in California who installed solar panels on her home in 2011. Theoretically, she could keep the panels in place for 30 years, i.e., until 2041. At the time of installation, the total cost was $40,800, 30% of which was tax deductible thanks to the Solar Investment Tax Credit. In 2011, Ms. Brown could expect to generate 12,000 kilowatts of energy through her solar panels, or roughly $2,100 worth of electricity. In each following year, the efficiency of her panel decreases by approximately one percent due to module degradation.

Now imagine that in the year 2026, halfway through the life cycle of her equipment, Ms. Brown starts to look at her solar options again. She's heard the latest generation of panels are cheaper and more efficient — and when she does her homework, she finds that that is very much the case. Going by actual current projections,

the Ms. Brown of 2026 will find that costs associated with buying and installing solar panels have fallen by 70% from where they were in 2011. Moreover, the new-generation panels will yield $2,800 in annual revenue, $700 more than her existing setup when it was new. All told, upgrading her panels now rather than waiting another 15 years will increase the net present value (NPV) of her solar rig by more than $3,000 in 2011 dollars. If Ms. Brown is a rational actor, she will opt for early replacement. And if she were especially shrewd in money matters, she would have come to that decision even sooner — our calculations for the Ms. Brown scenario show the replacement NPV overtaking that of panel retention starting in 2021.

The Solar Trash Wave

According to our research, cumulative waste projections will rise far sooner and more sharply than most analysts expect, as the below graph shows. The green "no failure" line tracks the disposal of panels assuming that no faults occur over the 30-year life cycle; the blue line shows the official International Renewable Energy Agency (IRENA) forecast, which allows for some replacements earlier in the life cycle; and the red line represents waste projections predicted by our model.



Source: International Renewable Energy Agency, Electricity Data Browser, Global Solar Atlas

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If early replacements occur as predicted by our statistical model, they can produce 50 times more waste in just four years than IRENA anticipates. That figure translates to around 315,000 metric tonnes of waste, based on an estimate of 90 tonnes per MW weight-to-power ratio.

Alarming as they are, these stats may not do full justice to the crisis, as our analysis is restricted to residential installations. With commercial and industrial panels added to the picture, the scale of replacements could be much, much larger.

The High Cost of Solar Trash

The industry's current circular capacity is woefully unprepared for the deluge of waste that is likely to come. The financial incentive to invest in recycling has never been very strong in solar. While panels contain small amounts of valuable materials such as silver, they are mostly made of glass, an extremely low-value material. The long life span of solar panels also serves to disincentivize innovation in this area.

As a result, solar's production boom has left its recycling infrastructure in the dust. To give you some indication, First Solar is the sole U.S. panel manufacturer we know of with an up-and-running recycling initiative, which only applies to the company's own products at a global capacity of two million panels per year. With the current capacity, it costs an estimated $20–$30 to recycle one panel. Sending that same panel to a landfill would cost a mere $1–$2.

The direct cost of recycling is only part of the end-of-life burden, however. Panels are delicate, bulky pieces of equipment usually installed on rooftops in the residential context. Specialized labor is required to detach and remove them, lest they shatter to smithereens before they make it onto the truck. In addition, some governments may classify solar panels as hazardous waste, due to

the small amounts of heavy metals (cadmium, lead, etc.) they contain. This classification carries with it a string of expensive restrictions — hazardous waste can only be transported at designated times and via select routes, etc.

The totality of these unforeseen costs could crush industry competitiveness. If we plot future installations according to a logistic growth curve capped at 700 GW by 2050 (NREL's estimated ceiling for the U.S. residential market) alongside the early-replacement curve, we see the volume of waste surpassing that of new installations by the year 2031. By 2035, discarded panels would outweigh new units sold by 2.56 times. In turn, this would catapult the LCOE (levelized cost of energy, a measure of the overall cost of an energy-producing asset over its lifetime) to four times the current projection. The economics of solar — so bright-seeming from the vantage point of 2021 — would darken quickly as the industry sinks under the weight of its own trash.

Who Pays the Bill?

It will almost certainly fall to regulators to decide who will bear the cleanup costs. As waste from the first wave of early replacements piles up in the next few years, the U.S. government — starting with the states, but surely escalating to the federal level — will introduce solar panel recycling legislation. Conceivably, future regulations in the U.S. will follow the model of the European Union's WEEE Directive, a legal framework for the recycling and disposal of electronic waste throughout EU member states. The U.S. states that have enacted electronics-recycling legislation have mostly cleaved to the WEEE model. (The Directive was amended in 2014 to include solar panels.) In the EU, recycling responsibilities for past (historic) waste have been apportioned to manufacturers based on current market share.

A first step to forestalling disaster may be for solar panel producers to start lobbying for similar legislation in the United States immediately, instead of waiting for solar panels to start

clogging landfills. In our experience drafting and implementing the revision of the original WEEE Directive in the late 2000s, we found one of the biggest challenges in those early years was assigning responsibility for the vast amount of accumulated waste generated by companies no longer in the electronics business (so-called orphan waste).

In the case of solar, the problem is made even thornier by new rules out of Beijing that shave subsidies for solar panel producers while increasing mandatory competitive bidding for new solar projects. In an industry dominated by Chinese players, this ramps up the uncertainty factor. With reduced support from the central government, it's possible that some Chinese producers may fall out of the market. One of the reasons to push legislation now rather than later is to ensure that the responsibility for recycling the imminent first wave of waste is shared fairly by makers of the equipment concerned. If legislation comes too late, the remaining players may be forced to deal with the expensive mess that erstwhile Chinese producers left behind.

But first and foremost, the required solar panel recycling capacity has to be built, as part of a comprehensive end-of-life infrastructure also encompassing uninstallation, transportation, and (in the meantime) adequate storage facilities for solar waste. If even the most optimistic of our early-replacement forecasts are accurate, there may not be enough time for companies to accomplish this alone. Government subsidies are probably the only way to quickly develop capacity commensurate to the

magnitude of the looming waste problem. Corporate lobbyists can make a convincing case for government intervention, centered on the idea that waste is a negative externality of the rapid innovation necessary for widespread adoption of new energy technologies such as solar. The cost of creating end-of-life infrastructure for solar, therefore, is an inescapable part of the R&D package that goes along with supporting green energy.

It's Not Just Solar

The same problem is looming for other renewable-energy technologies. For example, barring a major increase in processing capability, experts expect that more than 720,000 tons worth of gargantuan wind-turbine blades will end up in U.S. landfills over the next 20 years. According to prevailing estimates, only five percent of electric-vehicle batteries are currently recycled — a lag that automakers are racing to rectify as sales figures for electric cars continue to rise as much as 40% year-on-year. The only essential difference between these green technologies and solar panels is that the latter doubles as a revenue-generating engine for the consumer. Two separate profit-seeking actors — panel producers and the end consumer — thus must be satisfied in order for adoption to occur at scale.

...

None of this should raise serious doubts about the future or necessity of renewables. The science is indisputable: Continuing to rely on fossil fuels to the extent we currently do will bequeath a damaged if not dying planet to future generations. Compared with all we stand to gain or lose, the four decades or so it will likely take for the economics of solar to stabilize to the point that consumers won't feel compelled to cut short the life cycle of their panels seems decidedly small. But that lofty purpose doesn't make the shift to renewable energy any easier in reality. Of all

sectors, sustainable technology can least afford to be shortsighted about the waste it creates. A strategy for entering the circular economy is absolutely essential — and the sooner, the better.

AA

Atalay Atasu is a professor of technology and operations management and the Bianca and James Pitt Chair in Environmental Sustainability at INSEAD.

SD

Serasu Duran is a professor at the University of Calgary's Haskayne School of Business in Calgary, Alberta.

LW

Luk N. Van Wassenhove is the Henry Ford Chaired Professor of Manufacturing, Emeritus, at INSEAD and leads its Humanitarian Research Group and its Sustainable Operations Initiative.

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- **40,000 pounds** – Average annual amount every American uses of newly mined materials
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- **$6 billion** – Value of minerals the U.S. imports from foreign countries, despite being home to reserves estimated at over $6 trillion
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- **$119 billion** – Annual U.S. revenues generated through mining

- **1,000%** – Projected increase in demand for minerals needed for future energy technologies, according to the Center for Strategic and International Studies
- **4,000%** – Increase in lithium demand by 2040 under the International Energy Agency's Sustainable Development Scenario
- **4.7 tons** – Amount of copper needed for a single wind turbine
- **330 metric tons** – Amount of gold the technology sector required in 2021
- **$2.45 billion** – Amount of platinum, which is used in 20 percent of all manufactured goods, that the U.S. imported from Russia in 2021
- **183 pounds / 439 pounds** – Amount of copper used on average in electric vehicles / Amount of copper used in the average American home
- **67%** – Portion of global zinc production used to coat steel for infrastructure and manufacturing to make it resistant to corrosion
- **105%** – Increase in global nickel demand by 2030 for transportation technologies
- **38%** – Portion of US electricity that comes from coal and nuclear energy powered by uranium
- **70%** – Portion of the world's steel that requires coal for production

- **35%** – CO2 emission reductions achieved through high efficiency, low emissions coal plants

- **$100 billion** – Amount coal plant owners have invested in advanced emissions control technologies over the last 20 years

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- **1.2 million +** – Number of direct and indirect jobs generated by the mining industry

- **$85,000 +** – Average annual salary for a U.S. miner (26% above avg. U.S. wage)

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Sincerely,

Ryan Jackson

Senior Vice President for Government and Political Affairs
rjackson@nma.org

CIRCUIT BREAKER:

Electrification won't break the grid, it will make it smarter.

By Sam Calisch (Rewiring America); Cora Wyent (Rewiring America)

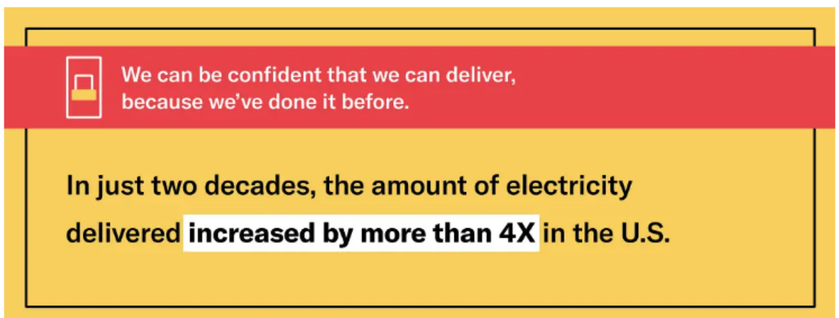
July 4, 2022

Focus points:

- To meet our climate goals, we'll need to deliver two to three times as much electricity as today. Fortunately, we've scaled the grid faster than this before and can do it again [1].
- Smart grid technologies can allow more electricity to be delivered by the same infrastructure, reducing the amount of new grid build-out and increasing resilience.
- Smart electric panels can enable whole home electrification, including EVs and heat pumps, largely without upgrading upstream infrastructure like wires or transformers, cutting the cost and time required for electrification.

To meet our climate goals, we must electrify nearly everything in our economy. That will require delivering about two to three times more electricity than we do today [2].

A share of this will come from clean solar energy generated right on our rooftops [3], but our grid will also need to grow significantly to deliver the remaining electricity demand. Skeptics of electrification say the grid won't be able to handle this [4], but history says otherwise. In just one decade, between 1950 and 1960, the amount of electricity delivered more than doubled in the U.S, and by 1970 it had more than doubled again [5], largely in response to the proliferation of uses for electricity beyond lighting [6]. As American households now similarly spur increased electricity demand to power electric vehicles and heat pumps [7], we can be confident that we can deliver, because we've done it before.



In order to grow the grid as efficiently and effectively as possible, we can leverage a host of technologies that make it smarter, more responsive and capable of delivering more electricity [8]. The cost of infrastructure – like wires and transformers – is driven by assumptions about worst case demand: the grid is typically designed to operate even if all consumers were to turn on nearly all of their devices at the same time. Because these events are so exceedingly rare, we aren't using these components to their full potential. A smarter grid would use the inherent flexibility of electricity demand [9] to avoid these situations altogether, allowing more electricity to be delivered by the same infrastructure.

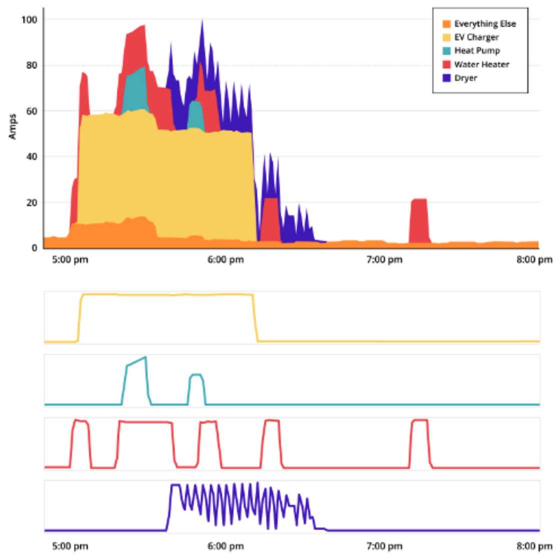
While this may seem far-away and complex, there are significant opportunities hiding right in our basements and utility closets, embodied in the humble electrical panel

[10]. These pieces of infrastructure are responsible for safely regulating the flow of electricity between the grid and loads in a building.

As homes electrify, adopting electric vehicles, heat pumps and electric stoves in place of fossil fuel machines, they may demand more electricity than the panel was originally designed for. Like other grid infrastructure, panels are sized for the peak electricity load: roughly the amount of electricity required if your electric vehicles, heat pump, water heater, stove and everything else is turned on at the same time [11]. This peak load, however, is 10-20 times higher than the average load over time [12]. Thus, if we can better manage peak events, substantially more electricity can be delivered without increasing panel capacity.

Fortunately, we have “smart panels”, which are electrical panels designed to do just this, measuring the flow of electricity and allowing individual circuits to be automatically turned on and off to regulate a home’s peak electricity demand. As an example, in Figure 1 at left, we show a peak event from an actual electrified home around dinner time, using data provided by SPAN, a leading manufacturer of smart panels. The householder likely arrived home from work, plugged in their car, started a load of laundry and turned up the thermostat. As a result, the total electricity drawn from the grid exceeded 80 amps for several minutes [13], exceeding a safe limit for a 100 amp panel [14]. If not for a smart panel, this household would likely have needed a 200 amp service upgrade when electrifying. On the right, we see the same event as could be mediated by the smart panel. By shifting 34 minutes of EV charging (shown in orange) with no inconvenience to the householder, the maximum load is kept below that 80 amp threshold at all times [15]. In data from SPAN’s electrical panels covering all contiguous U.S. climate zones, over 80 percent of peak events [16] were less than 12 minutes long, and shifting the operation of just one of the water heater, dryer, EV charger, or HVAC system can mitigate 90 percent of all peak events. These data indicate that the vast majority of peak loads could be shifted without any noticeable effect to the household.

A real-world peak event of over 80 amps around dinner time, caused by an EV charger, heat pump, water heater, and dryer all cycling on at the same time.



Sam Calisch, Rewiring America, Data from SPAN.i.o

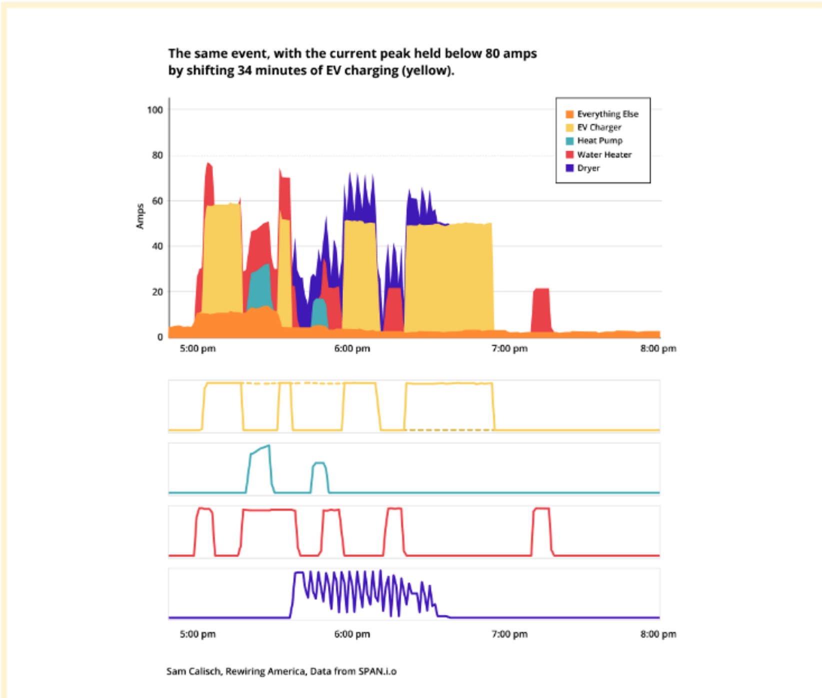


Figure 1: *Top) A real-world peak event of over 80 amps around dinner time, caused by an EV charger, heat pump, water heater, and dryer all cycling on at the same time. Bottom) The same event, with the current peak held below 80 amps by shifting 34 minutes of EV charging (orange). Data provided by Span.IO, Inc. and analyzed by Rewiring America.*

Today, approximately 50-60 million single-family homes (or approximately 60-70 percent) have electrical panels with ratings less than 200 amps [17]. If these households fully electrify (including two electric vehicle chargers, heat pump HVAC, heat pump water heating, electric range, and electric dryer), it is likely that most will need a new, larger electrical panel [18]. If this new panel is not a smart panel, a further upgrade to the incoming electrical service (that is, the wires carrying electricity from the street) may also be required. While buying a smart panel is

incrementally more expensive than a conventional panel, the avoided costs of a resulting service upgrade can be hefty [19]. Particularly for households receiving electrical service through underground wires, the avoided costs are likely to pay for the smart panel upgrade many times over.

To encourage electrification, policymakers should provide incentives to homeowners to reduce the costs of panel upgrades, especially for low- and moderate-income households. For example, the climate provisions of the 2021 budget reconciliation bill passed by the House of Representatives [20] included direct rebates of up to $3,000 for this. The Senate should move quickly to pass this legislation with these measures intact. Utilities can also play a role, providing information on smart panels and incentives to defray the upfront cost premium when a customer applies for a service upgrade [21]. Further, the National Fire Protection Association's Committee on the National Electrical Code should modernize regulations on electrical panel sizing to clarify that smart panels allow extra load to be added to an existing electrical service. Finally, in cases where a service upgrade is unavoidable, utility regulators should reallocate subsidies for natural gas connections [22] to electrical service upgrades.

Our grid today is built for the worst-case scenario: the short, rare instances where households are using all of their machines at once. This is an inefficient use of electric infrastructure, and makes scaling our electric grid to support an increasingly electrified economy harder than it needs to be. Smart grid technologies like smart panels can maintain the necessary reliability and resiliency of the grid, while allowing us to scale our infrastructure more efficiently and cost-effectively.

Sam Calisch is the Head of Special Projects at Rewiring America, where he conducts research, writes, and occasionally dresses like a heat pump. He also is a founder of Channing Street Copper, a start-up broadening access to electrification by commercializing a retrofit-ready induction range. Previously, Sam was a Research Fellow at Lawrence Berkeley National Lab and has run projects with the National Science Foundation and Department of Energy. Sam completed his PhD at MIT and BA at Grinnell College.

Cora Wyent is a Research Associate at Rewiring America, where she is conducting research and analysis to enable rapid electrification of everything in the economy. She completed her PhD in Physics at Caltech, where she studied new materials for ultrathin solar cells and performed technoeconomic analysis of new photovoltaic and carbon capture technologies. Cora received her bachelor's degree in Physics from UNC Chapel Hill. She currently lives in Los Angeles with her wife and their cat.

Acknowledgement:

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Notes:

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[1] Grid expansion and resilience is a huge topic – in this article we focus on technologies near the point of use, namely smart panels. Consider this to be part one of a series on the larger topic.

[2] In The Rewiring America Handbook (Saul Griffith, Sam Calisch and Laura Fraser, July 2020) and Electrify (Saul Griffith, MIT Press, 2021), the authors show how the U.S. economy can be run on roughly 45 Quads of energy per year. Over the 8,760 hours in the year, this amount of energy is equivalent to an average power of 1500GW. Arguing conservatively, we ignore the biofuels and other non-electric energy sources likely to be responsible for a portion of this total, and assume all of this energy is supplied by electricity. In contrast, according to the EIA, today we deliver approximately 4.1 million GWh over the 8,760 hours of the year. This is equivalent to an average power of approximately 470 GW. Thus, in this nearly-completely electrified future scenario, we need to supply about 3.2 times as much electricity as we do today.

The IPCC also estimates the increase in electricity delivered, assuming the use of biofuels, carbon capture and sequestration, hydrogen, and significant behavior change for demand side mitigation. To achieve a likely 2°C temperature rise, approximately 200 to 225 EJ of electricity per year are required globally (See AR6 WGIII Figure 3.23). This represents an increase of approximately 2.2 to 2.5 times over today's levels.

In the IEA Net Zero scenario (see Net Zero by 2050 - A Roadmap for the Global Energy Sector Figure 3.9), the electricity demand is expected to double by 2050 in "advanced economies" like the U.S.

These estimates are based on a top-down energy transition model based on climate goals. In contrast, other studies use a bottom-up technology adoption model based on current trends. These studies generally find the increase to the amount of delivered electricity to be lower. For example, in NREL's Electrification Futures Study, the "High" adoption scenario projects an increase in delivered electricity of roughly 160%. This scenario is based on "a combination of technology breakthroughs, policy support, and underlying societal and behavioral shifts that yield an electrification transition." The rate of adoption is "impacted by a wide range of factors including economic trade-offs, consumer preference, and policies".

[3] According to a 2016 NREL study, our collective rooftops represent about 1,118 GW of potential solar capacity. After subtracting the roughly 27GW of small scale solar currently installed (see EIA Table 4.3. Existing capacity by energy source), the difference is remarkably close to the additional capacity needed, even at the upper estimates of increased demand. However, after taking into account the economic feasibility of each installation, and the need to supply power to match demand, the amount likely to be deployed is likely less.

[4] Much of this skepticism is not based in fact, but there are legitimate concerns about ensuring adequate investment in the grid. In places where adoption of electrification has taken off and investments have not kept pace, there are signs of strain. For a good narrative description of such a scenario, see Old Power Gear Is Slowing Use of Clean Energy and Electric Cars, Ivan Penn, The New York Times. For quantitative analysis, see Can Distribution Grid Infrastructure Accommodate Residential Electrification and Electric Vehicle Adoption in Northern California?, Anna Brockway, Duncan Callaway, and Salma Elmallah, June 2022.

[5] According to the EIA's Table 7.2a Electricity Net Generation: Total (All Sectors), in 1950, 334 GWh were delivered. By 1960, 759 GWh were delivered, a 227% increase. By 1970, 1,535 GWh were delivered, a 202 percent increase over 1960 and a 460 percent increase over 1950!

[6] Major national campaigns were used in this time to spread public awareness, including the Live Better Electrically: The Gold Medallion Electric Home Campaign by General Electric and Westinghouse.

This campaign extolled the virtues of electric appliances and featured then-actor Ronald Reagan as the main spokesperson.

[7] See Argonne National Lab's Light Duty Electric Drive Vehicles Monthly Sales Updates and the Air Conditioning, Heating, and Refrigeration Institute's Central Air Conditioners and Air-Source Heat Pumps Sales Data.

[8] To date, these technologies have been referred to as the "smart grid", where information about grid conditions is passed alongside the electricity in order to increase resilience and efficiency. See Grid Modernization and the Smart Grid | Department of Energy and Demand Response | Department of Energy.

[9] See FERC's National Action Plan on Demand Response for examples.

[10] The electrical panel (also known as breaker box, panelboard, distribution board, switch box, and probably more) is responsible for safely delivering electricity from the utility's power lines to your home's outlets and appliances. Electricity first travels from the power lines on the street through either underground or above-ground service wires. It passes through a second set of service entrance wires, through your meter, and then arrives at your electrical panel. The electrical panel splits the electricity into different circuits for the locations and appliances in your home. The utility owns the service wires and the meter, and the customer owns everything else: the service entrance wires, the electrical panel, and the wires that distribute electricity throughout the home.

[11] When installing a new circuit for such an appliance, an electrician sizes an electrical panel by calculating a given home's peak electricity usage, summing up how much electricity all of the appliances and loads would use if they were turned on at the same time. An example of an electrical load calculation worksheet is shown here. A few example homes are shown on Redwood Energy's Watt Diet Calculator, and Pecan Street's study Addressing an Electrification Roadblock: Residential Electric Panel Capacity. A typical electrified 2000-square foot home might have approximately the following loads:

- Lighting = 6 kVA
- EV charger = 10 kVA
- Electric cooktop & oven = 10 kVA
- Electric dryer = 5 kVA
- Heat pump (no back-up heat) = 5 kVA
- Heat pump water heater = 5 kVA
- Dishwasher, microwave, washing machine, garbage disposal, 2 x other appliances = 1.5 kVA each

This sums to 50 kVA total. Per the National Electric Code (NEC), to size an electrical panel, we sum up 1) 100 percent of the first 10 kVA, then 40 percent of the remaining kVA, for lighting and appliance loads, and 3) all of the heating/cooling load (whichever is greater if separate appliances are used for heating and cooling). For this home, that yields 10 + 0.4*35 + 5 = 29 kVA, which is 121 A after dividing by 240V. With traditional electrical panels and no circuit-sharing devices, this home would need a 150 A or 200 A electrical panel. Having solar panels could further increase the necessary amperage.

[12] This figure is based on data from over 1,000 homes with smart panels provided by SPAN. Peak loads are evaluated as a maximum of current measurements taken every second through the main breaker, while averages are the total energy delivered through the main breaker divided by the time in operation. There is some regional variation in this ratio, with the "Very Cold" climate region having average values near 20, while "Mixed Humid" region had values of approximately 10. See DOE Building America Climate Zone Guide for climate zone definitions.

[13] The amp (short for ampere) is the unit of electrical current, or flow of electricity. Electrical panels are measured by how many amps they can provide. Older, smaller houses may have panels that can provide 60 or 100 amps, while newer, larger houses likely have 200 amp panels.

[14] This can be confusing, but in short, 80 amps is considered a safe, conservative, continuous load limit for a 100 amp panel. The National Electric Code rules for load sizing are complex (see NFPA 70: National Electrical Code) and not designed with active load management in mind. However, conductor sizes and overcurrent protection for feeders and services are specified so continuous loads are limited to 80 percent of the overcurrent limit (See 215.3 and 230.42(A)(1) of the NEC). Further, most standard circuit breakers themselves are only designed to sustain 80 percent of their nameplate ratings for an extended period of time (i.e., 80 percent of the number of amps that will cause the breaker to trip and disconnect the circuit). See Clearing up Confusion over 80% vs. 100%-rated Circuit Breakers, Schneider Electric Blog. Even with continuous loads limited to 80 amps, startup surges will create brief spikes above this baseline. If the continuous load baseline were higher, these spikes would frequently trip the main breaker, cutting power to the house and inconveniencing the homeowner.

Finally, the house from which this data comes actually had a panel larger than 100 amps, but we use this threshold to illustrate the common case of electrification with this panel size.

[15] The majority of home electrical loads, like water heaters and HVAC equipment, operate cyclically, turning full-on for a period, and then full-off for a period, supplying the right amount of average power to keep the house comfy and the water hot. Because of this, under most conditions, such loads can be synchronized to avoid turning on at the same time without any noticeable interruption in service to the homeowner. Other loads (like electric vehicle charging) can be easily shifted within a window of time (e.g., when the car is plugged in) in order to avoid drawing too much electricity.

[16] Here "peak event" is defined as any instance where total load exceeds 80 amps.

[17] To our knowledge, there is no complete data on US-wide panel sizes. Three independent sources give us the 60 percent estimate. First, the Addressing an Electrification Roadblock: Residential Electric Panel Capacity study from Pecan Street looked at a sample of 263 Texas homes and extrapolated to the US, finding that 48 million single-family households (out of 86 million total single-family households) would likely need a panel upgrade in order to electrify. In their Texas sample, 60 percent of homes have electrical panels sized below 200A. Second, the Service Upgrades for Electrification Retrofits Study Draft Report estimates that 70 percent of California homes have at least 100A panels based on year of construction. (This overestimates the number of <200A panels because it includes those with larger panels, but underestimates because it excludes those who upgraded their panels to install air conditioning. As all new construction in CA must have 200A panels, we assume that the number with less than 200A panels is around 60 percent). Third, we can assume as a general rule of thumb that single-family homes 2500 square feet and over have at least 200A panels, and most homes that are less than 2500 square feet have less than 200A panels. According to the Residential Energy Consumption Survey, about 70 percent of US homes are under 2500 square feet in size. This is certainly a rough estimate, and better data on electrical panel sizes across the US is needed.

[18] There are additional methods that allow households to electrify while avoiding electrical panel and service upgrades in some cases. Circuit-sharing plugs allow two colocated appliances that use a lot of electricity, like an EV charger and a clothes dryer in a garage, to share a plug and gracefully avoid turning on at the same time. Two examples of companies that sell circuit-sharing devices are NeoCharge and Splitvolt. Smart breakers can also provide some of the functionality of a smart panel for individual circuits. Another option is use of a meter collar, such as this one from Siemens and ConnectDER, which installs between the existing electric meter and meter socket. In addition to avoiding upgrading the electric panel, these collars can monitor the total load and modulate the downstream circuit (such as an EV charger) to stay within the limits of the incoming service.

Alternatively, households can also select power-efficient appliances and lower amp EV chargers to keep their electrical needs under 100 amps. Several handy electricity budget calculators exist to help with this. For instance, Redwood Energy's Watt Diet calculator can help households and electricians size electrical panels, and select power-efficient appliances in order to avoid panel and service upgrades. For example, although 50-amp circuits are commonly used for EV charging, a 20-amp circuit can provide 100 miles of charge overnight, more than enough for most people to get to and from work each day. Power-efficient appliances are coming to the market, including 120-volt heat pump water heaters, 120-volt stovetops and ranges, and 120-volt ductless mini-split heat pumps, as well as lower-amp versions of those appliances.

[19] Electrical service upgrades can be lengthy and expensive, involving swapping out the wires that connect your house to the power lines on the street with larger ones. In some cases, it may also involve some other upstream upgrades, such as swapping out transformers and high voltage power lines. Because of the need for trained technicians and shutting off electricity to the lines, service upgrades can take upwards of six months, and can cost anywhere from $2,000–$30,000, without including the electrical panel upgrade. Though the utility typically covers a portion of the costs, even the costs that the utility covers will ultimately be distributed among ratepayers. If we assume a cost of $5,000 per home for a service upgrade, the cost to upgrade electrical service on all homes in the U.S. would be roughly $250 billion.

The total project costs can be broken into three categories: 1) the cost of the electrical panel, 2) the cost of the service line replacement, and 3) other related costs, such as replacing the pole and transformer. Within each of these categories, there are costs associated with labor, materials, and permits, and all are incorporated into the following cost estimates. The cost of the electrical panel is always the customer's responsibility, and can range from $2,000–$4,500. The cost of the service line replacement is supposed to be covered by a service extension allowance, which is in the range of $2000–$3000 and represents the average cost paid by the utility. Customers are responsible for any costs above that allowance. Any project that is not a simple above-ground line replacement (e.g. if service wires are underground) is likely to exceed the allowance, and can cost up to $16,000. Replacing the pole and the transformer is the customer's responsibility if they are the only customer on the transformer, the utility's responsibility if there are three or more customers on the transformer, and split otherwise. A transformer replacement can cost $6,000–$8,000, and a pole replacement can cost $9,000–$11,000. In total, the cost to upgrade the electrical service (not including the electrical panel upgrade) can range from $2,000 to upwards of $30,000. See the Service Upgrades for Electrification Retrofits Study Draft Report.

Beyond cost, the long timelines of service upgrades can be a deterrent for consumers considering electrification, and can often result in customers deciding instead to purchase new gas-powered appliances, locking in fossil fuel usage for decades.

[20] In the text passed by the House (see 117th Congress (2021-2022): Build Back Better Act), electric service panels rebates are included in the High-Efficiency Electric Home Rebate program. In the Senate finance committee text (see TITLE XII—COMMITTEE ON FINANCE), electric panels are also included in the 25C residential energy property tax credit.

[21] It is important to note that the ideal time for a customer to install a smart panel is when they are already doing a panel upgrade, since there is typically no incremental installation cost, only a minor incremental hardware cost.

[22] For example, see Revisiting California's natural gas hookup subsidies, Utility Dive.

CIRCUIT BREAKER:

Exporting oil and gas does not create energy independence, electrification does.

By Sam Calisch (Rewiring America)

May 5, 2022

Focus points:

- Even though the U.S. now exports more oil and gas than it imports (often called "energy independence"), we remain very dependent on world energy markets, buying and selling fossil fuels at prices we don't control.
- There are technical, economic, and political reasons for this, but the result is the same: global fossil fuel price volatility exposes everyday Americans to economic hardship, a fact laid bare by the 2022 invasion of Ukraine.
- There is, however, a path to true energy independence: full electrification powered by renewable energy. This not only results in low, stable energy prices, but also combats the existential threat of climate change.

In 2019, the U.S. became a net exporter of energy for the first time in nearly 70 years [1]. In other words, it sold more oil and gas to other countries than it bought from them. This shift was largely driven by the shale revolution, where hydraulic fracturing ("fracking") and horizontal drilling enabled access to previously unreachable oil and gas deposits [2] and the adoption of liquefied natural gas (LNG) export facilities, which allowed gas to be shipped around the world just like oil [3].

Did you know?

Even now, as a net exporter of energy the U.S. does not get to set prices for fuels.

Much has been said about how being a net exporter of energy establishes the U.S. as "energy independent," theoretically making it immune to changes in supply and demand of energy across the world. As the argument goes, if geopolitical events upset global energy markets, the U.S. can keep energy affordable by using its own production to meet domestic demand [4].

This argument is flawed in several ways.

The first flaw is that fossil fuels are commodities traded on global markets and exposed to global prices. Because of this, even now, as a net exporter of energy, the U.S. does not get to set prices for fuels.

> The destabilization of energy markets following the 2022 invasion of Ukraine by Russia has laid these forces bare.[10]
>
> **The price of gasoline, required to get Americans to work every day, has risen by 54 percent over the last year, representing an additional $800 of annual spending for the average household.[11]**

These prices fluctuate based on global events, and the U.S. is forced to handle the resulting volatility.

Second, for technical reasons we cannot just use our own oil and gas exclusively. In the case of oil, this is because crude oil (what comes out of the ground) is not used directly; it must first be refined into gasoline, diesel, kerosene, distillates, and other products by selling crude oil to a vast network of refineries across the globe. Further, not all crude oil is the same. U.S. refineries are mostly set up to process “heavy” crude oils, but our domestically produced crude tends to be “light” [5]. Because of this, the U.S. imports a substantial amount of heavier crude oil to operate the domestic refinery fleet economically.

In the gas market, many regions of the country lack sufficient infrastructure to transport and store natural gas, and hence must rely on imports, typically liquefied natural gas (LNG), to meet demand. For instance, New England lacks any gas production or storage facilities, and is isolated from domestic LNG supply by Jones Act shipping restrictions [6]. Hence, when demand outstrips supply in the winter heating season, international LNG imports are the region’s only option to keep households’ gas furnaces and water heaters running [7]. Thus, despite being the

world's largest natural gas producer, the U.S. still must import significant quantities of natural gas [8].

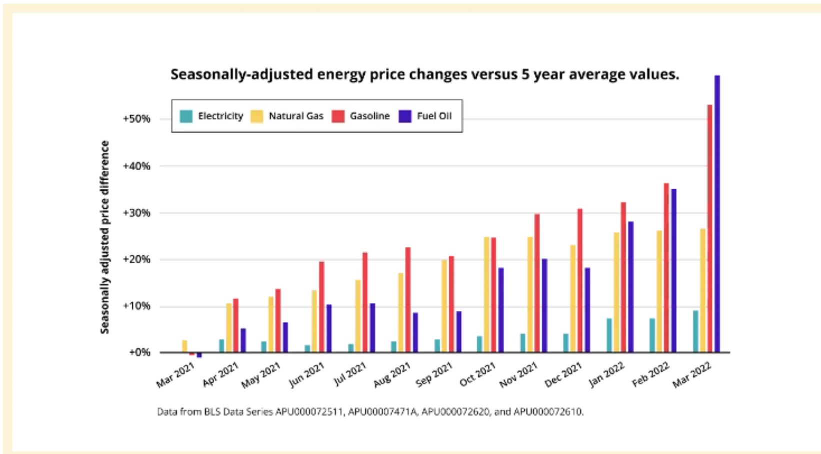

Figure 1: Seasonally-adjusted energy price changes versus 5 year average values. Data from BLS Data Series APU000072511, APU00007471A, APU000072620, and APU000072610.

The third flaw in the argument is that it ignores how volatility in the global price of fossil fuels hits everyday Americans. The households depending on gasoline-powered cars to get to work and gas furnaces to stay warm have no recourse when energy prices go up. The small businesses struggling to keep their doors open must pay their bills, even when they rise unexpectedly. Meanwhile fossil fuel companies rake in record profits as their products are suddenly more valuable, and those who depend on them will continue to pay, despite the high prices. In these times, the government steps in to set domestic and international policies to alleviate hardships on those affected [9]. This mechanism is yet another reason the U.S. is not "independent" from the global energy markets, despite being a net exporter.

The destabilization of energy markets following the 2022 invasion of Ukraine by Russia has laid these forces bare [10]. The price of gasoline, required to get

Americans to work every day, has risen by 54 percent over the last year, representing an additional $800 of annual spending for the average household [11]. Prices of heating oil, used for space and water heating by over seven million American households [12], rose by 72 percent over the last year, representing an additional $960 of annual spending for the average household [13].

Fortunately, there is a path to true American energy independence: electrification.

Using electricity is cheaper and less volatile than using fossil fuels. As an example, see Figure 1, showing price changes over the last year of common fuels compared to their five year average price [14]. As we have seen, prices for fossil fuels have risen rapidly over the past year, especially in 2022. In contrast, electricity prices have remained relatively low and stable, rising roughly three times less than even natural gas, the fossil fuel often touted as affordable [15]. Why is this?

First, electricity markets are inherently local, not global [16]. Today, the average distance between households and the nearest major electricity generation facility is just 5 miles [17]. If that electricity comes from a rooftop or community solar project, this distance is even less. Long distance transmission lines do move electricity around the U.S., but major international trade is not possible. In contrast to fossil fuels, dollars spent on electricity largely stay inside the U.S., if not within your community [18].

Second, the price of electricity produced by cheap renewables like wind and solar is inherently stable. Because the wind and sun are free, the cost of this renewable electricity is largely set by taking the upfront costs to build the solar or wind farm and simply spreading them out over the 20-30 year lifetime [19]. Without unpredictable fuel prices, wind and solar can provide stable, low cost electricity and protect consumers from energy price shocks. Today, the price of electricity still exhibits some volatility because fossil fuels are used to power a portion of the grid. This volatility is diluted, however, by the financed cost of power plant capital equipment, as well as the portion of electricity supplied by renewables. Over the past year, however, 17

states got the majority of their electricity from stable, clean sources [20]. As this number continues to grow, the price of electricity will become even more stable.

As we have seen, the notion that exporting oil and gas makes the U.S. energy independent is not true, and current trends make this clear. In contrast, electrification really is a path to true energy independence, combating not only the burden of rising fuel prices but also the worst effects of climate change. The U.S. should double down on clean energy technologies and electrification investments today. We have the technology we need today to be energy independent, and electrifying everything is the key.

Sam Calisch is the Head of Special Projects at Rewiring America, where he conducts research, writes, and occasionally dresses like a heat pump. He also is a founder of Channing Street Copper, a start-up broadening access to electrification by commercializing a retrofit-ready induction range. Previously, Sam was a Research Fellow at Lawrence Berkeley National Lab and has run projects with the National Science Foundation and Department of Energy. Sam completed his PhD at MIT and BA at Grinnell College.

Notes:

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[1] In the 1950s, the U.S. imported only about 2 Quads of energy (quadrillion British thermal units), while exporting approximately the same amount. Both amounts were small compared to the roughly 30-40 Quads of energy that were produced and consumed domestically. Over the next 20 years, consumption approximately doubled, while production grew more slowly. As a result, imports grew by roughly ten times, while exports remained roughly the same. This state of being a net energy importer remained true until 2019, when the rapid rise in domestic production fueled by the shale revolution reached a point when exports surpassed imports. See the EIA's Monthly Energy Review.

[2] Widespread use of fracking and horizontal drilling have increased access to previously-unreachable oil and gas formations, and are largely responsible for the dramatic rise in U.S. energy production in

the last ten years (See the EIA's SEDS Data). The use of these techniques has also had significant negative effects, including groundwater and soil contamination, methane pollution, fracking-induced earthquakes, and a host of public health risks. See Natural Gas Operations From a Public Health Perspective, Methane and the greenhouse-gas footprint of natural gas from shale formations, Human health risk assessment of air emissions from development of unconventional natural gas resources. For a good discussion of the shale revolution and U.S. energy policy, see the IEA's Energy Policies of IEA Countries: United States 2019 Review.

[3] Liquefied natural gas (LNG) is a way to ship gas in much the same way we ship oil. The key to this is cooling the gas down to -260 degrees Fahrenheit, at which point it becomes a liquid, and has a volume roughly 600 times smaller than when it was a gas at standard pressure and room temperature. This shrink is key to fitting enough gas on a ship to be economically feasible. Between 2015 and 2020, the amount of LNG exports from the U.S. increased by approximately ten times. Critically, this liquefaction process takes a good deal of energy – the EIA estimates that 15-18% of the gas transported as LNG is consumed by the process requirements. See Natural gas explained: Liquefied natural gas, U.S. EIA and Liquefied Natural Gas (LNG), Office of Fossil Energy and Carbon Management, U.S. DOE

[4] The notion of energy independence largely dates to the 1970s, when the U.S. became a net oil importer, and an oil embargo was placed against the U.S. in retaliation for actions taken in the 1973 Arab-Israeli War. President Nixon created "Project Independence," a plan to eliminate imports of foreign oil (a good historical timeline is given in Energy Independence: A Short History). The U.S. then passed the Energy Policy and Conservation Act (EPCA) in 1975, which created the Strategic Petroleum Reserve and the first fuel economy targets for automobiles. The EPCA also included the Crude Oil Export Ban, which eliminated nearly all exports of domestic oil.

In 2015, after 40 years in effect, the ban was repealed in the Consolidated Appropriations Act of 2016. Despite this, after the ban was lifted U.S. oil imports remained largely unchanged. See the EIA's US Imports of Crude Oil and Petroleum Products for data, and the GAO's Effects of the Repeal of the Crude Oil Export Ban for discussion.

[5] The "heavy" and "light" designations refer to the oil density, as measured by API gravity, named after the American Petroleum Institute. A light oil has a high API gravity (>31), while heavy oils have low API gravity (<22). The shale formations associated with the increase in U.S. domestic production generally contain light crude oils (see the EIA's Crude Oil and Lease Condensate Production by API Gravity, Percentages of Total Imported Crude Oil by API Gravity, and Today in Energy: August 23, 2019). Another important parameter of crude oil is sulfur content. Low sulfur content oils are called "sweet", while higher sulfur content is called "sour".

[6] The Merchant Marine Act of 1920 (also known as the Jones Act) is a major U.S. statute pertaining to commercial maritime shipping, put in place after World War I to build the domestic shipping industry. The statute states that any ship moving goods from one domestic port to another must be built, owned, and operated by American citizens or permanent residents. A vessel meeting the requirements of the statute is often called Jones-Act-compliant.

There are currently no Jones-Act-compliant LNG tankers capable of transporting bulk quantities of LNG. According to the CATO Institute, as of 2019 there were only two compliant barges, but barges differ from tankers in that they carry significantly less LNG (40-70x less in this case), and are meant for refueling other vessels running on LNG rather than transporting large quantities of LNG to port. Shell and Crowley recently announced building the largest Jones-Act-compliant LNG barge to date, set to be placed in service in 2024, but its capacity is still about 15x less than a common tanker size, and is slated to be used for refueling other ships. The lack of compliant tanker vessels is largely driven by the high cost of building in American shipyards. Industry experts estimate building a Jones-Act compliant LNG tanker would cost approximately $500 million, about three times more than building the same vessel in an Asian shipyard. The Jones Act has accumulated considerable political support (including Senator Mitch McConnell), and any changes to it would face a considerable uphill battle.

[7] The EIA's New England Dashboard contains detailed information on the region's natural gas infrastructure, including LNG terminals. The Natural Gas Weekly Update contains data on overall U.S. deliveries by LNG tanker and pipeline, as well as the state of national storage facilities. The Underground Natural Gas Working Storage Capacity reports that natural gas storage capacity was essentially unchanged during 2020. The 2021 article, The Role of Liquefied Natural Gas in the US Gas Market, contains a discussion of LNG and the constraints in New England.

[8] Data on natural gas production by country are available from the EIA here. Data on U.S. natural gas import quantities are available from the EIA here.

[9] A poignant example is the recent and unprecedented release of one million additional barrels per day from the U.S. strategic reserve. See FACT SHEET: President Biden's Plan to Respond to Putin's Price Hike at the Pump | The White House.

[10] The dramatic rise in fossil fuel prices during the last six months are the combination of two major events. First, extreme weather and supply chain shortages disrupted production during the summer of 2021. This led to historically low levels of gas in storage reservoirs leading into the winter. (See the IEA's What is behind soaring energy prices and what happens next? and Rewiring America's Energy Bill Security for American Households Through Electrification). Then, in February 2022, Russia's invasion of Ukraine sent prices still higher, as many countries moved to stop importing oil from Russia.

[11] Gasoline price data is available from the Bureau of Labor Statistics (BLS) as series APU00007471A. Annual household spending on gasoline ($1,447) is available in the BLS Consumer Expenditure Survey. For the lowest income decile, over 11% of pretax income goes to gasoline. With price increases, this rises to 18%. See Table 1110. Deciles of income before taxes: Annual expenditure means, shares, standard errors, and coefficients of variation, Consumer Expenditure Surveys, 2020.

[12] The U.S. Census Bureau's American Housing Survey finds that approximately 7.3 million households use fuel oil for space or water heating, and that 5.7 million of these use it as their primary fuel. The EIA estimates more conservatively; according to the March 2022 Short Term Energy Outlook Table WF01, 5.3 million households use fuel oil as their main heating fuel. Together these households consume approximately 3 billion gallons per year of fuel oil for residential space and water heating, according to the EIA's Fuel Oil and Kerosene Sales Report. This is the highest consumption of distillate oil (the class of products including diesel and fuel oil) after use on roads and farms.

[13] Fuel oil price data is available from the Bureau of Labor Statistics (BLS) as series APU000072511. Annual household spending on fuel oil ($1,328) is available in the Energy Information Administration's Short Term Energy Outlook Table WF01.

[14] Data from BLS Data Series APU000072511, APU00007471A, APU000072620, and APU000072610. Propane prices are not included as a series by the BLS, but are available from the EIA here, though only for six months of the year.

[15] Clearly, a large number of electric power plants run on fossil fuels, and hence are impacted by global markets, but this only represents a small component of the price seen by the end consumer, and hence the volatility is reduced.

[16] Of the annual U.S. electricity demand, just 1% is imported, almost exclusively from Canada to states just across the border. The EIA International Electricity data contains year-over-year electricity imports, showing the U.S. imports approximately 60 billion kWh per year, almost exclusively from Canada.

[17] This value is calculated based on the EIA's location data for all generating facilities in the U.S., available from the EIA's Form EIA-860 detailed data with previous form data (EIA-860A/860B) and visualized in the Electricity Data Browser. For every census tract in the U.S., we calculate the distance from the tract centroid to the closest generating facility, and then compute a population-weighted average over all census tracts using data from the Census Bureau's Population and Housing Unit Estimates Datasets.

[18] For a discussion of where money spent on gasoline goes, see the Union of Concerned Scientists' Where Your Gas Money Goes and the EIA's Gasoline Pump Components History.

Critics of electrification may object that dollars spent on capital upgrades like solar and electric vehicles are destined for overseas because the panels and batteries are manufactured abroad. These hardware costs, however, are only a small portion of the cost of these goods. For instance, according to NREL's US Solar Photovoltaic System and Energy Storage Cost Benchmarks: Q1 2021, panels were just 13% of the cost of a residential photovoltaic system. The largest portions of the remainder are domestic expenditures like sales and marketing, installer profit and overhead, and various balance-of-system components. In the case of EVs, according to the International Council on Clean Transportation's Update on electric vehicle costs in the United States through 2030, battery costs are approximately one-third of vehicle costs.

[19] This is called the "levelized cost of electricity" (LCOE). The financial management firm Lazard regularly publishes its data on LCOE, and NREL regularly publishes up-to-date analysis. Besides the upfront capital costs of a solar or wind farm, there are additional operations and maintenance (O&M) costs. These have very minor impact on the price of renewable electricity because they make up just 1.5% of the solar LCOE according to NREL's 2021 Solar Benchmark and 4% of wind LCOE according to NREL's 2020 Cost of Wind Energy Review. Further, these costs themselves are quite stable, as they consist of line items like regular solar panel cleaning, vegetation trimming, inspection, property taxes, and insurance payments.

[20] Monthly net electricity generation by source by state is available from the EIA here. The 17 states with more than half of their generation from clean sources from 2021 to 2022 are CA, IA, ID, IL, KS, ME, MN, MT, NH, NJ, NY, OR, SC, SD, TN, VT, WA. Further, 33 states obtained over a third of their generation from clean sources.

Today's Electric Vehicles Can Greatly Reduce Emissions From Driving

March 20, 2023 | 2:03 pm

David Reichmuth

Senior Engineer, Clean Transportation Program

Transportation is the largest source of global warming emissions in the US and the passenger vehicles many of us drive are responsible for the majority of transportation global warming emissions. Avoiding the worst impacts of climate change will require the rapid reduction in these emissions from the vehicles we drive. Electric vehicles (EVs) can eliminate tailpipe emissions altogether and are also more efficient than gasoline vehicles making EVs an important technology for reducing both global-warming and harmful air pollution from personal transportation.

In 2022, my colleagues and I analyzed the global warming emissions benefits of electric cars and trucks in our report "Driving Cleaner." Earlier this year, the EPA released newer power plant emissions data, which I've used to update our assessment of the relative benefit of driving an EV as compared to the gasoline alternative.

As new, more affordable EV models like this Chevy Equinox become

available, more drivers will be able to reduce their emissions from driving. (UCS/Reichmuth)

Comparing EV and gasoline vehicle emissions

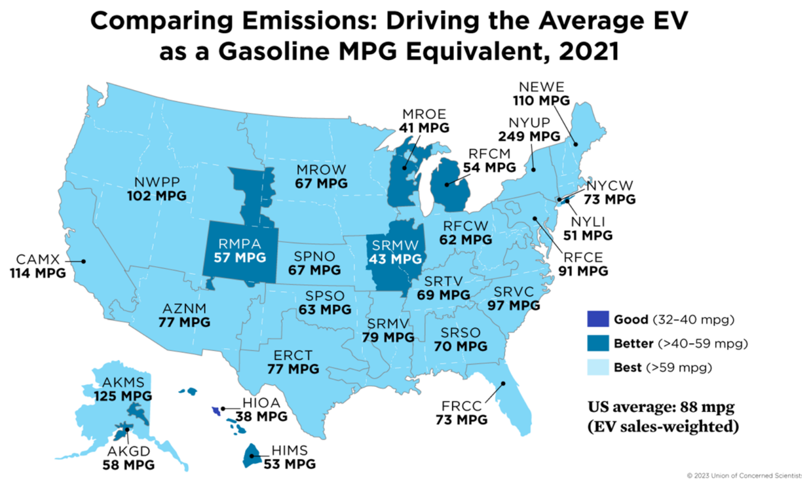
When we compare driving on electricity versus gasoline, we consider the global warming emissions that occur in producing and using those fuels. For a fully-electric EV, that means:

- Emissions that result from raw-material extraction, such as coal mining and natural gas drilling;
- Emissions from delivering these fuels to power plants;
- Emissions from burning those fuels in power plants to generate electricity;
- Electricity losses that occur during distribution from power plants to the point where the electric vehicle is plugged in; and
- The efficiency of the vehicle in using electricity.

Similarly, our assessment of the global warming emissions from comparable gasoline and diesel vehicles addresses emissions that result from:

- Oil extraction at the well;
- Transporting crude oil to a refinery;
- Refining oil into gasoline;
- Delivering fuel to gas stations; and
- Combusting fuel in the vehicle's engine.

Because of differences in electricity generation across the United States, the emissions produced from driving the average EV varies depending on where the vehicle is driven. Despite this variance, driving the *average* EV results in lower emissions than the *average* new gasoline vehicle everywhere in the United States.

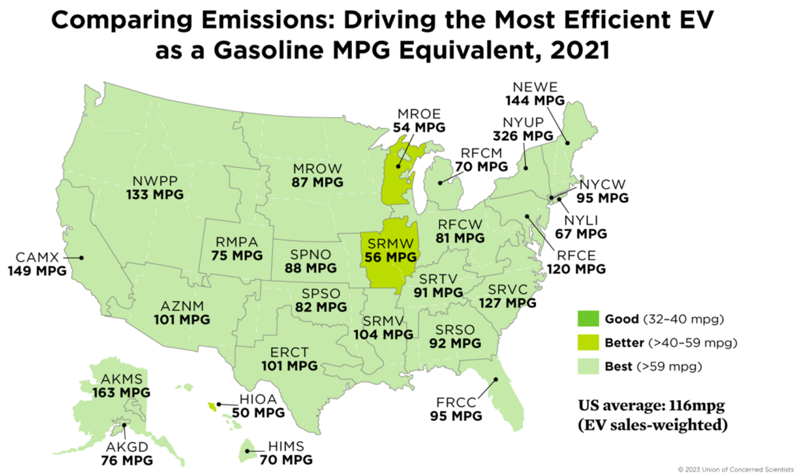


Over 90 percent of people in the United States live where driving the average EV produces fewer global warming emissions than the most efficient gasoline vehicle (57 mpg). Based on where EVs have been sold in the United States, driving on electricity produces emissions equal to those of a gasoline car getting 88 miles per gallon. Note: Acronyms refer to electricity grid regions as defined by EPA's eGRID database.

Driving a more efficient EV maximizes the benefits

While using the average efficiency EV has clear climate benefits compared to gasoline-powered vehicles, emission reductions are maximized by choosing the most efficient EVs available. Vehicles like the Lucid Air and Tesla Model 3 require the least amount of electricity per mile because of their more efficient powertrains and low aerodynamic drag design. A high-efficiency design also means that a smaller capacity and therefore lighter battery pack can be used to achieve the desired driving range, further reducing the energy required to move the car. These most-efficient EVs have lower driving emissions than every gasoline model for 97% of people in the country. In many parts of the US, including the entire West Coast and New

England, driving one of these EVs means global warming emissions are less than a quarter of the average gasoline vehicle.



Choosing the most-efficient EV minimizes emissions from driving. For example, drivers of the most efficient EV in New England will produce global warming emission equal to a hypothetical 144 MPG gasoline-powered car.

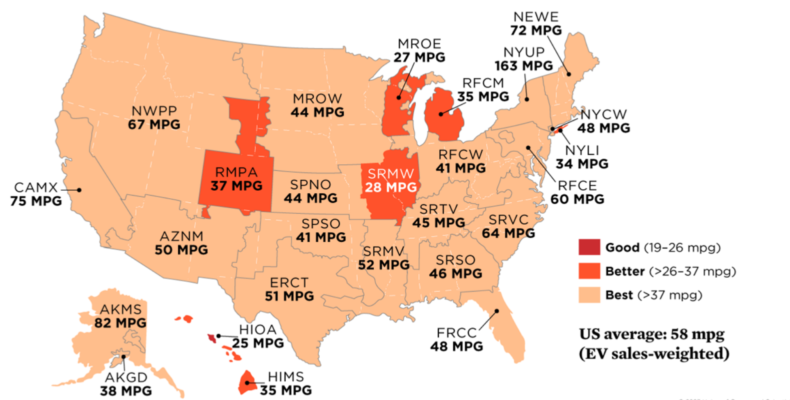
Electrifying larger vehicles like pickups can also reduce emissions

Larger EVs are now available, including an electric version of the Ford F-150 pickup truck, the best-selling vehicle in the US. Larger vehicles, whether gasoline or electric-powered, are less efficient than the average car. However, switching from gasoline to electricity still has an advantage. Everywhere in the United States, the emissions from driving an EV pickup truck are lower than those for the average new gasoline or diesel pickup truck.

Switching from a gasoline truck to an EV truck has clear benefits and is a good choice for drivers that need the hauling or towing ability of

these vehicles. However, moving from an efficient gasoline car to a large EV like a pickup truck can reduce the climate benefits of electrification. To reduce emissions, drivers should choose EVs over gasoline vehicles when possible. But regardless of the fuel, car buyers should choose more efficient models that meet their mobility needs, both to reduce emissions from driving and to save on fuel costs. Simply put, electrification shouldn't be seen as justification to drive a Hummer.

Comparing Emissions: Driving the Average EV Pickup Truck as a Gasoline MPG Equivalent, 2021



Driving an electric pickup truck produces lower emissions than the most efficient gasoline model in most of the United States. For example, recharging and driving the Rivian R1T or Ford F-150 Lightning pickup in New England has the emissions impact of a hypothetical 72 mpg gasoline truck. Overall, based on where EVs have been sold, EV pickups on average would have emissions equal to a 58 mpg gasoline truck, significantly better than gasoline trucks.

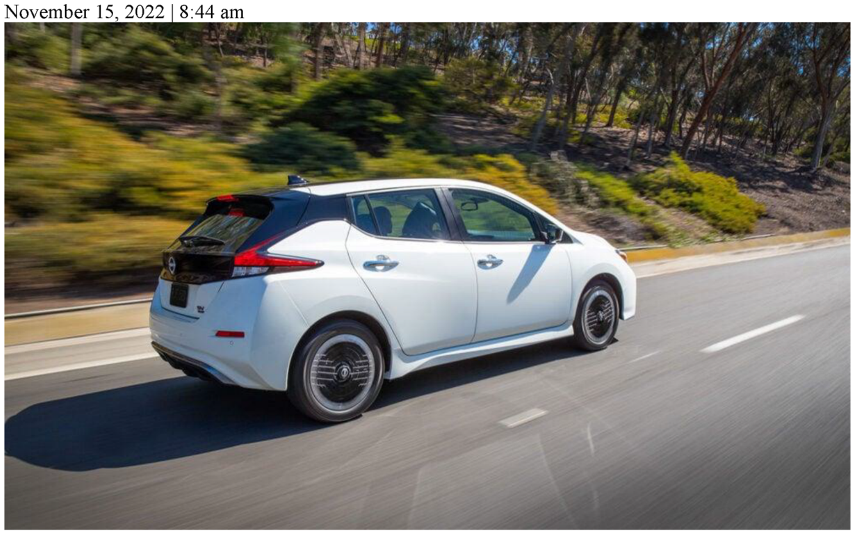
Avoiding driving altogether is even better than driving an EV

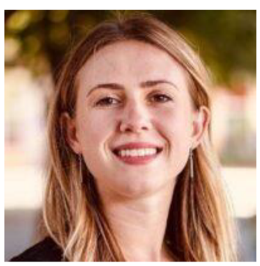
Choosing to drive an EV (especially a more efficient one) instead of a gasoline car will help reduce carbon pollution that is a major cause of climate change. And this choice to drive using electricity is now significantly cleaner than when we first looked at the benefits of EVs. However, avoiding driving is even better. Using mass transit instead of a personal vehicle can reduce emissions. And walking and biking means avoiding air pollution and climate-changing emissions altogether. With our current transportation system, it's difficult for many people to switch all of their trips to transit, walking, or biking, but using these modes even part of the time can make a positive difference in the pollution from personal transportation.

Posted in: Transportation
Tags: electric vehicle, global warming emissions, Maps

Are There Enough Materials to Manufacture All the Electric Vehicles Needed?

November 15, 2022 | 8:44 am





Jessica Dunn
Senior Analyst

The short answer is yes. But this is a complicated question, so let's dig in further.

The transition to electric vehicles (EVs) is necessary to decrease climate-changing emissions. As deployment increases, so will the demand for EV battery materials such as lithium, cobalt, and nickel. These materials are primarily supplied through two sources: 1) newly mined or 2) recovered by recycling batteries already in circulation.

Using recycled materials results in significantly less environmental impacts and is a substitute for those newly mined, although it requires the materials to have already been extracted, manufactured into a battery, and then retired from use.

Research shows there are enough explored or prospective reserves to electrify the global transportation sector using current technology *if* a high amount of battery recycling occurs. In this scenario, global demand in 2100 will amount to about 55% of cobalt reserves and 50% of lithium reserves.

This is in stark contrast to a future without high recycling rates.

If recycling doesn't ramp up, a shortage of lithium, nickel, or cobalt is not likely, but it is estimated that the demand would exceed what is economically accessible to extract. In this scenario, demand in 2060 is more than cobalt reserves and about 90% of lithium reserves. In other words, for the forecasted demand to be met, extraction must go beyond what is seen as economically viable. This dwindling of reserves would likely raise material costs, triggering increased exploration and development, and potentially expand reserves.

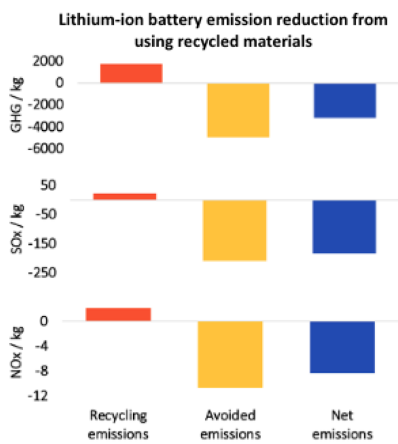
Scientists evaluating resource availability through mining typically look at two categories: the total available resources and the reserves. This distinction is important because the reserves represent the global resources that are *economical* to extract, while the total resources represent an estimate of the *finite global resources*. Reserve estimations

are therefore much less than total resources and fluctuate based on material value, mineral exploration, and technological development.

Recycling has many benefits

Recycling can drastically decrease new mining needs and is an essential strategy to sustainable, secure, and affordable electrification.

How is recycling more sustainable? The environmental impacts from using recycled content are much lower than newly mined materials. Since the materials recovered through recycling were already in the economy, the only impacts associated with their production are from transporting the battery to recycling, pre-processing, and recycling. By using recycled instead of newly mined materials, reduction of climate-changing greenhouse gas emissions is approximately 64%. Emissions which create smog and impact human health can also be mitigated; sulfur oxides can be reduced by 89% and nitrogen oxides by 78%.



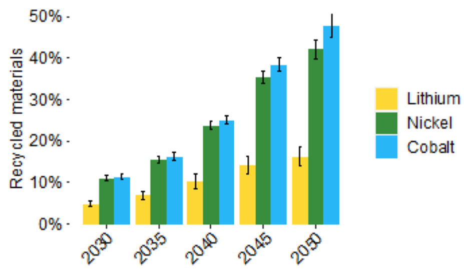
'Net emissions' represents the net emissions abated from using recycled instead of newly mined materials to manufacture 1kg of lithium-ion battery. 'Recycling emissions' represent the emissions from recycling using hydrometallurgical processing and 'avoided emissions' represent the total emissions that were abated by not

manufacturing a kg of battery from newly mined materials. Information for this figure was taken from Dunn et al. (2022).

Why is recycling an essential strategy to achieve secure and affordable electrification? In addition to comparing the available supply and demand, there are a lot of other factors that can lead to material shortages such as inadequate processing capacity and geopolitical supply chain issues. Recycling can secure a local supply of materials and decrease new material demand, all factors that can keep costs down.

How much demand can be met with recycled materials?

Estimates show that in the United States a large portion of future EV material demand can be met with recycled content. In 2050, recovered material can supply approximately 45–52% of cobalt, 40–46% of nickel, and 22–27% of lithium demand for EVs. In the short-term, recycled content will represent a smaller amount of battery materials—this grows as more material is in the economy and EV batteries retire.



The percent of EV battery material demand in the United States that is estimated to be able to be met by recycled materials. This can also be referred to as recycled content. Information for this figure was taken from Dunn et al. (2022).

Since mined materials will be needed to supplement recycled content, we need to ensure ethical and sustainable sourcing. In addition, it is essential that material demand is decreased through increasing the material efficiency of batteries and EVs and shifting away from car dependency and towards more public transportation.

Is recycling profitable?

While the exact economics of recycling facilities in operation are unknown, the plans for recycling facility expansion, along with recycling cost estimates using National Lab models, indicate lithium-ion battery recycling is (or soon will be) profitable. Since recycling is not a requirement in the US, current recycling is happening because of economics or funded research and development.

Recycling revenue is heavily influenced by the materials contained in the battery and their market value. Within a lithium-ion battery there is an anode, the negative electrode, and a cathode, the positive electrode. The battery charges and discharges by cycling lithium-ions between the anode and the cathode.

The materials used in the lithium-ion battery cathode vary. Until recently, most of the popular EVs contained a battery with cobalt and nickel because it enables them to have a long range in a compact size. Tesla and Ford are now transitioning towards a chemistry without cobalt for their lower range EVs, called lithium-iron phosphate (LFP). Nickel and cobalt are expensive materials and have some of the highest associated environmental and social impacts. Lessening the use of these materials is overall beneficial, but it also reduces the battery's worth to recyclers.

As cobalt and nickel are reduced in batteries (or phased out completely) recycling can still be done, but it may not be profitable with current recycling technology. Since recycling isn't a requirement, and the recycling occurring is mostly based on the positive economics, it is essential that policy is enacted to ensure all batteries are recycled, even if there are not high economic returns.

What does this mean for the long-term sourcing of materials for lithium-ion batteries?

There are enough materials to make EVs, but recycling is necessary to make them more sustainable, ethical, and affordable.

The switch from gasoline to electric presents a huge opportunity for efficient resource use. Unlike our current system, where we continually extract petroleum and burn it up in our cars and trucks adding to air pollution and climate change, the minerals we use to build EVs can be captured and reused to support the next generation of clean vehicles.

Currently, the United States doesn't require lithium-ion battery recycling, but we do know that recycling is occurring, thanks to reports by recyclers and contracts between automakers and recyclers. While this is a good indicator, a policy that requires and supports the recycling of EV batteries is still necessary to ensure as many batteries are recycled as possible, even if it isn't profitable.

EV battery recycling policy in the United States to-date consists of investment in recycling research, development, and demonstration, such as in the Bipartisan Infrastructure Law. California, on the other hand, is more actively exploring recycling requirements. A group of stakeholders recently submitted policy recommendations to the legislature, including the requirement that automakers are responsible for the recycling of EV batteries when they are retired. An outline of their process and findings can be found in a recent blog of mine. We will be following the next legislative session closely with the hope that good policy is developed.

Posted in: Transportation
Tags: climate-change, critical materials, electric vehicles, Lithium-ion batteries

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About the author
MORE FROM JESSICA
Jessica Dunn is a senior analyst in the Clean Transportation Program, specializing in lithium-ion battery sustainability. She conducts research on material circularity and reducing battery impacts through repurposing and recycling.

How Much Land Would it Require to Get Most of Our Electricity from Wind and Solar?

February 22, 2023 | 4:48 pm

Steve Clemmer
Director of Energy Research & Analysis

Critics of wind and solar routinely raise concerns about how much land would be required to decarbonize the US power sector. Fortunately, the answer is relatively little. A recent National Renewable Energy Laboratory (NREL) study shows that it would take less than 1 percent of the land in the Lower 48—that's an area comparable to or even smaller than the fossil fuel industry's current footprint. And when wind and solar projects are responsibly sited, the environmental and public health impacts would be far less harmful than those from extracting, producing and burning fossil fuels.

A key role for wind and solar

The fact that renewables will not require an inordinate amount of land is welcome news because limiting climate change's worst impacts will require us to cut global heat-trapping emissions roughly in half by 2030 and to achieve net-zero emissions by 2050, according to the Intergovernmental Panel on Climate Change. Acknowledging that the United States is a leading contributor to carbon emissions, the Biden administration has committed to cutting US emissions 50 to 52 percent below 2005 levels by 2030. Most studies show that achieving these targets will require an unprecedented increase in wind and solar power to decarbonize the power sector and meet the increased demand for zero- carbon electricity to replace fossil fuels in building, industrial and transportation sectors.

A 2022 NREL study found that, to achieve President Biden's goal of generating 80 percent zero-carbon electricity by 2030 and 100 percent by 2035, we will need to increase wind and solar power from about 14 percent of the US electricity mix in 2022 to between 60 and 75 percent by 2035 under the main scenarios. When combined with modest increases in geothermal and hydropower capacity at existing unpowered dams and upgrades to existing facilities, renewable energy would provide 70 to 85 percent of total US electricity generation by 2035. NREL projects that most of the remaining generation would come from existing nuclear plants and a small amount from gas plants, carbon capture and storage, hydrogen and biogas.

NREL also found that meeting the growing demand for zero-carbon electricity means overall US generation capacity would need to roughly triple between 2020 and 2035, including a combined 2,000 gigawatts (GW) of wind and solar capacity. This would require growth rates in the range of 43 to 90 GW per year for solar and 70 to 145 GW per year for wind by the end of the decade, which would mean more than quadrupling the current annual deployment rates for each technology.

Although siting, permitting and ramping up manufacturing for all of this new wind and solar generation will be challenging in this time frame, NREL's study and other studies suggest that it is technically and economically feasible. For example, about 930 GW of wind and solar capacity and 420 GW of storage projects are now awaiting approval to connect to the transmission system, according to Lawrence Berkeley National Lab. This year alone, developers are planning to install 29 GW of utility-scale solar. That's more than double the current record and represents more than half of all new US capacity, according to recent Energy Information Administration (EIA) data. EIA also projects US battery storage capacity to more than double in 2023.

The federal Inflation Reduction Act (IRA) also will make a big difference by making available hundreds of billions of dollars in new incentives for these technologies. NREL's 2022 Standard Scenarios study found that these federal incentives would accelerate the deployment of wind and solar, helping to reduce US power sector carbon dioxide emissions to 80 percent below 2005 levels by 2030.

Comparatively small footprint

NREL found that the land area directly occupied by wind and solar infrastructure by 2035 would make up less than 1 percent of the land in 94 percent of the country and less than or equal to 7 percent of total land area in just three states. A key reason why a relatively small amount of land is needed is because only 2 percent of the total area within a wind farm is occupied by wind infrastructure, while the remaining 98 percent is available for agriculture, grazing or other

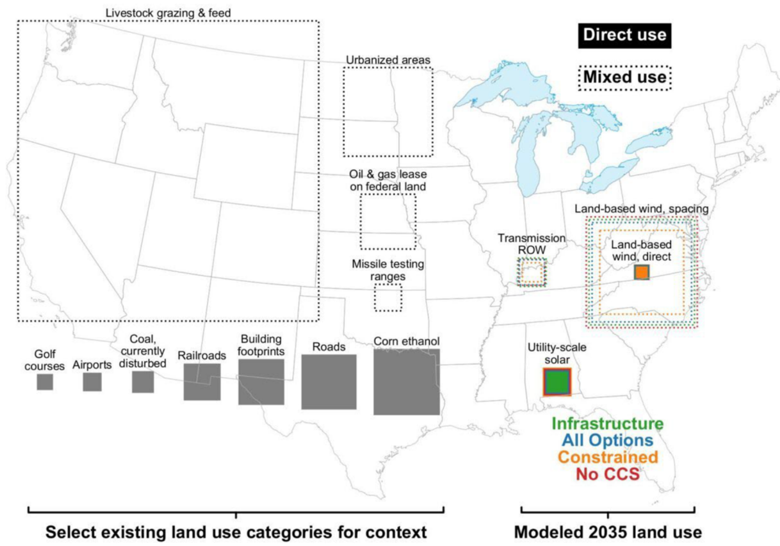
uses. Offshore wind turbines also have a relatively small footprint and are able to use much larger turbines than land-based projects. Rooftop solar deployment, meanwhile, doesn't require any land.

Of course, to deliver all this clean energy from wind-rich regions in the Midwest and Plains states to major load centers in the East will also require a lot of additional transmission lines. NREL found that total US transmission capacity would have to increase by 1.3 to 2.9 times current levels by 2035. This would require 1,400 to 10,100 miles of new high-capacity lines per year, assuming new construction began in 2026.

But the big news is NREL found that the total amount of land needed by 2035 to achieve our clean power goals with wind, solar and long-distance transmission lines (19,700 sq. mi) would be:

- equivalent to the land area currently occupied by railroads (18,500 sq. mi)
- less than half the area of active oil and gas leases (40,500 sq. mi)
- less than one-third of the area currently needed for ethanol production (59,500 sq. mi), and
- only slightly more than the historically disturbed land area for coal mining (13,100 sq. mi).

Plus, NREL's main "All Options" scenario projects roughly 250,000 wind turbines in the United States, which is considerably less than the nation's 1.5 million oil and gas wells.



Total area occupied by wind turbines and solar photovoltaic infrastructure (solid colored boxes) is roughly equal to the land occupied by railroads. (Map courtesy of NREL)

Environmental and public health benefits

Perhaps most important, though, is the fact that replacing fossil fuels with wind and solar will dramatically reduce the amount of land needed for mining, drilling, transporting, producing and using fossil fuels. Land used for these activities—and for disposing of coal ash and other wastes—often creates significant long-term environmental and public health problems for local communities.

By contrast, the land-use impacts of wind and solar projects tend to be short-term and reversible. As mentioned above, 98 percent of the land needed for a wind farm is available for agriculture, grazing or other productive uses. Co-located solar and agriculture, or "agrivoltaic," systems can make agriculture more sustainable by improving both energy and food production. Utility-scale solar projects also can be

built on previously disturbed and contaminated land that was remediated for reuse, including brownfields, landfills, abandoned mine lands, invasive species-impacted land, gravel pits and quarries, Resource Conservation and Recovery Act and Superfund sites, and retired coal- and natural gas-power plant sites.

And, unlike fossil fuels, electricity generated by wind and solar does not use water or produce any emissions or wastes that can contaminate the air, land or waterways. When wind and solar projects reach the end of their useful lives, they can be removed and the land can be easily restored.

That said, mining some critical minerals for wind turbines, solar panels and batteries can have significant land-use impacts. Stringent policies and safeguards are needed to avoid, minimize and mitigate these impacts. Most of this mining currently occurs in other countries, but the IRA and the infrastructure law both include incentives to source more of these minerals domestically. In addition, several efforts are underway to recycle and reuse wind turbine components, solar panels and batteries instead of disposing them in landfills. (See more on these issues in these recent UCS blogs).

Responsible siting required

Transitioning to a clean energy economy that relies heavily on wind and solar is a big and vitally important undertaking. Minimizing land-use impacts will require responsible siting of wind and solar projects that avoids use of sensitive, or otherwise inappropriate, land and waters.

Fortunately, NREL's modeling takes much of this into account in its report and related video:

- For wind power, NREL excludes protected land (such as state and national parks, conservation areas, and water bodies), urban areas, and mountainous or difficult terrain. It also considers state and county setbacks as well as height ordinances and

excludes land that conflicts with other existing infrastructure, such as buildings, roads, railroads and radar.

- For utility-scale solar, NREL also excludes "prime" or "important" cropland and farmland as designated by the US Department of Agriculture. It also limits potential new solar PV facilities to sites within 12.4 miles of existing transmission in most scenarios.

When these assumptions are taken into consideration, roughly 29 percent of the land in the Lower 48 is available for wind development and 39 percent could be used for solar development under most of NREL's scenarios.

NREL doesn't consider changes to land-use patterns, including climate change impacts on land availability. But its implications are clear and heartening: If we develop wind and solar production in a responsible and sustainable way, the land-use demands are manageable and the environmental, public health, and land-use benefits of replacing fossil fuels will be enormous.

Posted in: Energy
Tags: clean energy, Renewable energy, renewable energy land use, solar power, wind power

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About the author
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As director of energy research for the Union of Concerned Scientists' Climate and Energy program, Steve Clemmer conducts research on the economic and environmental benefits of implementing renewable energy technologies and policies at the state and national levels.

Challenges and Opportunities in Mining Materials for Energy Storage Lithium-ion Batteries

December 22, 2022 | 8:02 am

Charlie Hoffs
Former Schneider Sustainable Energy Fellow

Batteries are key to enabling the renewable energy transition. When the sun isn't shining or the wind isn't blowing, batteries help store clean energy to continue supplying electricity to the grid and to customers consistently and reliably. Generating and storing clean energy is a lifeline for the planet's future; burning coal, oil, and gas fossil fuels causes 75% of greenhouse gas emissions. Fossil fuel

extraction not only ignites climate change, but degrades land and wildlife ecosystems, pollutes waterways, acidifies the oceans, exacerbates natural disasters, expropriates Indigenous land, and leads to devastating chronic health impacts for fossil fuel industry workers and adjacent communities.

A fossil fuel energy grid extracts and expends finite resources. It is wasteful by design. By contrast, nearly every part of a renewable energy grid can be circular. Energy from the sun and wind never runs out and is used again and again. Rechargeable large-scale batteries can be charged with solar or wind power and cycled thousands of times in their lifetime. At end-of-life, the valuable metals in batteries can be recovered and reused.

A circular battery life cycle is possible. More batteries are being recycled through good policy, innovation, and corporate commitment. Public action and awareness-raising is bringing increased attention to the urgency of responsible sourcing.

This post takes a closer look at the supply chain of energy storage batteries from material mining to manufacturing. I explore solutions for more just, transparent, sustainable sourcing including ensuring materials are obtained with the Free, Prior, and Informed Consent of adjacent communities. I also explore alternatives like expanding production of and inventing new battery technologies with fewer critical minerals and reducing car usage by increasing public transit and walking through equitable urban planning. Our next post will then explore pathways to achieving a circular battery economy through battery repurposing and recycling.

While here I will focus on energy storage batteries for the power grid, electric vehicles—a much larger slice of the battery market—have very similar supply chains, manufacturing processes, and recycling infrastructure. Explore some of UCS's resources on electric vehicle (EV) battery recycling *here*, *here*, *here, here* and *here*.

Mining and manufacturing present challenges

There are seven main raw materials needed to make lithium-ion batteries. Among these, the US defines graphite, lithium, nickel, manganese, and cobalt as critical minerals: metals of essential importance to US energy needs, but which have supply chains vulnerable to disruption. For lithium, cobalt, and nickel in particular, the battery industry drives global demand. Check out my previous post to understand how batteries use each of these materials.

Lithium mining via brine well water evaporation in the Atacama Salt Flat in Chile. Source: Coordenação-Geral de Observação da Terra/INPE/Flickr.

Lithium

At the center of attention in the battery world, lithium is a mighty metal spurring the global battery revolution. It is ideal for batteries in many ways because it is very light (made of merely 3 protons, 3 neutrons, and 4 electrons) and highly reactive, capable of storing lots of energy between its bonds. It is also rechargeable, and does not degrade significantly over hundreds of recharges.

According to the US Geological Survey (USGS), global lithium consumption increased 33% from 2020 to 2021, due largely to battery

demand (for both EVs and the power sector). More than half (55%) of lithium comes from Australia, 26% from Chile, 14% from China, and 6% from Argentina.

Lithium extraction presents challenges. In places such as Argentina, Chile, Bolivia, Serbia, and the US, Indigenous and allied environmental justice advocates charge that lithium mining operations have accelerated drought, thus decreasing agricultural yields, local food security, and rural livelihoods. They also say mining has contaminated waterways and soil, led to police violence against mine protestors, and threatened sacred Indigenous sites.

A prospective new site in Southern California's Salton Sea could produce an estimated 20,000 metric tons of lithium carbonate per year (for reference, global production in 2021 was 100,000 metric tons). While the site has the potential to use much less water and produce less waste than traditional lithium operations, technical challenges loom, and local residents of the 82% Latine Imperial Valley community are concerned that mining may exacerbate local environmental and public health risks, without resolving pre-existing challenges of drought, toxic pollution, unemployment, and poverty.

In the scenario where humankind moves to 100% renewable energy by 2050, total demand for lithium for batteries from now until 2050 could approach or significantly exceed all known world reserves. ("Reserves" refers to how much mineral can currently be mined economically, not the estimated total amount of discovered and undiscovered minable lithium in the world, known as the total global resources.)

Lithium's supply and demand challenge offers an opportunity for recycling and reuse innovation to help sustain lithium availability responsibly into the clean energy future.

Cobalt

The name cobalt comes from "kobold," the German word for goblin. This is an appropriate moniker for a metal of almost mythical

importance to battery cathode production and that sometimes carries urgent environmental and social implications.

Global cobalt consumption increased 20% from 2020 to 2021 due to demand for EV batteries, which can contain up to 20 kilograms of cobalt per 100 kilowatt-hour (kWh) pack, the size of a Tesla Model S battery.

*A cobalt mining pit in the Democratic Republic of Congo reaches down 90 feet. Source: Fairphone/Flick*r.

A third of global cobalt is used for EV batteries, and more than two-thirds of the world's cobalt comes from the Democratic Republic of Congo. A 2021 study by Bamana et al. reported that 15-20% of Congolese cobalt is sourced from 110,000 to 150,000 artisanal, small-scale miners. The study documents how waste from the small mines and industrial cobalt mines can degrade the local environment and impact food security. Artisanal, small-scale miners have also been linked to human rights violations including child labor, residential displacement, and lack of humane work conditions and wages for miners.

In a scenario where the world achieves 100% renewable energy by 2050—and if lithium-ion batteries continue to rely on cobalt—cumulative demand (between now and 2050) for cobalt for batteries could vastly exceed all known world reserves.

But there is good news: most of the cobalt in a used battery can be successfully recovered and used to manufacture new batteries. In addition, battery manufacturers are working to reduce or remove cobalt from the next generation of lithium-ion batteries. Some EV companies, for example, are transitioning from "NMC111" batteries (containing nickel, manganese, and cobalt in a 1:1:1 ratio) to "NMC811" with a fourth or fifth as much cobalt. They're also adopting cobalt-free batteries such as LFP (containing a **L**ithium-Iron-**P**hosphate cathode). For example, half of all Tesla vehicles produced in the first three months of 2022 had LFP batteries. LFP batteries may overtake NMC in energy storage applications by 2030 because they are more affordable, can have longer lifespans, and are less dependent on critical metals.

Nickel

The shift towards lower-cobalt batteries means more nickel is needed. Like cobalt, nickel (of "Class 1" 99.8% pure status) is a component of the metal-mix used in the cathode of batteries.

A Nornickel mine in Murmansk, Oblast, Russia. . *Source: Hans Olav Lien/Wikimedia Commons*.

Nickel sourcing is more geographically diverse than cobalt; 37% of nickel comes from Indonesia, 14% the Philippines, and 9% from Russia. Nickel mines can cause deforestation and water and soil contamination, such as in Claver, Philippines. Mine pollution in Indonesia has severely impacted indigenous fishing grounds, and state policies repress activist protests. Indigenous Russian communities are protesting Nornickel for tailing leaks into waterways that are killing fish and endangering public health.

Meanwhile, a new company called Prony Resources in New Caledonia—a French territory with large nickel deposits—is majority owned by tribal and local stakeholders and may offer a more equitable model for stakeholder governance and mine co-ownership.

Prony Resource's Goro Nickel Mine in New Caledonia. Source: Barsamuphe/Flickr.

The International Energy Agency (IEA) projects that nickel demand for EV batteries will increase 41 times by 2040 under a 100% renewable energy scenario, and 140 times for energy storage batteries. Annual nickel demand for renewable energy applications is predicted to grow from 8% of total nickel usage in 2020 to 61% in 2040. Like cobalt, opportunities to reduce nickel demand lie in new battery chemistries and recycling.

Copper

Twenty-seven percent of copper production occurs in Chile, 10% in Peru, 8% in China, and 8% in the Democratic Republic of Congo. And 70% of the copper used in batteries is already recycled. Researchers predict that the world will need to expand copper mining to meet the

future supply deficit. However, of the top 300 undeveloped copper orebodies in the world, 47% are located on or in Indigenous lands, 65% are in high water risk areas, and 65% are in or near biodiversity conservation areas.

Washing copper ore in the Democratic Republic of Congo. Source: Fairphone/Flickr.

Similar to other critical minerals, the copper industry—such as in Chile and Peru—can be connected to environmental, labor, and public health problems that have incurred intense community resistance.

To secure a just energy transition that contests, rather than deepens, oppression and extraction, mining projects must uphold environmental justice and human rights.

Graphite

Graphite makes up 95% of battery anodes. EV batteries can contain up to 280 pounds of graphite, over a quarter of their total weight. Demand for graphite in batteries is projected to grow by 30% each

year until 2030, and may constitute 8 to 25% of global demand for graphite by 2040. China produces 82% of the world's natural graphite (which is more commonly deployed than artificial or synthetic graphite). Intensive graphite mining in Heilongjiang and Shandong provinces in China releases soot particulates into the air that damage crops, coat homes in a layer of dark powder, and contribute to heart and lung disease.

As advocates push for just graphite mining regulation and transparency, companies are innovating new circular economy technologies capable of recovering battery-grade graphite from used batteries and other materials, and doing so without the use of corrosive chemicals.

Other battery materials

The lithium-ion battery industry also uses a very small portion of global manganese, iron, phosphorous, and aluminum supplies. While small in volume, ensuring these battery material supply chains are just and sustainable is also important. In particular, manganese mining, sometimes undertaken without community compensation nor consent, has been linked with toxic contamination and chronic illness in Ukraine, South Africa, and Guyana. Iron ore mining, which releases large amounts of emissions, has resulted in devastating mine waste leaks causing water contamination and hundreds of fatalities. Across all mining sectors, government and industry commitments to just mining policy and a transparent circular economy is critical.

Manufacturing

After the raw materials are extracted, they must be refined and processed for use in batteries. China processes 72% of the world's cobalt, 61% of lithium, and 95% of manganese, while Russia leads in nickel processing.

China also leads in lithium-ion battery cell manufacturing. The country has invested over $60 billion in this industry, and produced 80% of the world's cells. While the US currently produces 13% of global cells (about 520 gigawatt hours per year, mostly in Tesla-

Panasonic plants in Nevada), production is projected to increase due to significant investments within the Bipartisan Infrastructure Law and the Inflation Reduction Act.

Can battery manufacturing be more responsible and sustainable?

Yes, and the industry can and must get there.

Lithium-ion batteries—many for grid energy storage, and many more for electric vehicles—play an important role in the clean energy future. They not only store renewable energy for the grid, but also power electric vehicles, which have significantly lower environmental impacts than gasoline cars. The average electric vehicle in the US emits 52% fewer greenhouse gas emissions over its lifetime than the average gasoline vehicle (which burns about 4,500 gallons of gasoline over its lifetime). The average EV's emissions are equal to a gasoline vehicle getting 91 miles per gallon.

To ensure the transition to a more battery-powered future is equitable and effective, energy storage and vehicle battery supply chains must be just and sustainable.

Here are four strategies government and business decisionmakers can use to improve lithium-ion battery materials sourcing and manufacturing:

- **Require ethical, sustainable sourcing and strong supply chain standards.** Companies and organizations can join the Global Battery Alliance and the Initiative for Responsible Mining Assurance. Industry leaders can actively respond to journalists and researchers from groups like the Business & Human Rights Resource Centre, and ensure upstream critical minerals suppliers obtain the Free, Prior, and Informed Consent of the communities near which they operate. The US could consider implementing binding rules on more just and sustainable mining, including considering reforms to the outdated 1872 Mining Law, which still governs hardrock

mining 150 years later. The US could also consider rejoining the Extractive Industries Transparency Initiative (EITI), a coalition of over 50 countries dedicated to increasing just and environmentally friendly sourcing.

- **Produce batteries with reduced reliance on high impact critical minerals.** Policymakers and companies can accelerate the transition to batteries that use materials with lower environmental and social impacts. LFP batteries, for example, result in lower impacts because they contain no cobalt nor nickel.
- **Support development of new battery technologies for energy storage.** New solid-state, sodium-ion, and redox-flow batteries, along with other innovations, may offer more affordable, secure, long-duration, and critical-metal-free options for energy storage.
- **Invest in infrastructure and urban planning solutions that increase public transit usage, walking, and biking.** While accelerating the transition from internal combustion engine vehicles to electric vehicles is an urgent priority, the most effective strategy for reducing US car emissions—and the impacts of battery critical metal mining—is reducing car ownership and usage overall. Governments must undertake the difficult and essential work of building accessible, affordable, efficient public transportation systems, and built environments that encourage biking and walking.

Fleets of batteries—acres and acres of unassuming stationary metal boxes—are a key to unlocking the renewable energy future. But are batteries, themselves, renewable? Can they be reused or recycled at the end of their life? Where do their raw materials come from, and how can we ensure their valuable contents are recovered rather than wasted? Click to learn more!

How are Lithium-ion Batteries that Store Solar and Wind Power Made?

Want Clean Energy? Then You Also Want Battery Recycling.

And what about the solar panels and wind turbines, which generate the electricity that batteries store? Check out our previous posts on solar panel and wind turbine life cycles!

Editors note (1/4/23): Following feedback from colleagues in the mining justice sector, we've made edits to better reflect equitable, effective strategies for mining reform and advocacy.

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About the author
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Charlie Hoffs served as a 2022 UCS Summer Schneider Fellow in Cambridge, Massachusetts. She earned her BS Chemical Engineering from Stanford University in 2022, and is currently pursuing an MS in Community Health and Prevention Research at Stanford. In April 2020, she co-founded and continues to co-lead unBox, a youth-led organization working to unite and empower young people to fight US food insecurity.

What Happens to Wind Turbine Blades at the End of Their Life Cycle?

December 12, 2022 | 12:02 pm

Charlie Hoffs
Former Schneider Sustainable Energy Fellow

Perched atop towers hundreds of feet tall, overlooking grassy plains or windy seas, sleek white blades trace slow powerful circles through the

air. Can the life cycle of wind turbine blades, lasting about 25 years, be as circular as the elegant arcs they carve in the sky?

This post will follow the wind turbine blade from "cradle-to-grave," then explore solutions for a more responsible, sustainable life cycle. To learn about the current lifecycle and a more sustainable solution for the rare earth elements in wind turbine generators, read How Are Wind Turbines Made?

Blade materials are special

A wind turbine includes a foundation, a tower, electrical wiring, a nacelle between the blades, and the blades themselves. The raw materials used in the foundation and tower (steel and concrete) and wiring (copper and aluminum) are relatively inexpensive, and the wind industry uses a small fraction of global demand for these materials.

Wind turbine blades are a different story. Blades are made mainly of carbon fiber, fiberglass, and balsa wood and the wind industry drives a significant portion of global demand for these materials: 10% of world demand for fiberglass and 24% for carbon fiber come from wind turbines. While today's carbon fiber and fiberglass require lots of energy to produce and are hard to recycle, incorporating more bio-materials into their composites and developing new recycling technologies can reduce their footprint. Also, fortunately, the fibers and epoxies needed to make these strong synthetic materials are widely available.

The supply of balsa wood, on the other hand, is highly concentrated in Ecuador and Peru. The high demand for balsa wood in blades for lightweight structural support has linked the wind industry's demand to increased Amazon rainforest logging and balsa plantation farming. By 2020, demand for balsa wood outstripped supply. Legal and illegal balsa exports have transformed forest landscapes near Indigenous communities with limited consultation or consent of those affected communities.

Balsa wood logging. Source: Firdaus Latif/Wikimedia Commons

To ensure the wind industry upholds environmental justice and stewards its raw materials, many companies are replacing balsa with other materials. For example, LM Wind Power has minimized balsa in its blades, substituting in synthetic plastic PET and PVC foams. Additionally, INCA Renewtech invented BioBalsa, a durable blade material made of hemp hurd cellulose. The energy research firm Wood Mackenzie estimates that the number of blades using PET as their core material instead of balsa will increase from 20% in 2018 to 55% in 2023.

Can wind turbine blades be recycled?

Yes! The good news is the steel, iron, aluminum, copper, concrete, and electronic components of wind turbine foundations, towers, and wiring can be completely recycled. Recycling the blades is a greater challenge, but an important one to overcome.

In 2021 in the US, 8,000 blades—which each average about 200 feet—were retired. By 2050, the world may be getting 15-18% of its energy from wind, but may also have 43 million metric tons of retired blades to address. Although landfilling of blades does not pose a threat of soil or groundwater contamination and would represent only a tiny fraction of global solid waste streams, the lifecycle of wind turbines would be more circular if there were more options to reuse or recycle the blades.

Composite materials like fiberglass and carbon fiber are tricky to break down, precisely because they are *composite*, finely blended mixes of different materials which must be separated to be recycled. Those composites make blades hardy and durable, resisting wear and tear for decades.

While today, many retired wind turbine blades end up in landfills, innovative companies have developed repurposing and recycling technologies to help avoid that fate. Veolia, partnering with GE, can shred down fiberglass blades and turn them into cement. Carbon Rivers can transform fiberglass blades into textiles and other synthetic materials, while Global Fiberglass Solutions turns recycled fiberglass into railroad ties and plastic pellets. Vestas and a network of partners have developed the CETEC plan (Circular Economy for Thermosets Epoxy Composites), which in the next three years will be able to separate blade fibers from epoxy and use the epoxy in new blades.

An onshore wind turbine being transported to Muirhall Wind Farm in the UK. Source: ShellASP/Wikimedia Commons

Companies have also started to develop new, more recyclable blade technologies which continue to guarantee strength while facilitating end-of-life processing. For example, Siemens Gamesa installed the first ever recyclable wind turbine blade at an offshore wind farm in Germany in July 2022. It employs a new type of blade epoxy resin. When the blade is immersed in an acidic fluid at high temperatures, the resin dissolves and the components separate, becoming recyclable. The company aims to make all its blades fully recyclable by 2030.

Responsible, circular solutions for wind turbine blades

All wind energy stakeholders, including states, the federal government, companies, suppliers, and consumers, can fuel the responsible, sustainable development of a circular wind energy industry. Some strategies include:

1. **Ensure an ethical, sustainable supply of balsa wood.** Companies can work with their balsa wood suppliers to ensure their materials are sustainably and ethically sourced, and that free, prior, and informed consent of logging- and plantation-adjacent communities is ensured. Governments can support research into, and companies can experiment with, new substitute materials for balsa wood in wind turbines.
2. **Hold companies accountable for end-of-life management.** Extended producer responsibility (EPR) is a proposed concept in which technology companies must plan, execute, and pay for their product's end-of-life processing through reuse or recycling. The EU has implemented such policies for batteries and solar panels, and governments around the world can follow this model for wind turbine blades. They can also reward companies that recycle their blades through incentives.
3. **Accelerate the use of recycled materials in new blades.** To create a circular economy for recycled blades, there must be a market. Blade manufacturers must establish contracts with today's nascent blade recyclers to speed up the transition to using recycled materials in new blades.
4. **Increase recyclable blade research and development.** States and the federal government can provide competitive grants, research funding, and incentives to labs and companies innovating new recyclable blade chemistries.

When we think about wind turbines, we visualize big circles high in the sky. The wind turbine blade life cycle can be just as circular. Governments, industry, and consumer commitments are moving us towards even more responsible, sustainable blade supply chains and end-of-life management.

How are wind turbines made? What happens when wind turbines reach the end of their service lifetimes? What will it take to ensure those colossal, majestic blades don't end up in landfills? Where do their raw materials come from, and when they retire, can we process those materials into other

useful products or recycled blades? How can we move towards a sustainable, responsible wind energy supply chain, and ensure all materials come "full circle"? Click the links below for answers:

How Are Wind Turbines Made

Just and Sustainable Solutions for the Mining and Recycling of Rare Earth Elements in Wind Turbines

Now that you've learned about wind power, are you interested in the life cycle of solar panels? Read on:

How Are Solar Panels Made?

Mining Raw Materials for Solar Panels: Problems and Solutions

Solar Panels Should Be Reused and Recycled. Here's How.

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Charlie Hoffs served as a 2022 UCS Summer Schneider Fellow in Cambridge, Massachusetts. She earned her BS Chemical Engineering from Stanford University in 2022, and is currently pursuing an MS in Community Health and Prevention Research at Stanford. In April 2020, she co-founded and continues to co-lead unBox, a youth-led organization working to unite and empower young people to fight US food insecurity.

Solar Panels Should Be Reused and Recycled. Here's How.

October 19, 2022 | 12:39 pm

Charlie Hoffs
Former Schneider Sustainable Energy Fellow

Picture this: Light energy from the sun zooms through the solar system to reach your sunny rooftop, gets absorbed into your solar panel, and charges the device or computer on which you are reading

this post. It is a perfectly closed, sustainable system. Can the life cycle of a solar panel itself be just as circular?

Today, unfortunately, the life cycle of a solar panel is not yet a "cycle."

It is more like a straight line from silica mine, to refining factory, to shimmering batch of shining polysilicon ingots, to panel assembly, to a couple decades generating clean electricity—and then, far too often, to a landfill.

Only 10% of solar photovoltaic, or PV, panels are recycled today in the US, and the rest meet their inglorious end in the garbage heap. Among those that are recycled, very few have 100% of their material recovered. There is presently no federal law or regulation regarding residential or utility-scale solar panel reuse or end-of-life management.

But there is hopeful progress in state policy, business and research innovation, and nonprofit solutions. This post explores current case studies of responsible, sustainable end-of-life solutions, and makes recommendations for future circular solar supply chains.

Meet today's end-of-life solar leaders

Several states have pioneered innovative public policy to recycle and repurpose retired residential and commercial solar panels. For example, the state of Washington requires photovoltaic module manufacturers either take back and reuse or recycle modules at no cost to owners. New Jersey has formed a commission to create recommendations for solar panel recycling, and North Carolina directed their Department of Environmental Quality to adopt rules for governing panels' end-of-life management in utility-scale projects. Meanwhile, a California law reclassified PV modules as "universal waste" as opposed to "hazardous waste," which involves less stringent handling regulations.

In the for-profit and nonprofit sectors, several companies and organizations lead the solar panel reuse and recycling transition. US company First Solar can recover 90% of its panel's materials (which

are cadmium telluride, not crystalline silicon). Good Sun is a nonprofit organization based in California that sells used solar panels for a discounted price for installation in low-income US communities. And Solarcycle aims to recycle up to 95% of panel materials, including the difficult-to-extract silver, copper, and silicon, via an electrostatic separations process that separates these particles by mass and electrical properties.


SUN
AT WORK
SOLARWORLD.DE
SOLARWORLD
THE SUNPOWERED COMPANY
JUNGHEINRICH

German company SolarWorld recyling decades-old solar panels. Photo credit: Spot Us/Flickr.

What solutions exist for a more circular end-of-life?

While promising legislation and private and nonprofit sector efforts are leading the way towards a more circular solar supply chain in the US, much more acceleration of reuse and recycling is needed. The myriad challenges involved in mining and manufacturing solar panels add to the reasons why the industry must increase its reuse and recycling of used panels. There are many paths forward for ensuring that the lifecycle of a solar panel is circular not linear. Here are two:

1. Use regulation to increase solar panel reuse.

Like driving a car more than 200,000 miles to its very last sputter, extending the life of a solar panel should be the first obvious solution. Solar panels should be used as long as possible. They do, however, lose some of their generating capacity over time.

An analysis by the Harvard Business Review predicts that those capacity decreases, along with cheaper and better panels coming on the market, may incentivize solar customers to discard their old panels early, and buy new ones. If too many consumers choose to get rid of their panels in 10-15 years as opposed to 30 years, discarded panels could outnumber new panels installed by 2.5 times in 2035, compounding the need for increased reuse solutions.

Early retired solar panels usually retain 70-90% of their original capacity. However, few solar manufacturers currently invest in the repairs to prepare panels for secondary life resale because repair costs often exceed resale profits. But there is a way through this problem.

The EU requires manufacturers to handle the reuse and recycling of solar panels with no cost to consumers. The US could create similar rules here. This would incentivize companies to provide additional refurbishing, life-extending services to their customers. Governments can also provide tax credits for companies providing robust repair and refurbishing services that extend client usage. To boost the secondary sale of good-condition solar panels for reuse, the US could also enact a nationwide standard that facilitates labeling and diagnostics of the quality of used PVs, so producers and buyers can better assess their price, value, and safety.

Manufacturers have a responsibility here, too; they can design panels with reuse in mind and facilitate parts disassembly and refurbishing for resale. States and the federal government can enact policies to reduce the regulatory burden and liability associated with reuse.

2. Boost the solar panel recycling industry.

Governments and the panel manufacturing industry can create a robust system for solar panel recycling. Effective solar panel recycling necessitates policy enactments at the state and federal levels and increasing the recycling market so that the cost of recycling per panel is less than the cost of sending it to a landfill.

According to the National Renewable Energy Laboratory (NREL), recycling a solar panel in the US can cost $15-45, while sending a panel to the landfill costs only $1-5. In the EU, on the other hand, recycling costs $0.75 per panel because of mandates requiring manufacturers pay into a fund that subsidizes recycling. Consequently, in the EU, solar recycling rates reach 95%.

Additionally, US consumers need more information from manufacturers on the cost and value of recycling and reusing their PV panels. Manufacturers and secondary buyers should have open access to reliable data on the cost-benefit of different end-of-life options.

The federal government has a role to play, too. It could invest in research to optimize cost-effective recycling that processes the majority of the solar panel.

Lastly, and crucially importantly, solar panels must be recycled safely, sustainably, and ethically, both in the US and abroad. Corporate commitment and government regulation can help ensure that the solar industry upholds stringent labor and environmental standards, as some general e-waste industry operations continue to endanger recycling worker health and safety.

The path forward

We all want the most sustainable, responsibly sourced solar panels on our rooftops and in our communities. Governments, businesses, and consumers are increasingly committed to achieving that goal. Supply chain and end-of-life challenges also present opportunities for better circular innovation and stewardship as we move into the clean energy future.

Want to learn more about how solar panels are made and the solar panel supply chain? Which countries are driving PV material mining and PV manufacturing? Click the links for answers:

How Are Solar Panels Made?

Mining Raw Materials for Solar Panels: Problems and Solutions

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Charlie Hoffs served as a 2022 UCS Summer Schneider Fellow in Cambridge, Massachusetts. She earned her BS Chemical Engineering from Stanford University in 2022, and is currently pursuing an MS in Community Health and Prevention Research at Stanford. In April 2020, she co-founded and continues to co-lead unBox, a youth-led organization working to unite and empower young people to fight US food insecurity.

EARTHJUSTICE

BUILDING A SUSTAINABLE MINERAL SUPPLY CHAIN FOR A CLEAN ENERGY ECONOMY

To avoid the worst effects of the climate crisis, we must swiftly ramp down our reliance on fossil fuels and transition to clean energy. But we have the opportunity to do what the fossil fuel industry never did–to protect the communities and environments impacted by energy development. The transition to clean energy will require more of certain types of minerals to build the solar panels, batteries, and other clean energy technologies of the future. These minerals, including lithium and cobalt, are often referred to as "critical minerals." The current policies we have in place are not sufficient to ensure we have a truly sustainable supply chain that protects communities from the impacts of mining and extraction.

A just transition should not come at the expense of communities or the environment. This threat is real: According to EPA, hardrock mining is the country's most toxic industry. Tribes and communities across the country are worried about the impacts of mining near their homes, schools, and sacred places. For example, the Hualapai Tribe are fighting the Big Sandy lithium project in Arizona, which threatens their sacred spring.

It is imperative that we protect communities that could be harmed by critical minerals mining and development by providing sufficient protections for the environment, health, and cultural resources, and by creating a more sustainable supply chain for the products we use to make and store clean energy. We can't move energy "sacrifice zones"–where people bear the brunt of the impact–from oil-and-gas-impacted communities to mining-impacted communities.

Ways to Create a Sustainable Clean Energy Supply Chain:

- **Reforming Domestic Mining Law:** Mining in the United States is currently governed by a more than 150-year old law. Updating this outdated law for the 21st century can provide protections to communities, lands, waters, and cultural resources while also ensuring community input is robust from the outset of a mining project, which will reduce permitting delays and uncertainty. Legislation like the Clean Energy Minerals Reform Act and ensuring Free, Prior, and Informed Consent (FPIC) would do just that.

- **Setting Standards for Domestic and Imported Minerals:** If we want other countries to have strong labor and environmental standards for mining, the U.S. must lead by example and implement high standards for itself, as well as negotiate high standards in trade agreements–including through verifications and certifications like the Institute for Responsible Mining Assurance (IRMA).

- **Employing a Precautionary Approach to Deep Seabed Mining:** The exploitation of the deep sea for critical minerals poses unknown risk to the ocean, climate, fisheries, biodiversity, and the people, economies, and communities that depend on the ocean. We must protect these ecosystems and resources for generations to come.

- **Creating the Circular Economy:** We must meet the demand for critical minerals in the most sustainable way possible: by recycling, reusing, and extending the life of materials and products we already have. The U.S. is behind our international partners on the creation of a circular economy for our minerals. A more sustainable supply chain will ensure we have an adequate supply of products necessary for an equitable transition by reducing the need for virgin material.

How We Jumpstart our Circular Economy:

- **Federal Government Leadership:** Build on language in the 2023 National Defense Authorization Act to establish a recycling program within the federal government, including the Department of Defense, to show leadership by example, and create a market. This should include both electronics and the federal fleet of vehicles.

- **Recycled Content Requirement:** Require all purchasers of critical materials and producers (clean energy manufacturers, car manufacturers, etc.) to purchase or use a certain percentage of critical materials from recycled sources. In the EU, a recycled content requirement will go into effect for electric vehicle batteries in 2026.

- **Domestic Battery Labeling:** Require all batteries manufactured or sold in the United States to be labeled with sourcing data and other important information. This enables consumers and recyclers to identify the source of the critical materials used, the percentage of the critical materials that were sourced from recycled content, and other key environmental and social factors. One way to do this is through a digital identifier or "Battery Passport," which will be required for EV batteries under the EU battery regulation.

- **Tax Incentives:** Tax credits could be established for entities such as waste recyclers for recycling qualified electronic waste, companies for building responsible recycling facilities, or manufacturers for reducing the use of virgin critical minerals.

- **Certification Program/Consumer Education:** EPA can establish a certification program, modeled after the Energy Star program, that will give recognition to batteries and other renewable energy products made with the highest environmental, human rights, and labor standards. Such a certification program should also recognize, and thus incentivize, high percentages of recycled materials.

- **Producer Responsibility Model:** Extended producer responsibility is defined as "an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle" by the OECD. Following the example of the European Union, the U.S. can put the onus on producers to collect and recycle products at end-of-life.

FOR MORE INFORMATION CONTACT:
Blaine Miller-McFeeley, Senior Legislative Representative
bmcfeeley@earthjustice.org

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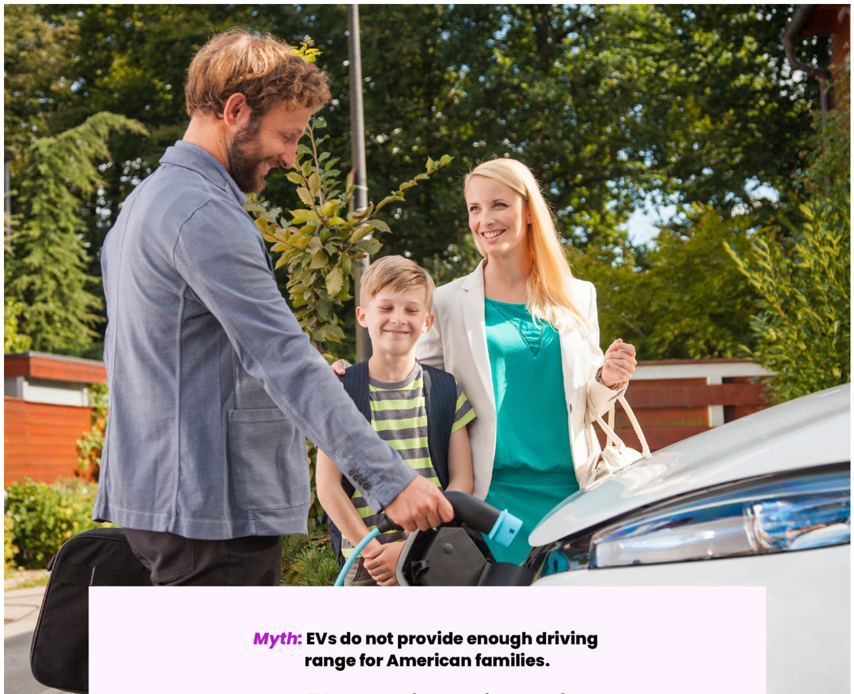
Electric Vehicle Factsheet

Myth: **EVs are too expensive.**

The Truth:

There are many models on the market today that are below or equal to the cost of an equivalent gas-powered car.[1] Recently passed tax credits will help make EVs more affordable, while drivers continue to experience significant savings due to lower maintenance and charging costs.

- Many EVs cost less than the average price of a new gas-powered vehicle.[2]
- The purchase price of EVs is expected to reach parity with new internal combustion engine vehicles (ICEVs) in the mid-2020s.[3]
- EVs typically cost less over their lifetime due to lower maintenance and fueling costs.[4]
- Drivers can receive $6,000–$10,000 in total cost of ownership savings by driving an EV.[5]
- On average, EVs can cost the equivalent of $2 a gallon or less to charge.[6] EVs provide American families with protection from fluctuations in oil prices caused by foreign governments and international conflicts.[7]
- EVs will become even more accessible to American families as the used-car market grows - more than 70% of car sales in the U.S. are pre-owned vehicles.[8]
- The Inflation Reduction Act includes several tax credits to help Americans afford EVs, including credits for new, American-made vehicles (section 30D) and used vehicles (section 25E).[9]



Myth: **EVs do not provide enough driving range for American families.**

The Truth: **EVs can easily meet the everyday transportation needs of American drivers.**

- There are many EVs that provide more than 200 miles of range per charge, and at least 18 models that have driving ranges above 300 miles.[10]
- The average American only traveled 39 miles per day in 2019 (pre-COVID);[11] rural Americans traveled further at 48.6 miles per day.[12]
- Access to public charging stations is expected to increase with the launch of the NEVI program, which aims to place EV charging stations at least every 50 miles along our nation's highways.[13]

***Myth:* EVs are not made in America and will take away American jobs**

The Truth: **The EV industry is creating thousands of good-paying jobs around the country. Recent eligibility requirements for tax credits will provide new opportunities for workers across the country.**

- Nearly 340,000 Americans already work in the domestic clean vehicle sector.[14] This number is estimated to rise above two million by 2035.[15]
- EVs account for three of the top five highest-scoring cars on Cars.com's 2022 American-Made Index.[16]
- Public investment through the Inflation Reduction Act and the Infrastructure Investment and Jobs Act will further grow domestic supply chains, including through funding critical minerals and battery production. This is in addition to research, development, and demonstration of new technologies, and the physical process of car manufacturing.[17]
- Recently, the Department of Energy announced $2.8 billion in grants as a result of the bipartisan infrastructure bill. The grants were distributed to 20 companies working in 12 states to support the development of the domestic EV supply chain.[18]
- The Defense Production Act has been used to increase the nation's ability to produce critical minerals for EV batteries.[19]
- Meanwhile, the private sector is expected to invest $1.2 trillion worldwide through 2030.[20]
- More than $700 million in private investment has already been announced to manufacture more than 250,000 new EV chargers in the U.S alone.[21]

Myth: **EVs are a fire hazard and put firefighters, individuals, and infrastructure at risk**

The Truth: **EVs have been shown to be as safe, or even safer, than conventional vehicles.**

- All EVs must meet the same Federal Motor Vehicle Safety Standards used by gas-powered vehicles.[22]
- EV battery packs have extensive safety testing standards and are designed to shut down when a collision or short circuit is detected.
- Injury claims for EV drivers and passengers were more than 40 percent lower than that of identical gas-powered vehicles between 2011-2019.[23]

***Myth*: EVs are not environmentally friendly**

The Truth:

Regardless of where they are charged, EVs are cleaner when compared to internal combustion engine vehicles. As the U.S. energy grid moves toward more renewable energy sources, EVs will become even cleaner over time, especially when compared to internal combustion engine vehicles and the fossil fuel-based infrastructure that supports them.

- Transportation is the largest carbon-emitting sector in the United States and is responsible for one-third of our total carbon emissions.[24]
- An overwhelming amount of research has found that EVs release lower emissions per mile over the lifetime of the vehicle, regardless of how their electricity was sourced from the grid.[25]
- A 2022 study by the Ford Motor Company and University of Michigan researchers found that light-duty EVs can lower vehicle lifetime emissions by as much as 64% compared to gas-powered vehicles.[26]
- Achieving 100% EV sales by 2030 and a cleaner grid would prevent $1.3 trillion in health and environmental costs in the coming decades.[27]

Related ZETA Publications

ZETA-EF releases independent research and in-depth analysis on policy proposals and their impact on EV adoption. Access these resources and more at: https://www.zeta2030.org/education-fund/resources.

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For more information, visit: zeta2030.org/EVmyths

CLEAN ENERGY BOOM

THE 142,016 (AND COUNTING) NEW CLEAN ENERGY JOBS ACROSS THE UNITED STATES

UPDATED: MARCH 31, 2023

Since the landmark Inflation Reduction Act (IRA) became law in August 2022, companies are racing forward with massive investments to build our clean energy future. New manufacturing in wind, solar, batteries, and electric vehicles — along with storage projects across the country — mean new, good-paying jobs for hard-working Americans. In the months since the landmark climate and clean energy investments became law, clean energy companies have announced or moved forward with projects accounting for **more than 142,000 new clean energy jobs** for electricians, mechanics, construction workers, technicians, support staff, and many others.

As the largest U.S. investment in clean energy and climate in history, this national clean energy plan will continue to reshape and recharge our economy for many decades to come. The Made in America clean energy boom is just getting started.

This report analyzes public announcements from the private sector since the passage of the Inflation Reduction Act to demonstrate the breadth and scale of the growing clean energy economy being built all across the country.

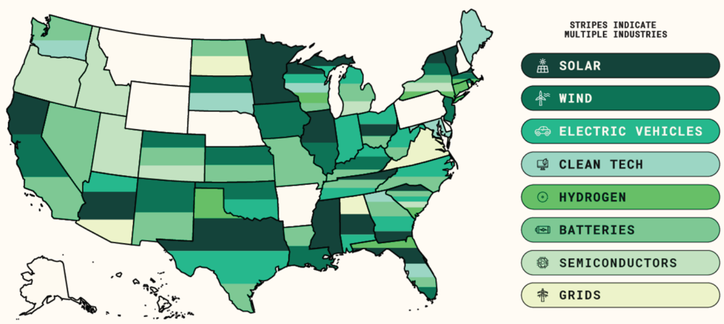
MORE THAN 142,016 NEW JOBS ACROSS THE COUNTRY

Clean energy projects creating **142,016 new jobs** in **41 states were announced or advanced** between August 16, 2022 and March 31, 2023. As of March 31, 2023, there are **191 new clean energy projects** in small towns and bigger cities nationwide totaling **$242.81 billion in new investments**.

Plans include 65 new battery manufacturing sites in places like Tucson, Arizona; Rochester, New York; and Florence County, South Carolina So far, companies have announced plans for 40 new or expanded electric vehicle manufacturing facilities in Savannah, Georgia; Montgomery,

Alabama; Auburn Hills, Michigan — and more. A further 34 plans were announced to expand wind and solar manufacturing in cities including Pensacola, Florida; Hutchinson, Kansas; and Georgetown, Texas. The majority of the projects are in 10 states — Arizona, California, Georgia, Michigan, New York, North Carolina, Ohio, South Carolina, Tennessee, and Texas.

NEW CLEAN ENERGY JOBS SINCE THE PASSAGE OF THE INFLATION REDUCTION ACT



SOURCED FROM NEWS ANNOUNCEMENTS AS OF 03.31.23

Driven in part by the certainty created by the clean energy plan and its incentives to build the clean energy future here at home, American companies restored almost 350,000 manufacturing jobs in 2022 — a 25 percent increase from 2021. A recent analysis by the BlueGreen Alliance and the Political Economy Research Institute at the University of Massachusetts Amherst projects that the Inflation Reduction Act will create over 9 million clean energy and climate-related jobs over the next decade.

STATE SNAPSHOTS: THE CLEAN ENERGY ECONOMIC BOOM

States around the country have benefited from the provisions of the national clean energy plan. Even climate skeptics have touted the benefits of the law for their communities because they now understand that this clean energy plan means big investments in their communities and new jobs. Already, the new law has significantly benefited local economies and will provide family-sustaining wages in ZIP codes from coast to coast. The local economic benefits

will continue to spread across the country. Just in the first quarter of 2023, clean energy projects were announced or advanced in six new states: Connecticut, Florida, Maine, Mississippi, Utah, and Vermont.

10 STATES WITH MAJORITY OF PROJECTS	
STATE	**# OF PROJECTS**
ARIZONA	12 PROJECTS
CALIFORNIA	8 PROJECTS
GEORGIA	14 PROJECTS
MICHIGAN	14 PROJECTS
NEW YORK	11 PROJECTS
NORTH CAROLINA	7 PROJECTS
OHIO	9 PROJECTS
SOUTH CAROLINA	14 PROJECTS
TENNESSEE	9 PROJECTS
TEXAS	12 PROJECTS

ARIZONA

→ LGES announced it would invest $5.6 billion in an Arizona gigafactory to meet growing demand for U.S.-made EV batteries that qualify for Inflation Reduction Act tax credits, a fourfold increase from previous plans. KORE Power CEO Lindsay Gorrill applauded the passage of the Inflation Reduction Act and said it provides an "incredible lift" to his company's project in Buckeye, where it is developing a gigafactory in hopes of claiming the law's tax credits.

$8.31 B	12,720
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN ARIZONA SINCE PASSAGE OF THE IRA

CALIFORNIA

→ Newly launched company Statevolt has plans to construct a $4 billion and 54 GWh lithium-ion manufacturing plant in Southern California, to further the production of EV batteries in the state.

$5.45 B	3,300
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN CALIFORNIA SINCE PASSAGE OF THE IRA

COLORADO

→ CS Wind announced plans to expand the largest wind turbine factory in the world, located in Pueblo, Colorado. The CS Wind expansion will add two new buildings and triple the workforce, rivaling the state's steel plant.

$1.07 B	1,467
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN COLORADO SINCE PASSAGE OF THE IRA

GEORGIA

→ Freyr Battery invested in a new Gigafactory in Coweta County, QCells is building a new $2.5 billion solar panel factory and planning to hire 400 new employees to meet demand driven by the Inflation Reduction Act, and Hyundai Motor Group and SK On jointly invested $4 to $5 billion to build

electric battery plants outside of Atlanta that will supply Hyundai and Kia EVs built in the U.S.

$13.34 B	12,888
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN GEORGIA SINCE PASSAGE OF THE IRA

MICHIGAN

- Our Next Energy, a Michigan-based company, invested $1.6 billion in their first battery manufacturing campus in Wayne County, EV battery maker Gotion Inc. laid plans for a $2.4 billion factory in Big Rapids, and Magna invested $526 million across several expansion projects to further Michigan's status as the "home of the auto industry and the future of mobility in Michigan," according to Governor Whitmer.

$20.23 B	13,702	167,000
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN MICHIGAN SINCE PASSAGE OF THE IRA	CLEAN ENERGY JOBS PROJECTED IN THE NEXT 10 YEARS

MINNESOTA

- Cummins is driving the clean hydrogen economy forward in Minnesota, with the announcement of its first U.S. electrolyzer production facility in Fridley, Minnesota.
- Regulators approved Xcel Energy's plans to build Minnesota's largest solar power plant, replacing electricity lost from closing coal-fired power plants across the state. The company also recently announced the addition of battery storage at the site, which will enable them to increase the grid's renewable capacity.

$575 M	914
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN MINNESOTA SINCE PASSAGE OF THE IRA

NEVADA

- Tesla is resuming construction on its $3.5 billion expansion gigafactory in Nevada, set to produce 105 GWh of battery cell production and over 150 GWh of battery packs annually. The Department of Energy also funded several projects to help Nevada achieve its goal of becoming the "Silicon Valley of lithium."

$4.54 B	10,800	40,000
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN NEVADA SINCE PASSAGE OF THE IRA	CLEAN ENERGY JOBS PROJECTED IN THE NEXT 10 YEARS

NEW YORK

- Furthering New York's vision to become the nation's offshore wind manufacturing hub, GE proposed two new offshore wind energy manufacturing facilities in the state and Zinc8 Energy Solutions announced a $68 million investment plan to relocate its battery manufacturing facility and U.S. headquarters to the mid-Hudson region. New York's EV battery workforce is also growing with GM announcing a $68 million investment to upgrade its Rochester, NY plant for EV battery components.

$101.52 B	13,355
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN NEW YORK SINCE PASSAGE OF THE IRA

NORTH CAROLINA

→ Several new projects benefiting EV production are coming to North Carolina, including Toyota's $2.5 billion investment in their EV battery facility and Wolfspeed's commitment to building the world's largest silicon carbide materials facility in Chatham County, producing a material used for components in electric vehicles and solar equipment. Kempower credited the Inflation Reduction Act for the company's decision to build a $41 million EV charging station manufacturing facility in Durham.

$9.59 B	**3,640**
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN NORTH CAROLINA SINCE PASSAGE OF THE IRA

OHIO

→ Honda and LG Energy Solutions are partnering on a $4.4 billion investment to develop a battery plant project in Fayette County, the largest direct private investment in Ohio's history. Ohio is also becoming a hub for solar manufacturing, as First Solar made a $680 million investment to expand their solar plant in Wood County and Invenergy made a $600 million investment for a new solar plant that will create 850 new jobs.

$7.76 B	**5,200**
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN OHIO SINCE PASSAGE OF THE IRA

SOUTH CAROLINA

→ BMW announced a $1.7 billion investment in South Carolina in their shift to EV manufacturing, and Bosch announced production of electric motors in Charleston to the tune of $260 million.

- ABB E-mobility will expand its EV charger facility to `create up to 10,000 chargers` a year for transit buses, Envision AESC is `investing $810 million` in a new battery gigafactory in Florence County in partnership with BMW, and Redwood Materials is `investing $3.5 billion` to build a battery materials campus in Berkeley County.

$10.92 B	**11,060**
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN SOUTH CAROLINA SINCE PASSAGE OF THE IRA

TENNESSEE

- Tennessee has several projects set to bring jobs to the state: Piedmont Lithium announced plans to invest `$600 million in a new lithium hydroxide plant`, Daejin Advanced Materials announced a `$10.2 million investment` in a new EV battery plant, NOVONIX Anode Materials shared a new battery plant project expected to `cost upwards of $1 billion`, and LG Chem plans to invest `$3.2 billion in a battery cathode plant`.

$5.49 B	**3,700**
INVESTMENTS IN CLEAN ENERGY PROJECTS	JOBS IN TENNESSEE SINCE PASSAGE OF THE IRA

TEXAS

- Since the passage of the law, Texas has seen record investments: `SK Signet announced plans` for an EV fast charger manufacturing facility, `Tesla plans to invest $770 million` toward expanding its Austin EV factory, and Air Products and AES jointly announced a `$4 billion investment` for the companies' first mega-scale green hydrogen production facility.
- OCI and Mission Solar announced a `$40 million investment` to expand domestic solar module production facilities, and SEG Solar announced a new residential solar

project that will bring 500 jobs to the state.

$4.95 B		2,743
INVESTMENTS IN CLEAN ENERGY PROJECTS		JOBS IN TEXAS SINCE PASSAGE OF THE IRA

WEST VIRGINIA

- SPARKZ, Form Energy, and Our Next Energy each announced plans to build battery plants. Form Energy will invest $760 million in a longer lasting iron-air battery project, and Our Next Energy will invest $22 million for a utility-scale battery factory.

$782 M		4,755
INVESTMENTS IN CLEAN ENERGY PROJECTS		JOBS IN WEST VIRGINIA SINCE PASSAGE OF THE IRA

ACROSS THE COUNTRY, NEW INVESTMENTS MADE IN ONGOING CLEAN ENERGY PROJECTS CONTINUE TO SPUR NEW JOBS.

BY THE NUMBERS		
STATE	**INVESTMENT**	**JOBS**
ALABAMA	$1.33 BILLION	1,480 JOBS
ARIZONA	$8.31 BILLION	12,720 JOBS
CALIFORNIA	$5.45 BILLION	3,300JOBS
COLORADO	$1.07 BILLION	1,467JOBS
CONNECTICUT	$25.1 MILLION	45 JOBS
FLORIDA	$451 MILLION	1,500 JOBS
GEORGIA	$13.34 BILLION	12,888 JOBS
IDAHO	$15 BILLION	2,000JOBS

ILLINOIS	$895 MILLION	485 JOBS
INDIANA	$2.22 BILLION	717 JOBS
IOWA	-	700 JOBS
KANSAS	$4 BILLION	20,600 JOBS
KENTUCKY	$3.26 BILLION	1,503 JOBS
LOUISIANA	$861.4 MILLION	230 JOBS
MAINE	$6 MILLION	200 JOBS
MARYLAND	$70 MILLION	460 JOBS
MASSACHUSETTS	$200 MILLION	250 JOBS
MICHIGAN	$20.23 BILLION	13,702 JOBS
MINNESOTA	$575 MILLION	914 JOBS
MISSISSIPPI	$115 MILLION	300 JOBS
MISSOURI	$400 MILLION	150 JOBS
NEVADA	$4.54 BILLION	10,800 JOBS
NEW JERSEY	$1.07 BILLION	200 JOBS
NEW MEXICO	$404 MILLION	250 JOBS
NEW YORK	$101.522 BILLION	13,355 JOBS
NORTH CAROLINA	$9.59 BILLION	3,640 JOBS
NORTH DAKOTA	$871 MILLION	150 JOBS
OHIO	$7.76 BILLION	5,200 JOBS
OKLAHOMA	$1.45 MILLION	2,015 JOBS
OREGON	$1 BILLION	280 JOBS
RHODE ISLAND	$729 MILLION	1,850 JOBS
SOUTH CAROLINA	$10.92 BILLION	11,060 JOBS
SOUTH DAKOTA	$1 BILLION	1,280 JOBS
TENNESSEE	$5.49 BILLION	3,700 JOBS
TEXAS	$4.95 BILLION	2,743 JOBS
UTAH	$11 BILLION	800 JOBS
VERMONT	-	12 JOBS
VIRGINIA	$37 MILLION	165 JOBS
WASHINGTON	$1.72 BILLION	800 JOBS
WEST VIRGINIA	$782 MILLION	4,755 JOBS
WISCONSIN	-	200 JOBS
STATE NOT SPECIFIED	$107 MILLION	3,150 JOBS

TOTAL OF 142,016 JOBS

METHODOLOGY

This report analyzes public announcements from the private sector since the passage of the Inflation Reduction Act to demonstrate the breadth and scale of the clean energy economic boom happening all across the country. It tracks public announcements from the private sector between August 16, 2022 to March 31, 2023.

THE CLEAN ENERGY BOOM
IN HOUSE REPUBLICAN DISTRICTS

MORE THAN HALF OF NEW CLEAN ENERGY PROJECTS, JOBS AND INVESTMENTS ARE LOCATED IN DISTRICTS REPRESENTED BY HOUSE REPUBLICANS

Since the landmark Inflation Reduction Act (IRA) became law in August 2022, the private sector has been racing forward with massive investments to build our clean energy future. New manufacturing in wind, solar, batteries, and electric vehicles — along with storage projects across the country — mean new, good-paying jobs for hard-working Americans. In the months since the landmark climate and clean energy investments became law, clean energy companies have announced or moved forward with projects accounting for more than 142,000 new clean energy jobs for electricians, mechanics, construction workers, technicians, support staff, and many others.

At the same time as this massive clean energy boom is creating jobs in communities across the country, MAGA extremists in Congress have chosen this moment to try to repeal the IRA, killing clean energy jobs and reversing our nation's clean energy progress. All of this is made more confusing by the fact that **more than half of clean energy projects** that have been announced or moved forward since the passage of the IRA are located in districts represented by House Republicans. **In short, Republican MAGA extremists in Congress are ready to kill new, good paying jobs coming to their own districts to play politics and prioritize their oil and gas allies.**

This report analyzes the more than 191 clean energy projects that have moved forward since the passage of the IRA and finds:

- More than half of all clean energy projects that have moved forward since the passage of the IRA are in districts represented by House Republicans: 107 clean energy projects in total located in 72 congressional districts across the country.
- Projects in these districts will create 77,261 jobs and generate more than $198 billion in investments.
- The districts with the most clean energy projects include NV-2 (Rep. Mark Amodei), KY-1 (Rep. James Comer), TN-7 (Rep. Mark Green), GA-12 (Rep. Rick Allen), IN-5 (Rep. Victoria Spartz), SC-2 (Rep. Joe Wilson), WA-4 (Rep. Dan Newhouse).

- The districts with the highest number of clean energy jobs include NV-2 (Rep. Mark Amodei), NY-22 (Rep. Brandon Williams), GA-11 (Rep. Barry Loudermilk), WV-2 (Rep. Alexander Mooney), AZ-5 (Rep. Andy Biggs), MI-5 (Rep. Tim Walberg), and MI-2 (Rep. John Moolenaar).
- The districts with the largest dollar investment in clean energy include NY-22 (Rep. Brandon Williams), ID-2 (Rep. Michael Simpson), UT-3 (Rep. John Curtis), GA-11 (Rep. Barry Loudermilk) and AZ-5 (Rep. Andy Biggs).

107 CLEAN ENERGY PROJECTS IN 72 CONGRESSIONAL DISTRICTS REPRESENTED BY HOUSE REPUBLICANS ACROSS THE COUNTRY

According to a Climate Power analysis, more than half of the 191 clean energy projects with $242.81 billion in new investments are in districts represented by House Republicans. In total of the 72 Republican members of Congress with new clean energy projects, 62 of them voted against the IRA on August 16, 2023. The 10 who didn't take the vote are freshman so they were not in Congress last year at the time of the vote. However, at least 7 of these members who were not in Congress at the time of the vote have said they oppose the bill.

The district with a House Republican representative with the highest number of new clean energy jobs is NV-2, the district represented by Rep. Mark Amodei, with 9,750. The second highest number of clean energy jobs is in NY-22 represented by Rep. Brandon Williams with 9,000 jobs.

Districts with the highest number of jobs:

- **Most:** 9,750 in NV-2 (Rep. Mark Amodei)
- **Second:** 9,000 in NY-22 (Rep. Brandon Williams)
- **Third:** 6,000 in GA-11 (Rep. Barry Loudermilk)
- **Over 2,000:** 3,750 in WV-2 (Rep. Alexander Mooney), 2,800 in AZ-5 (Rep. Andy Biggs), 2,500 in MI-5 (Rep. Tim Walberg), 2,350 in MI-2 (Rep. John Moolenaar), 2,205 in SC-5 (Rep. Ralph Norman), 2,200 in OH-15 (Rep. Mike Carey), 2,000 in ID-2 (Rep. Michael Simpson), 2,000 in OK-5 (Rep. Stephanie Bice)
- **Over 1,000:** 1,801 in TN-7 (Rep. Mark Green), 1,686 in GA-12 (Rep. Rick Allen), 1,515 in OK-2 (Rep. Josh Brecheen), 1,500 in SC-1 (Rep. Nancy Mace), 1,490 in TX-13 (Rep. Ronny Jackson), 1,280 in SD-At Large (Rep. Dusty Johnson), 1,170 in SC-7 (Rep. Russell Fry), 1,165 in AZ-9 (Rep. Paul Gosar), 1,150 in OH-12 (Rep. Troy Balderson), 1,142 in GA-1 (Rep. Earl Carter), 1,120 in TN-3 (Rep. Charles Fleischmann), 1,103 in KY-1 (Rep. James Comer), 1,005 in WV-1 (Rep. Carol Miller)

The district with a House Republican representative with the largest investments in clean energy projects is NY-22 represented by Rep. Brandon Williams with a $100 billion investment.

Districts with the largest investments:

- **Largest:** $100 billion in NY-22 (Rep. Brandon Williams)
- **Over $10 billion:** $15 billion in ID-2 (Rep. Michael Simpson) and $11 billion in UT-3 (Rep. John Curtis)
- **Over $5 billion:** $7.5 billion in GA-11 (Rep. Barry Loudermilk), $5.6 billion in AZ-5 (Rep. Andy Biggs)
- **Over $2 billion:** $4.42 billion in NV-2 (Rep. Mark Amodei), $4.4 billion in OH-15 (Rep. Mike Carey), $4.09 billion in TX-13 (Rep. Ronny Jackson), $3.8 billion in NC-9 (Rep. Richard Hudson), $3.58 billion in TN-7 (Rep. Mark Green), $3.5 billion in SC-1 (Rep. Nancy Mace), $3.5 billion in MI-5 (Rep. Tim Walberg), $2.6 billion in GA-3 (Rep. A. Ferguson), $2.4 billion in MI-2 (Rep. John Moolenaar)
- **Over $1 billion:** $1.74 billion in SC-5 (Rep. Ralph Norman), $1.7 billion in KY-2 (Rep. Brett Guthrie), $1.7 billion in SC-4 (Rep. William Timmons), $1.62 billion in TN-3 (Rep. Charles Fleischmann), $1.56 in KY-1 (Rep. James Comer), $1.5 billion in IN-8 (Rep. Larry Bucshon), $1.45 billion in OK-2 (Rep. Josh Brecheen), $1.07 billion in NJ-4 (Rep. Christopher Smith), $1 billion in SD-At Large (Rep. Dusty Johnson), $1 billion in AL-4 (Rep. Robert Aderhot)

DISTRICT SNAPSHOTS: OUR NATION'S CLEAN ENERGY BOOM IS BRINGING JOBS AND INVESTMENTS TO DISTRICTS REPRESENTED BY HOUSE REPUBLICANS

Thanks to the Biden administration's clean energy plan, billions of dollars are flooding into districts represented by House Republicans across the country. These investments are popular. According to a recent poll from Navigator Research, the IRA is supported by 89% of Democrats, 62% of Independents, and 44% of Republicans.

Despite the popularity of these investments, Republicans in Congress voted against the IRA and now, are threatening to repeal the job-creating investments, directly impacting the local economies in their districts and their constituent's wallets and jobs.

- **Arizona's 6th Congressional District:** Rep. Juan Ciscomani represents Arizona's 6th Congressional district where 2 new clean energy projects are creating 245 jobs. As a freshman,

Rep. Ciscomani did not vote for the IRA in August 2022 but he has stated he opposed the IRA, and incorrectly claimed it would raise taxes without helping inflation.

- **Georgia's 14th Congressional District:** In January 2023, Qcells announced it would expand its operations in this Georgia district, adding 510 new jobs to capitalize on IRA incentives. Despite voting against the IRA and continuing to deny climate change, Rep. Marjorie Taylor Greene, who represents this district, told POLITICO that "we're excited to have jobs" in response to the announcement.
- **Michigan's 9th Congressional District:** In October 2022, Magna announced a $426 million expansion of its electric vehicle structures manufacturing facility in Rep. Lisa McClain's district, which will create 920 new clean energy jobs. Rep. McClain voted against the IRA and claimed the bill was deceptive because it would do "nothing to reduce inflation".
- **Nevada's 2nd Congressional District:** Represented by Rep. Mark Amodei, this district leads the nation in the highest number of clean energy jobs since the passage of the IRA. In total, the district has attracted 4 new clean energy projects generating 9,750 new jobs and more than $4.4 billion in investments. Rep. Amodei voted against the IRA, arguing that the legislation prioritizes climate initiatives over traditional energy sources at a time of historic inflation, and that, "the sad truth is that our country is amid a recession, and this bill will only deepen our country's economic troubles."
- **New York's 19th District:** Republican Rep. Marcus Molinaro represents this district. As a freshman, Rep. Molinaro didn't have the opportunity to vote on the IRA, but he called the legislation a "bad idea" that "does nothing to lower inflation." According to a release from Sen. Schumer, IRA tax credits were a large driver behind Zinc8's decision to build in New York, and more specifically in Moninaro's district. The manufacturing hub is expected to create 500 new jobs.
- **New York's 22nd District:** This district, represented by Rep. Brandon Williams, leads the nation in clean energy investment since the passage of the IRA. Micron has invested $100 billion in the district creating 9,000 direct clean energy jobs with the construction of their New York Semiconductor Megafab Facility. The project, announced in October 2022, will produce microchips for EVs and other technologies and will create another 40,000 indirect community jobs. Although Rep. Williams didn't have the opportunity to vote on the IRA, according to an October 2022 article in Politico, Rep. Williams "opposed the [IRA], which he called a giveaway to special interests that would drive continued inflation."
- **South Carolina's 1st Congressional District:** Redwood Materials announced it would invest $3.5 billion to build a battery recycling campus that will create 1,500 clean energy jobs in this district, represented by Rep. Nancy Mace. Redwood Materials cited the "benefits of the recent

[IRA]" in announcing the new campus. Rep. Mace voted against the IRA, and claimed the legislation's "massive spending" wouldn't lower inflation.

BY THE NUMBERS				
DISTRICT	MEMBER	NUMBER OF PROJECTS	TOTAL JOBS	TOTAL INVESTMENT
AL-3	REP. MIKE ROGERS	1	180	$8,000,000
AL-4	REP. ROBERT ADERHOT	1	700	$1,000,000,000
AL-5	REP. DALE STRONG	1	200	$125,000,000
AZ-5	REP. ANDY BIGGS	1	2,800	$5,600,000,000
AZ-6	REP. JUAN CISCOMANI	2	245	$0
AZ-9	REP. PAUL GOSAR	3	1,165	$0
CO-3	REP. LAUREN BOEBERT	2	700	$0
CO-5	REP. DOUG LAMBORN	1	400	$880,000,000
FL-1	REP. MATT GAETZ	1	0	$20,000,000
FL-2	REP. NEAL DUNN	1	300	$0
GA-1	REP. EARL CARTER	2	1,142	$367,000,000
GA-3	REP. DREW FERGUSON	1	723	$2,600,000,000
GA-6	REP. RICHARD MCCORMICK	1	200	$19,000,000
GA-9	REP. ANDREW CLYDE	1	400	$0
GA-10	REP. MIKE COLLINS	1	0	$0
GA-11	REP. BARRY LOUDERMILK	2	6,000	$7,500,000,000
GA-12	REP. RICK ALLEN	3	1,686	$872,000,000
GA-14	REP. MARJORIE TAYLOR GREENE	1	510	$171,000,000
IA-1	REP. MARIANNETTE MILLER-MEEKS	1	700	$0
ID-2	REP. MICHAEL SIMPSON	1	2,000	$15,000,000,000
IL-15	REP. MARY MILLER	1	0	$360,000,000
IN-5	REP. VICTORIA SPARTZ	3	75	$721,000,000
IN-8	REP. LARRY BUCSHON	1	642	$1,500,000,000
KS-1	REP. TRACEY MANN	1	100	$0
KY-1	REP. JAMES COMER	4	1,103	$1,569,564,400
KY-2	REP. BRETT GUTHRIE	1	400	$1,700,000,000
LA-5	REP. JULIA LETLOW	1	120	$444,816,850
MI-2	REP. JOHN MOOLENAAR	1	2,350	$2,400,000,000
MI-5	REP. TIM WALBERG	1	2,500	$3,500,000,000
MI-9	REP. LISA MCCLAIN	1	920	$426,000,000
MI-10	REP. JOHN HAMES	1	155	$96,170,000
MN-6	REP. TOM EMMER	1	914	$575,000,000
MS-4	REP. MIKE EZELL	1	300	$115,000,000

NC-9	REP. RICHARD HUDSON	1	350	$3,800,000,000
NC-10	REP. PATRICK MCHENRY	2	230	$375,525,233
ND-AL	REP. KELLY ARMSTRONG	2	150	$871,872,271
NJ-2	REP. JEFFERSON VAN DREW	1	200	$0
NJ-4	REP. CHRISTOPHER SMITH	1	0	$1,070,000,000
NV-2	REP. MARK AMODEI	4	9,750	$4,429,322,049
NY-19	REP. MARCUS MOLINARO	1	500	$68,000,000
NY-21	REP. ELISE STEFANIK	1	90	$500,000,000
NY-22	REP. BRANDON WILLIAMS	1	9,000	$100,000,000,000
NY-23	REP. NICHOLAS LANGWORTHY	1	250	$75,000,000
OH-4	REP. JIM JORDAN	1	300	$700,000,000
OH-12	REP. TROY BALDERSON	2	1,150	$782,514,939
OH-14	REP. DAVID JOYCE	1	0	$170,000,000
OH-15	REP. MIKE CAREY	1	2,200	$4,400,000,000
OK-2	REP. JOSH BRECHEEN	2	1,515	$1,450,000,000
OK-5	REP. STEPHANIE BICE	1	2,000	$0
SC-1	REP. NANCY MACE	1	1,500	$3,500,000,000
SC-2	REP. JOE WILSON	3	410	$397,000,000
SC-3	REP. JEFF DUNCAN	1	350	$200,000,000
SC-4	REP. WILLIAM TIMMONS	2	300	$1,700,000,000
SC-5	REP. RALPH NORMAN	2	2,205	$1,743,000,000
SC-7	REP. RUSSELL FRY	1	1,170	$810,000,000
SD-AL	REP. DUSTY JOHNSON	2	1,280	$1,000,000,000
TN-3	REP. CHARLES FLEISCHMANN	2	1,120	$1,627,260,704
TN-5	REP. ANDREW OGLES	2	650	$275,000,000
TN-7	REP. MARK GREEN	4	1,801	$3,584,740,145
TN-8	REP. DAVID KUSTOFF	1	150	$107,000,000
TX-4	REP. PAT FALLON	1	200	$0
TX-8	REP. MORGAN LUTTRELL	1	500	$0
TX-13	REP. RONNY JACKSON	2	1,490	$4,090,000,000
TX-26	REP. MICHAEL BURGESS	1	100	$0
UT-3	REP. JOHN CURTIS	1	800	$11,000,000,000
VA-5	REP. BOB GOOD	1	165	$37,000,000
WA-4	REP. DAN NEWHOUSE	3	800	$722,936,774
WI-1	REP. BRYAN STEIL	1	0	$0
WI-3	REP. DERRICK VAN ORDEN	1	0	$345,000,000
WI-8	REP. MIKE GALLAGHER	1	200	$0
WV-1	REP. CAROL MILLER	2	1,005	$22,000,000
WV-2	REP. ALEXANDER MOONEY	2	3,750	$760,000,000

TOTALS	72 DISTRICTS	107	77,261	$198,182,723,365

METHODOLOGY

This report analyzes public announcements from the private sector since the passage of the IRA. It builds on Climate Power's full analysis of all 191 public announcements from the private sector between August 16, 2022 to March 31, 2023.

POLITICO

ENERGY & ENVIRONMENT

Big winners from Biden's climate law: Republicans who voted against it

GOP lawmakers voted en masse against Biden's signature bill. But roughly two-thirds of green-energy projects announced since it became law are going to Republican-held congressional districts, a POLITICO analysis found.

The GOP is likely to find itself in an uncomfortable position as funding from the Inflation Reduction Act plays a growing role in Republicans home states and districts. | Godofredo A. Vásquez/AP Photo

By Kelsey Tamborrino and Josh Siegel

01/23/2023 01:14 PM EST
Updated: 01/23/2023 03:32 PM EST

They didn't vote for it, they don't like it and they're working to undermine it — but Republicans are reaping the benefits of Democrats' climate law.

In the five months since the Inflation Reduction Act became law, companies have announced tens of billions of dollars in renewable energy, battery and electric vehicle projects that will benefit from incentives in President Joe Biden's signature law, aimed at expanding domestic manufacturing in clean energy and reducing dependence on Chinese imports.

In fact, roughly two-thirds of the major projects are in districts whose Republican lawmakers opposed the Inflation Reduction Act, according to a POLITICO analysis of major green energy manufacturing announcements made since the bill's enactment.

The dynamic has prompted a tricky balancing act for the GOP: Tout the jobs and economic benefits coming to their states and districts, but not the bill that helped create them. The results are also potentially awkward for Democrats who expended political capital and more than a year of wrangling to enact the bill, only to see Republican lawmakers and governors sharing in the jobs and positive headlines it's creating — although Democrats say they also see longer-term benefits for the nation in building GOP support for alternatives to fossil fuels.

Republicans insist their positions on the bill and the jobs are not in conflict.

"Just because you vote against a bill doesn't mean the entire bill is a bad bill," said Rep. Garret Graves (R-La.), who was the top GOP member of Democrats' Select Climate Crisis Committee in the last Congress. "I go out there and advocate for our district to try and get transportation funds, to try and get energy funds. That's my job. I am not embarrassed about it. I don't think it's inconsistent with my vote."

To Democrats, the slate of new investments stand as proof that they were correct that the Inflation Reduction Act, H.R. 5376 (117), would expand the reach of clean power to rural and conservative areas — a promise that failed to sway a single Republican vote to support the bill.

"It's hard not to point out the hypocrisy for people who fought tooth and nail against the bill, those very incentives that are now creating opportunities in their [Republican] districts they are now leading," said Sen. Tina Smith (D-Minn.). "We just have to point out, thanks for your kind words, but this didn't just happen. It happened despite your best efforts."

Smith attended an October ribbon-cutting in her state for Canadian solar panel maker Heliene's expansion of its manufacturing facility — an effort that was started prior to the Inflation Reduction Act's passage and that has drawn praise from Rep. Pete Stauber (R-Minn.), whose district is home to the plant that will be one of the largest panel makers in the country.

Energy Secretary Jennifer Granholm welcomed the news that Republican districts were drawing the investments.

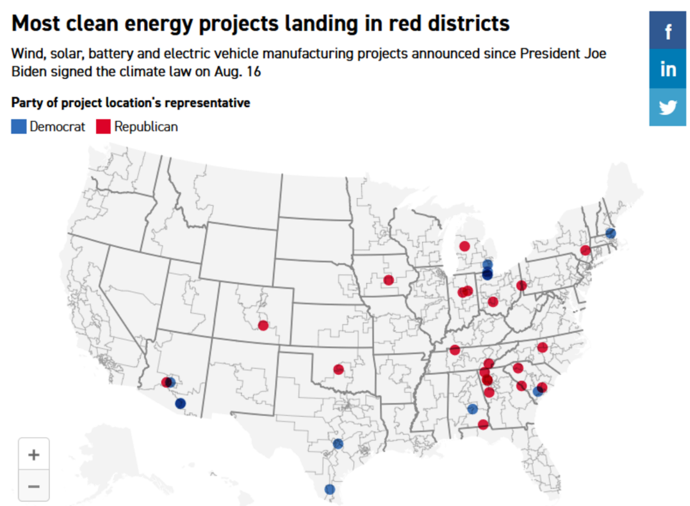
"Great, that is fantastic," she told reporters at the Monday White House briefing. "We want to be able to see energy — clean energy — produced in every pocket of the country. Blue states, red states, really it helps to save people money, so it's all about green."

Democrats' climate law includes billions of dollars to spur green energy technologies and cut greenhouse gas emissions, including a new tax credit for manufacturing the components crucial for solar, wind and electric vehicles, as well as additional incentives for using domestic content in projects.

Republicans, though, have moved to slash funding of the Internal Revenue Service, the central agency charged with implementing the climate law's incentives, over concerns that Democrats have expanded its mandate. And Friday, former President Donald Trump urged GOP lawmakers to target "billions being spent on climate extremism" in their fight over the debt limit.

Supporters of the Inflation Reduction Act say its success is due in part to the way it provides long-term certainty for companies looking to place a footprint in the U.S.

The bill is a "fundamental element" of the recent spate of manufacturing announcements, said Abigail Ross Hopper, the president and CEO of the Solar Energy Industries Association. "There certainly were a number of plans being evaluated and discussed [prior to the bill]. But I think the vast majority were contingent upon the passage of the IRA."



Company	House district	Representative	Location
American Battery Factory	● AZ-07	Raúl Grijalva	Tucson, Ariz.
BMW / Envision AESC	● SC-04	William Timmons	Woodruff, S.C.
Canoo	● OK-05	Stephanie Bice	Oklahoma City, Okla.
CS Wind	● CO-03	Lauren Boebert	Pueblo, Colo.
Factorial Energy	● MA-03	Lori Trahan	Methuen, Mass.
First Solar	● AL-04	Robert Aderholt	Lawerence County, Ala.
First Solar	● OH-09	Marcy Kaptur	Perrysburg, Ohio
Form Energy	● WV-02	Alex Mooney	Weirton, W.Va.
Freyr Battery	● GA-03	Drew Ferguson	Coweta County, Ga.
General Motors	● IN-05	Victoria Spartz	Marion, Ind.
General Motors	● OH-09	Marcy Kaptur	Toledo, Ohio
Gotion	● MI-02	John Moolenaar	Big Rapids, Mich.
Honda / LG Energy	● OH-15	Mike Carey	Fayette County, Ohio
Hyundai Mobis	● AL-07	Terri Sewell	Montgomery, Ala.
Hyundai / SK	● GA-11	Barry Loudermilk	Cartersville, Ga.
JA Solar	● AZ-07	Raúl Grijalva	Phoenix, Ariz.
Kontrolmatik Technologies	● SC-06	Jim Clyburn	Walterboro, S.C.
LG Chem	● TN-07	Mark Green	Clarksville, Tenn.
Meyer Burger	● AZ-09	Paul Gosar	Goodyear, Ariz.
Misson Solar	● TX-28	Henry Cuellar	San Antonio, Texas
Our Next Energy	● MI-06	Debbie Dingell	Van Buren Township, Mich.
Piedmont Lithium	● TN-03	Chuck Fleischmann	Etowah, Tenn.
Q Cells	● GA-11	Barry Loudermilk	Bartow County, Ga.
Q Cells	● GA-14	Marjorie Taylor-Greene	Dalton, Ga.

Redwood Materials	● SC-01	Nancy Mace	Ridgeville, S.C.
Sion Power Corp.	● AZ-07	Raúl Grijalva	Tucson, Ariz.
Solvay / Orbia	● GA-12	Rick Allen	Augusta, Ga.
Soulbrain MI	● IN-05	Victoria Spartz	Kokomo, Ind.
Tesla	● TX-35	Greg Casar	Austin, Texas
Toledo Solar	● OH-09	Marcy Kaptur	Perrysburg, Ohio
Toyota	● NC-09	Richard Hudson	Liberty, N.C.
TPI Composites	● IA-01	Mariannette Miller-Meeks	Newton, Iowa
Zinc8	● NY-19	Marc Molinaro	Ulster County, N.Y.

Note: This data does not include projects where the precise location was unavailable.
Source: American Clean Power Association, GovTrack.us, media reports and company announcements
Kelsey Tamborrino/POLITICO

In the three months after Biden signed the Inflation Reduction Act in August, companies announced more than $40 billion of new clean energy investments, according to a December report from the American Clean Power Association, an industry trade group. POLITICO's analysis of the law's early results includes those projects as well as separate news reports and company announcements of manufacturing expansions and plans, and additional announcements on electric vehicle plants.

Out of 33 projects examined, 21 are expected to be located in Republican-held congressional districts, compared with 12 in Democratic districts. POLITICO's analysis did not reflect every announcement made and does not include facilities where a specific congressional district could not be found.

Just this month, South Korean solar company Hanwha Q Cells announced it would invest $2.5 billion in Georgia to expand its solar panel manufacturing plant and construct another facility in the state.

That expansion is occurring partially in the district of conservative firebrand Rep. Marjorie Taylor Greene — who has described climate change as "actually healthy for us" and has blasted Democrats' bill. Greene, however, recently told POLITICO that she's "excited to have jobs" in her district that will come from the Q Cells announcement, though she gave credit to Georgia's GOP Gov. Brian Kemp, who has courted clean energy and electric vehicle manufacturing investments through state-level subsidies and tax incentives.

Federal and state incentives alike are playing a role in the companies' decisions, said J.C. Bradbury, an economics professor at Kennesaw State University in Georgia.

"They are coming to Georgia for one reason — we are paying them to come here with subsidies," Bradbury said in an interview, referring to the combination of federal and state tax credits. "These projects are being pitched as economic development projects 100 percent."

But while manufacturing proponents point to factors including geography, economic development plans and states' anti-union laws as factors drawing investment to deep-red districts, they also say the announcements are directly tied to the federal subsidies provided under Democrats' bill.

"It's not random," said Jason Walsh, executive director of the BlueGreen Alliance, which includes labor unions and environmental organizations. "It's because specific policies have been put in place and passed by the U.S. Congress to actually incentivize exactly the kind of activity that we're seeing."

And the investments are only expected to grow. Solar manufacturer and Bill Gates-backed CubicPV, for one, is planning a 10-gigawatt facility in the United States, but has not yet chosen a location, while Enel North America, a unit of an Italian energy company, is evaluating sites to build a new solar panel and cell manufacturing plant. Battery manufacturing facilities are also expected to come online in the years ahead across several states, including Michigan, Tennessee, Arizona and Georgia.

Companies aren't necessarily looking at which lawmaker represents the district when they invest, said Scott Paul, president of Alliance for American Manufacturing. They're looking instead at where the supply chains exist and where they can leverage the tax benefits and capital provided by lawmakers.

"Red state-blue state [is] not really a factor," Paul said, adding, "This isn't one of those things that looks like an electoral map at all."

Republicans express no regret about opposing the IRA despite previously supporting individual pieces of the bill, such as tax incentives for carbon capture, nuclear and hydrogen projects. GOP members argued that the bill would pump too much money into the economy and worsen inflation, and they've criticized Democrats for using the partisan reconciliation process that allowed them to pass it with a simple majority in the Senate.

"The overall process, the overall bill, particularly the spending, really frustrates Republicans — not necessarily every specific in the bill," said Rep. John Curtis (R-Utah).

But the GOP is likely to find itself in an uncomfortable position as funding from the Inflation Reduction Act plays a growing role in Republicans home states and districts.

Former Virginia Democratic Rep. Tom Perriello, who lost his reelection bid in 2010 after voting for the Affordable Care Act, said those dynamics put Republicans in a tricky spot once voters see the jobs stemming from Democrats' agenda.

"Biden has driven his agenda right down Main Street with a big 'Made in America' banner on the back of an electric truck, and people's only choices are to get on board with the parade or seem to be against making things in America again," he said. "I think of those two choices, Republican hypocrisy makes a lot more sense than standing in the way of jobs and American competitiveness."

He called it "squirrely" for lawmakers to argue to voters that they like certain parts of the bill, but not others.

"That's just not how legislating works. That's not how things pass," he said.

House Republicans have promised robust oversight of the climate law, pledging to seek out wasteful spending in search of would-be scandals such as the failed Solyndra loan guarantee of the Obama administration — even if the overall program is a success.

"I don't think it complicates the oversight," a House GOP leadership aide told POLITICO, who asked for anonymity to speak candidly. "Oversight is an important function. There could be 20 great projects [supported by IRA], but if one is bad, it's our job to understand why."

Republicans also criticized the Biden administration's rush to embrace greener energy while the country still relies on China for technology components, and they've been critical of government support that has helped companies with manufacturing in China.

Virginia Gov. Glenn Youngkin, a Republican, said he rejected Ford Motors' efforts to consider locating a battery plant in his state over concerns about China and national security.

Democrats, though, hope the trend of clean energy boosting the economic prospects of red states helps shift the rhetoric of Republicans and enables more bipartisan cooperation on narrow interests benefiting the climate.

"Over time, I anticipate their [Republican] talking points will change as their neighbors become a part of the clean energy economy," said former House climate committee Chair Kathy Castor (D-Fla.).

FILED UNDER: CONGRESS, WHITE HOUSE, CLIMATE CHANGE, JOE BIDEN, GOP,

Wind turbines. Image courtesy of Zach Shahan, CleanTechnica.

CLEAN POWER

Want To Electrify Everything? Train More

Electricians — Quickly

The US Bureau of Labor Statistics projects growth of electrician jobs will increase by 9.1% from 2020 to 2030.

By Carolyn Fortuna Published March 7, 2023

14 Comments

We have heard the call over the past few years to electrify everything. Doing so will rapidly decrease carbon emissions and help to stave off dangerous levels of global warming. The pace of installing EV chargers, solar panels, induction stoves, heat pumps, wind turbines, transmission lines, and everything else needed for the world to run on 100% clean power by 2050 is amazing to watch. It also requires the expertise of electricians. Unfortunately, there are not enough electricians to fulfill the enormous need. We need to train more electricians — a lot more electricians.

The electrical industry say the country is already facing an electrician shortage — and it could get worse as clean energy ramps up.

The Federal Push for Electrifying Everything

There is $72 million devoted in the Bipartisan Infrastructure Bill for training the clean energy workforce. Then there is the Inflation Reduction Act (IRA), which is appropriating $200 million for job training,

"Due to legislative achievements such as The Inflation Reduction Act, initiatives that increase investments in renewable energy are contributing to the growth of careers in the energy sector," says Jason Miller, CEO of PromoLeaf, a Utah-based promotional products company, told *CleanTechnica* in an exclusive. "In fact, green jobs in renewable energy are the fastest-growing when it comes to careers in the green sector."

	-16%

Products

EV REVIEWS

Miller reveals that some of the hot jobs for electricians within the next decade are Wind Turbine Technicians (set to grow by 68%) and Solar Photovoltaic Installers (expected in increase by 52%).

The median salary in a green job is $76,530/year, Miller describes, which is 31% more than the national median salary for the US workforce ($58,260). The information is part of PromoLeaf's Green Jobs Report analysis.

Rewiring America concurs, explaining that the Inflation Reduction Act (IRA) will deliver "huge savings" in the US:

- **Household benefits:** The average American household will receive $10,600 in IRA benefits to fully electrify.
- **Household savings**: Households will save on average $1,800 per year.

- **Number of households**: 120 million households across the country can benefit from these provisions.
- **Number of jobs created**: 1.4 million direct and 5 million total jobs can be created in the US.

New York, Boston, Seattle, and San Francisco are requiring that new buildings run only on electricity. Berkeley, California, pioneered the legislation in 2019.

What can the US and other countries do to train more electricians as the nation adapts to more renewable power generation? How will upgrades to transmission capacity be affected by a deficit of electricians? A robust workforce is needed to wire, connect, and install new electric lines.

However, moving away from fossil fuels is sometimes viewed as a dangerous decision since it might cost the country jobs in fossil fuel industries; coal mining is showcased as an example. Yet the coal mining industry today employs around 37,000 people — less than 6% of the number of people employed as electricians. Existential fear on the part of the fossil fuel industry has resulted in scare tactics that make legacy workers

question whether they'll find a place in the new all electric workplace.

Change is in the air, though.

Rewiring America explains that shifting the economy away from fossil fuels will require no fewer than 1 billion new electrical appliances, cars, and other items in US households alone. For example, people are becoming keenly aware that, on average, replacing a gas powered car with an EV will slash carbon pollution by about two-thirds when calculated over the car's life span — even when accounting for the grid's current makeup and the emissions associated with the vehicle and battery production.

Where are the electricians to install those EV chargers?

What Will It Take to Train More Electricians?

Green sector jobs continue to be on the rise. With that broad designation, the US Bureau of Labor Statistics projects growth of electrician jobs will increase by 9.1% from 2020 to 2030. New

approaches to incentify workers to join the electrical field will help.

Apprentices wanted: Workers wanting to become electricians have to do an apprenticeships first, either through a union or a company. The Inflation Reduction Act, the landmark climate law passed by Congress in August, includes a requirement that companies that receiving tax incentives for wind and solar energy also employ a certain portion of apprentices: 10% of labor hours in 2022 and 15% by 2024. The Biden-Harris administration has highlighted registered apprenticeship to address some of the nation's pressing workforce challenges, according to outgoing US Secretary of Labor Marty Walsh. The federal initiative "will further support private-public partnerships that help youth across the country access a college education, good-paying jobs, and strong pathways to the middle class."

The Organic Collection.
Cariuma

Bring unions into the conversation: It will be essential to collaborate with union labor so accepted standards and pay will be incorporated into large projects and retrofits. Union training programs can also help increase the number of electricians in the field, but they typically operate and blossom when there is guaranteed demand.

Replace the negative connotation to the Trades: More than 75% of high school and college students in 2021 wanted to work in technology, therefore more likely to attend college than pursue a skilled labor job. The desire for jobs with flexible hours and potential for remote work often steers them away from trade jobs. Some groups are working to expose more young people to the options of joining a trade like the electrical field. Those efforts include offering support through the first few months of employment.

Municipal help: Municipal governments can take on the role of converting their electrified buildings into training centers for workforce development. They can install charging networks directly wired to municipal power lines instead of requiring residents to go solo with new infrastructure.

Invest in underrepresented people and places: Additional investment in retraining and reskilling is imperative in order to train more electricians. So, too, is focusing on under-invested communities and demographics, veterans, and the persons who had once been incarcerated.

Final Thoughts

At least $25.7 billion in new US clean energy factories are in the works, thanks in part to the subsidies in Biden-Harris administration's landmark climate law, the Inflation Reduction Act. Beneficiaries of federal legislation will help the US to wean off fossil fuel power, but it will take more electricians to make the vision a reality.

Ever thought about being an electrician? You should, because the job is always in demand, you have potential for massive

career growth, and working as an electrician is both a challenging and rewarding career. The time has never been better to join the field!

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PREVIEW

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In this article: Inflation Reduction Act of 2022

WRITTEN BY

Carolyn Fortuna

Carolyn Fortuna (they, them), Ph.D., is a writer, researcher, and educator with a lifelong dedication to ecojustice. Carolyn has won awards from the Anti-Defamation League, The International Literacy Association, and The Leavy Foundation. Carolyn is a small-time investor in Tesla. Please follow Carolyn on Twitter and Facebook.

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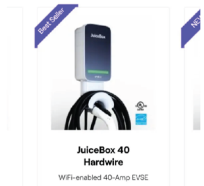

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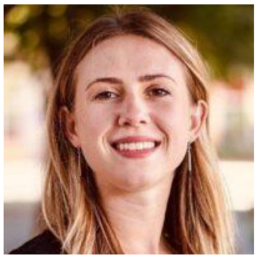
July 27, 2022 | 4:15 pm

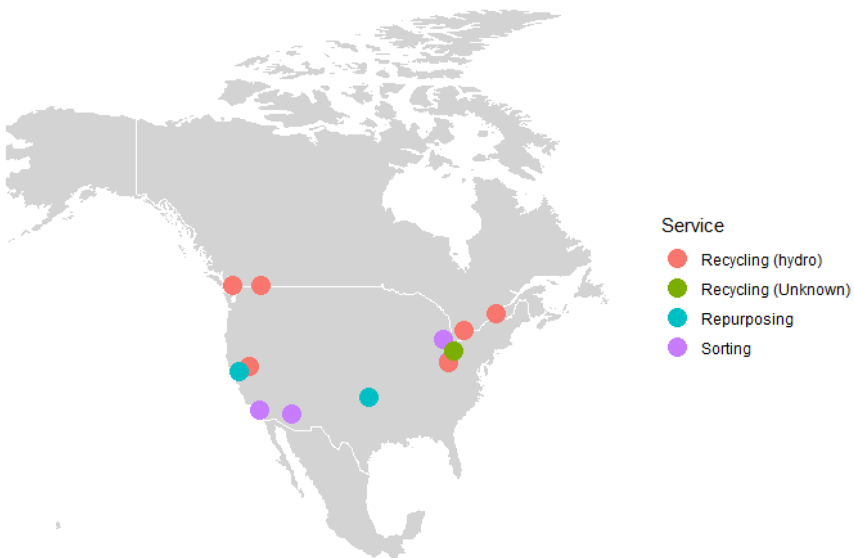


Jessica Dunn
Senior Analyst

As electric vehicle (EV) sales continue to increase, questions about how these cars and their batteries will be disposed of have been top of

mind for current owners, future buyers, policymakers, and many experts in the automotive industry.

EVs are a newer technology, and their batteries require different end-of-life processing than gasoline vehicles. Luckily, lithium-ion battery recycling research and development has been going on for years and there is an existing and growing repurposing and recycling system in North America for these components. The map below is from recent research that explores the network of companies already recycling and repurposing batteries – these include recycling companies such as Redwood Materials, Li-Cycle, and Ascend Elements. The industry is quickly growing capacity for future recycling, with planned facilities in Nevada, New York, and Georgia, to name just a few.



Current lithium-ion battery collection, repurposing, and recycling network in North America.
Slattery et al. (2021).

First reused and repurposed, then recycled

After a battery's first life in a car and before it is recycled, it can be reused, refurbished, and repurposed.

If the battery isn't damaged during its use in an EV, such as in a car accident, these batteries have additional usable capacity – an estimated 80% of the original rated capacity. This means that if the battery was manufactured to store 100 kWh, it can now store up to 80 kWh. In order to make use of the remaining capacity, the batteries can be broken down to salvage smaller components for reuse and refurbishment, or they can be repurposed and used in a less demanding application, such as stationary storage.

For stationary storage, companies such as RePurpose Energy and B2U Storage Solutions are repurposing these batteries to be used for renewable energy generation support. They connect multiple EV batteries together, along with battery monitoring and cooling technology, to create a larger battery that is about the size of a shipping container. The battery stores solar electricity generated during the day and supplies electricity at high-demand times in the evening. As the grid becomes cleaner, added grid storage becomes more necessary to support the generation variability of renewable sources. These used batteries are a great way to both extend the lifespan of a product that has already been manufactured and support the renewable energy transition. After this second-life use, the batteries are then ready to be recycled.

What's valuable in a vehicle battery?

Lithium-ion batteries contain many valuable materials worth recovering and saving from a landfill.

Prior to recycling, the battery is disassembled and shredded using large machinery, breaking the battery into small pieces. Once the shredding is completed, the materials are sifted and separated based on size. This divides them into three different categories: plastics, ferrous materials, and non-ferrous materials (also called black mass). The black mass consists of the critical materials, cobalt, lithium, nickel, and manganese, which can individually be recovered using a hydrometallurgical process.

Hydrometallurgical recycling begins with leaching to create a solvent that contains the critical materials. The individual materials are then recovered using solvent extraction, precipitation, and purification. Hydrometallurgy is well known in the metals industry as a similar process is also used to extract the materials from ore after it is mined. Many US-based lithium-ion recycling companies use a variation of this process and report a material recovery rate of 95%–98%.

Can we use recycled materials to manufacture new batteries?

Yes! Once materials have been recovered, they can then be processed and used in the manufacturing of new lithium-ion batteries. This is a preferable source to using virgin ore because it reduces the amount of mining necessary to produce EVs.

Recent research has shown that by 2050 recycled materials could supply 45–52% of cobalt, 22–27% of lithium, and 40–46% of nickel used in the United States light- and heavy-duty vehicle fleet. Efforts across the United States to increase the sales of EVs are underway – places like California expect to have 100% of all car sales be electric by 2035 – so being able to recycle batteries and reuse the metal within them is a critical step in the transformation to a cleaner transportation system.

Recycling is key to making EVs greener

EV batteries currently represent about half of the lithium-ion batteries (by mass) that are being recycled, which also includes consumer

electronics and waste from battery manufacturing. With 3.8 million EVs on the road today in North America and sales growing year over year, the number of EVs retiring in coming years will continue to increase as they eventually are totaled or age out of the fleet.

This increase will result in vehicle batteries comprising a much higher percentage of the recycling stream; retirements are expected to be 6 to 7 times higher in 2025 than in 2020 and 20 to 40 times higher in 2030. Companies recycling these batteries are setting themselves up to accommodate this upcoming wave by expanding their capacity.

These recycling companies are securing a battery stream by partnering with auto manufacturers. For example, major automakers are partnering with Redwood Materials, a recycling company based in Nevada. Redwood is not only recycling but will soon be closing the material loop by manufacturing battery components with recovered materials.

Redwood Materials has also implemented a recycling program to learn more about the location of retired and uncollected batteries, and how to decrease the costs of transporting these batteries to the recycling facility. Transportation from their location of retirement to the recycling plant is expensive, representing about 50-60% of the recycling costs. These costs are due to the special packaging and requirements needed for shipping retired batteries and their large size and weight. But, transportation costs can potentially be decreased if a more efficient collection system is developed.

Researchers have been modeling potential reverse logistics networks and now Redwood Materials is completing research of their own through a learning-by-doing approach. Their new Recycling Program consists of picking up and recycling any retired lithium-ion battery in California at no cost. They are also working with dealerships and dismantlers in order to collect as many batteries as possible.

California is considering battery recycling requirements

As you can see, there is a lot happening in the industry space. And while there is currently no recycling requirement in the United States, California passed a bill that indicates recycling may be a priority for the state.

Assembly Bill 2832 passed in 2018 creating the California Battery Recycling Advisory Group. This group consists of automotive and battery manufacturers, government agency representatives, and public interest groups. They recently recommended policies to the legislature that could increase the recycling of EV batteries. These recommendations included the creation of a California State requirement that batteries be recycled, holding the auto manufacturer responsible for ensuring that happens. This is not unlike how mattress, paint, and carpet disposal is currently regulated within California.

In addition to the California work, the federal government is also paying attention. In the Bipartisan Infrastructure Bill, funds were allocated toward battery recycling research and development. This is in addition to the funding of the ReCell Center, a lab created by the Department of Energy that is focused on decreasing costs and increasing yields of recycling.

Battery end-of-life is very important for ensuring that batteries are safely disposed of and that materials are recovered and used again in battery manufacturing. While there is a lot going on to push forward the uptake of EVs and replace gasoline cars for good, many people are simultaneously working to make sure that EV batteries are being reused, repurposed, and recycled.

Posted in: Transportation
Tags: electric vehicles, lithium ion batteries, Recycling Clean Energy Technologies

Battery State of Health – What is It? Why is It Important?

October 7, 2022 | 8:00 am

Jessica Dunn
Senior Analyst

Lithium-ion batteries are efficient, compact, and have a long lifespan – all factors that enable electric vehicles (EVs), which are powered by these batteries, to be a great substitute for their gasoline counterpart.

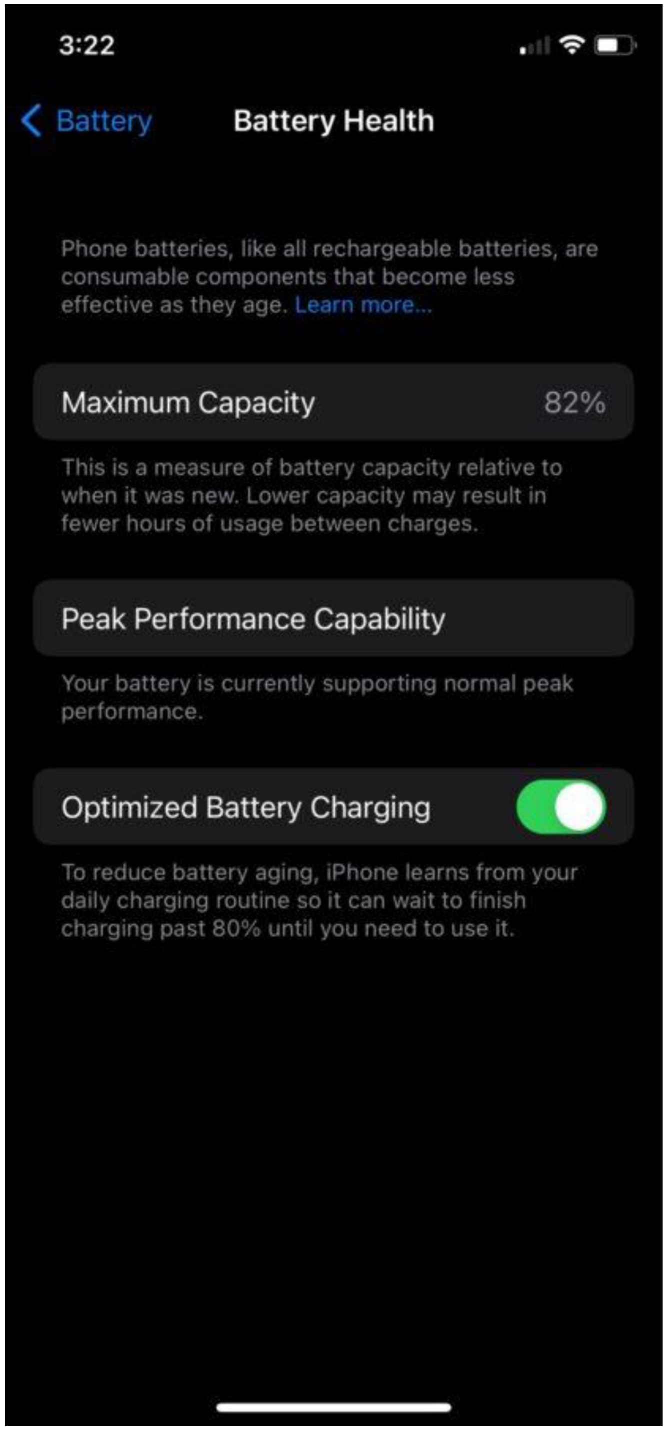
Transportation is a large contributor to greenhouse gas emissions. By switching to EVs, and away from these highly polluting gasoline vehicles, a huge reduction in planet-warming emissions is possible.

While these batteries are revolutionary, they don't last forever. As years pass, and as the batteries charge and discharge, their storage capacity begins to slowly reduce. This is a normal process that is influenced by factors such as temperature, number of cycles, and depth of discharge. Knowing how much life is left in an EV battery is pretty critical for someone who is buying a used EV and for deciding if a battery should be reused, repurposed, or recycled when the EV is retired.

Similar to gasoline vehicles, an EV is expected to last between 8-15 years, at which point the battery will likely have between 70-80% of its capacity left. While this reduced capacity is not ideal for use in an EV, it can continue to be utilized in a second-life application such as stationary storage. Stationary storage is a vital part of the renewable energy transition. The batteries help smooth the supply of renewable generation, such as solar, to meet energy demand. This is done by charging the batteries during the day, when the sun is out, and then using the energy in the evening.

In order to determine if the battery is suited for a second-life application, the state of health must be assessed. **The battery *state of health* is a measurement that indicates the level of degradation and remaining capacity of the battery.** It is essentially the difference between the health of a new battery and the health of a used battery, and typically represented as a percentage of its initial capacity.

The iPhone is a great example of how we interact with battery state of health in our daily life. Most of us have had the experience of noticing that over time our phone battery cannot hold a charge for as long. Apple got wind of this frustration and now includes a 'Battery Health' indicator in the settings. This communicates the battery's percent maximum available capacity in comparison to when the phone was new.


3:22
Battery
Battery Health
Phone batteries, like all rechargeable batteries, are consumable components that become less effective as they age. Learn more...
Maximum Capacity
82%
This is a measure of battery capacity relative to when it was new. Lower capacity may result in fewer hours of usage between charges.
Peak Performance Capability
Your battery is currently supporting normal peak performance.
Optimized Battery Charging
To reduce battery aging, iPhone learns from your daily charging routine so it can wait to finish charging past 80% until you need to use it.

Screenshot of the author's iPhone battery's state of health.
J. Dunn/UCS

The importance of information sharing

State of health has emerged as an important indicator throughout the lifespan of the battery. When the vehicle is on the road, EV owners want to know the reliability of their vehicle. When owners resell, battery state of health information can more accurately value the product and purchasers can have increased confidence in the EV's worth, longevity, and range. When the EV is retired, knowing the battery's state of health is essential for determining if the battery is viable for reuse and repurposing, or if it should be sent directly to recycling.

Currently, EV battery state of health information is only sometimes accessible at these points along the battery life cycle, and that's not good enough.

While the battery is in the vehicle, the EV owner can view their available range on the dashboard or download an app on their smartphone which predicts the state of health for some EV models. In addition, auto manufacturers can access further information through the onboard diagnostic system, a proprietary technology that is only available at certified mechanics. When the EV is retired, things get especially tricky. If the vehicle can't be turned on, or if the battery has already been removed, the automaker's state of health estimation can only be accessed via a proprietary connector that is not available at a mechanic, or for purchase.

So, how is state of health determined by repurposers?

Repurposers typically receive batteries that have already been removed from the vehicle. They purchase these batteries with the hope that they have adequate capacity for a second-life application but there is uncertainty about their state of health. If there is no visible damage to the battery, then the state of health is tested. This is typically

completed by monitoring a full charge and discharge – a process estimated to take about four hours.

Several research labs and startups have identified this process inefficiency and are developing technology that can be used to estimate the state of health. Repurpose Energy, a battery repurposing start-up that evolved out of UC Davis, has reported that they developed technology that can estimate the state of health of the previous generation Nissan Leaf batteries within 15-20 minutes. This estimation is model-driven and done by collecting data points during the testing process. This technology must be designed differently for each pack type — even for the newer Nissan Leaf batteries – due to the lack of standardization.

The California Advanced Clean Cars II regulation

California has already identified the sharing of battery health information to the EV owner as essential. The Advanced Clean Cars II regulation, the most recent version of clean air rules for passenger vehicles, includes requirements for a standardized state of health indicator that is displayed on the dashboard and available via a standardized connector for EVs produced in 2026 and thereafter. This indicator will increase consumer awareness and trust in the product, **but the regulation stops short of requiring access to the indicator after the battery is out of the vehicle.**

This shortcoming was also pointed out by the California Lithium-ion Battery Advisory Group, a group of stakeholders that was convened by Assembly Bill 2832. They identified this as a missed opportunity to advance the reuse and repurposing of batteries and make them more cost-competitive with new stationary storage batteries.

Why should the state of health be available once the battery is removed?

When batteries are retired from use in an EV, they should be routed to the most efficient next use. These batteries are a huge asset in the renewable energy transition and making the process for their reuse

and repurposing run smoothly can decrease unnecessary costs. Reuse and repurposing are also essential aspects in increasing battery sustainability. They prolong the lifespan of batteries already in circulation and potentially offset the need for new batteries to be manufactured.

Currently, repurposers are spending time and money developing technology to determine information already accessible to automotive manufacturers. In addition, there are parties involved in this process, such as automotive dismantlers, that don't have access to state of health information and are therefore unable to properly value the battery or determine the best next use.

The battery end-of-life industry can greatly benefit by being able to easily access state of health information after the battery is removed from the vehicle. The battery management system within the EV holds this valuable information, and by providing access through a standardized connector, the second-life industry could increase the efficiency of repurposing and potentially the safety, reliability, and consumer trust of the repurposed products.

Posted in: Transportation
Tags: Battery Electric Vehicle, lithium ion batteries, Mining, reduce reuse recycle

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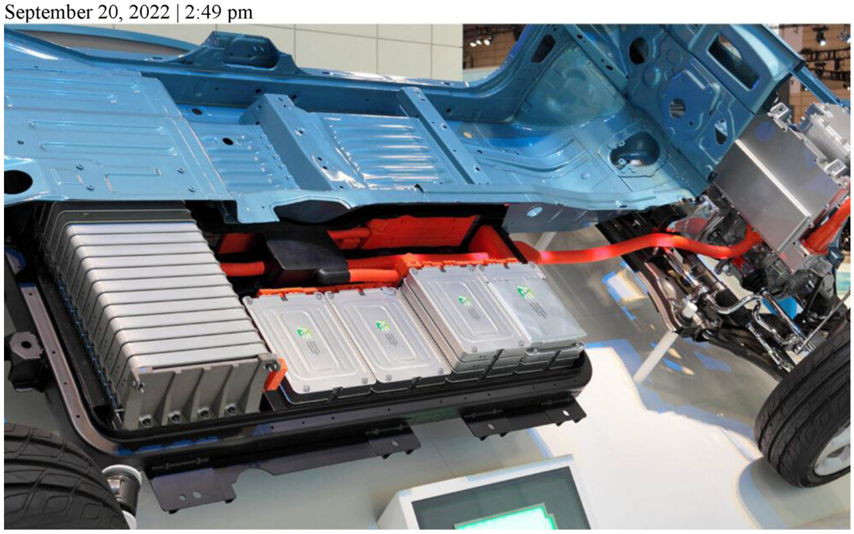
About the author
MORE FROM JESSICA
Jessica Dunn is a senior analyst in the Clean Transportation Program, specializing in lithium-ion battery sustainability. She conducts research on material circularity and reducing battery impacts through repurposing and recycling.

California's Progress Toward Recycling Policy for EV Batteries

September 20, 2022 | 2:49 pm



Jessica Dunn
Senior Analyst

As electric vehicle (EV) policies are implemented around the country, and sales continue to rise, a question many ask is if vehicle batteries are recycled.

Yes, EV battery recycling is happening in facilities around the United States. The materials recovered, including cobalt, nickel, lithium, and manganese, can be used in the manufacturing of new batteries. While this recycling market is growing, there is still no federal or state law or policy that requires it – an obligation that could ensure higher recycling rates and increased efficiency.

California is taking steps to change that.

In 2019, the state convened a group of experts and stakeholders – thanks to Assembly Bill 2832 – to develop policy recommendations that would increase EV battery recycling. That stakeholder group informed a recently released report containing policy recommendations for the state.

The report outlines a package of policies that could become the first lithium-ion US battery recycling regulation – including producer responsibility for battery recycling. While this is a huge win for those of us who want to see batteries recycled, there were also a handful of policies that could make incredible strides towards increasing the sustainability of batteries but weren't recommended.

I had the privilege of cofacilitating this group with my colleagues at the University of California, Davis along with some dedicated people at CalRecycle and the Department of Toxic Substance Control. So let me provide a (very) brief summary of the policy recommendations and some insights I gleaned.

Who were the members of the Advisory Group?

The Advisory Group had a final count of 19 members and consisted of representatives from the automotive and battery industries (6 members), waste industry (5 members), public interest organizations (3 members), and government agencies (5 members).

The final policy recommendations were based on a group vote which the government agency representatives recused themselves from. The voting members were, therefore, industry-leaning, with the automotive and battery industry representing 43% of members, the waste industry representing 36%, and the public interest organizations representing 21%. Each policy had to receive an affirmative vote by at least 50% of the group to be included as a recommendation in the report.

Did the group propose recycling requirements?

The group recommended that battery recycling be a requirement in the state and defined the party responsible for covering the costs of transporting and recycling batteries once a vehicle is retired. If this type of policy is passed it could be a great step towards increasing EV battery recycling.

Two policy options to determine the responsible party were proposed. The first says it should be the EV manufacturer (that is, the automaker like Ford or Tesla) who is responsible for ensuring their vehicles' batteries are recycled when the car or truck is no longer on the road. This policy, called extended producer responsibility, was recommended with 67% support from voting members. The automotive companies were the only members to not support this policy, although Tesla was the outlier and in favor of this policy option.

The second option received a greater level of support at 93%. All members voted in favor of this policy, except Tesla who abstained. This second policy option defines the EV manufacturer or an automotive dismantler as the responsible party, depending on a few important factors. These factors require some nuanced knowledge about what happens to a car when it is retired under different circumstances, such as if the vehicle fails under warranty, if it needs the battery to be replaced while out of warranty, or if it crashes or ages out of usefulness. The most common route of retirement is from crashing or getting old, so that will be the version of this policy explained here.

The proposed policy states that if the automotive dismantler (also known as an automotive recycler) acquires the EV and removes the battery, the dismantler is now responsible for making sure the battery is recycled.

To provide some background, after a car is retired, it typically goes to an automotive dismantler. These are certified facilities that take cars apart to sell the parts for reuse or recycling. The disassembly of EVs is very different from the disassembly of gasoline vehicles, therefore new equipment, training, and recycling partners are necessary for dismantlers to handle this new type of vehicle. These dismantlers range from small businesses to corporations, and their trade group, the United Recyclers Group, alone represents over 800 businesses in North America.

An automaker representative explained in an Advisory Group meeting that they support this policy instead of option 1 due to the potential value of the used EV. Batteries contain valuable materials like cobalt, nickel, and lithium, but some battery chemistries contain more of the valuable materials than others. If the dismantler disassembles the EV and does not want the remaining battery, it is likely the battery has a chemistry that is of lower value and will therefore be a burden to get rid of, instead of a net benefit. So, the auto manufacturer is essentially making sure they do not risk being responsible for an EV that has already been picked apart for valuable pieces and then left with a product that will be costly to dispose of.

What other policies were recommended?

There were three other areas that the advisory group recommended policies: increased access to information, support for industry development, and safe and efficient reverse logistics.

Providing access to battery information while the battery is in the car and after it is removed is crucial to enable efficient and safe reuse, repurposing, and recycling. It was recommended that a label for batteries be required on all EVs and that it include information such as chemistry, capacity, and automotive manufacturer. Labeling EV

batteries is not currently a common practice and makes it difficult to sort the batteries and evaluate the cost (or revenue) of recycling.

In addition to a label, the group recommended vehicle owners – whether that be an ordinary EV driver like you or me, or the dismantler who took the car after it was retired – have access to their battery's state of health information, or in other words, the leftover capacity and reusability of the battery. This is important in determining if the battery should be reused or repurposed, or if it should be sent directly to recycling. Since this information is not easily accessible, batteries must be fully tested through a full charge and discharge to know the battery's health. This is a time-consuming and expensive process that can be greatly improved by the sharing of information.

The Advisory Group recommended several policies which would support repurposing and recycling industry development. These policies include recycling incentive packages, expanding grid stationary storage incentives to include repurposed batteries, and expediting the permitting process for recycling facilities in California.

Most policies recommended by the group fell under the safe and efficient reverse logistics category. The group recognized that the high cost of transporting batteries after they have been removed from a vehicle is a large barrier to efficient and cost-effective recycling, representing 50-60% of costs. Some of the reverse logistics policies recommended include supporting research on collection and sorting networks, developing training materials for workers, lessening regulatory barriers to reusing or repurposing transporting batteries, and increasing regulations on EVs sold at auction.

Category	**Recommended policies**
Responsibility for battery at the end-of-life	• Core exchange and vehicle backstop • Producer take-back
Access to battery information	• Physical labeling requirement • Digital identifier • Universal diagnostic system

Support repurposing, reuse, and recycling industry development	• Recycling incentive packages • DTSC permit timeline • Expand eligibility for battery storage systems
Safe and efficient reverse logistics	• Support enforcement of unlicensed dismantling laws • Develop training materials • Support transportation research • • Develop strategic collection and sorting infrastructure • Universal waste regulations • Require pre-approval to bid on EVs at auctions

What policies weren't recommended?

Policies that would add requirements and standards to recycling processes or battery manufacturing did not receive support from a majority of the group members and were not included in the final recommendations to the state. These were discussed unfavorably by a majority of the members stating the potential for stifling the growth of a young industry. This is despite the sustainability benefits many of the policies would provide.

The policies include requiring batteries to be made with recycled content and designed with recycling and repurposing in mind. Recycling requirements discussed included minimum material recovery rates, third-party verification of the process efficiency and environmental impact, and the reporting of EV batteries retiring, recycled, and materials recovered. These are all policies that have been proposed by the European Commission and are expected to become law in the European Union.

These policies were all supported by the public interest organizations, along with many of the waste industry representatives. They were not supported by the automotive and battery industry. The combination of opposition from the automotive battery industry (43% of the votes) and some of the waste industry (36% of the votes) resulted in none of the circularity and quality recycling policies reaching over 50% support and being recommended.

Category	Policies with less than majority support
Circular economy and quality recycling	• Recycled content standards • Minimum material recovery targets • Third-party verification of recycling • Required design for reuse and recycling • Reporting system for EV batteries retired from use, recycling, and recovery rates

So, what's next?

California legislature, it's your move.

The report has been delivered to the legislature to advise them as to what policies will lead California to 100% recycling of EV batteries. They will be back in session in January of 2023, and it is still unknown what the next steps will be. UCS hopes to see policies passed in California which not only requires the recycling of these batteries, but also increases the circularity of materials and battery sustainability.

Posted in: Transportation
Tags: California, EV batteries, lithium ion batteries, policy, recycling

What Can We Learn From the EU Battery Law?

February 3, 2023 | 8:00 am

Jessica Dunn
Senior Analyst

Last December, the European Union (EU) agreed on a comprehensive battery policy that aims to make electric vehicles (EVs) more

sustainable. Included in the regulation are requirements for mineral sourcing, life cycle emissions, information sharing, and recycling. These regulations set a precedent for battery policy; an area where the US needs to do more.

The US doesn't need to reinvent the wheel here—many of these policies can and should be implemented domestically.

Why does the EU need new battery regulations?

The EU is transitioning away from gasoline vehicles because of their significant contribution to climate change and adverse health impacts– transitioning to EVs offers an attractive solution. EVs have no tailpipe emissions and their life cycle impacts are much less than the gasoline alternative, not even taking into account the potential for batteries to become more sustainable. The mining for minerals used in batteries is often associated with negative human rights and environmental impacts. However, innovative approaches can reduce those harms, including the creation of a circular economy through reuse and recycling.

Supporting a circular economy

This may seem counter-intuitive, but let's start by talking about regulations that touch retired EV batteries.

When a battery cannot be used in an EV, it should be repurposed for a different application, such as stationary storage, and then eventually be recycled. The materials can then be recovered and used in the manufacturing of next generation EVs. This process is referred to as the circular economy because materials are being returned to use, which lessens environmental impacts and reduces waste. *Essentially, it is decoupling economic activity from resource extraction.*

The EU battery law seeks to increase circularity through a plethora of measures that the US can replicate. These measures include requiring automotive companies to recycle the batteries when they reach the end of their life, recover a minimum amount of the materials through

recycling, and using these recovered minerals in the manufacturing of new batteries. The law also requires the increased sharing of information about the battery type and use, making repurposing and recycling more efficient.

Let's take a closer look...

Extended Producer responsibility and reporting: This regulation requires that automotive companies ensure retired batteries are collected and then reused, repurposed, or recycled. The companies are required to report the level of recycling, which provides a route to monitor compliance. The regulation also encourages the extended use of the battery through repurposing for second-life applications. They consider the repurposed battery to be a new product and therefore the repurposer is now responsible for ensuring it is eventually recycled.

Recycling recovery rates: Recovery rates specify that amount of material recovered from the recycling process. The regulation requires an overall recycling recovery rate of 65% by 2025 and 70% by 2030. Higher recovery rates are specified for the more valuable materials: in 2025 the recovery rate of cobalt, nickel, and copper must be 90% and lithium 50%, increasing to 95% and 80% respectively in 2030.

Recycled content standards: Once materials are recovered, they can be used to manufacture new batteries. The regulation proposes recycled content standards, a measure requiring a certain percentage of recycled materials to be used in the manufacturing of new batteries. These standards start at 16% for cobalt, 6% for lithium, and 6% for nickel in 2030 and then increase to 26%, 12%, and 15% respectively in 2035.

Sharing of information: Information such as battery chemistry, mineral sourcing, and battery health are not currently provided by the automotive companies. This lack of information results in several end-of-life complications: 1) it takes extensive testing to know if the battery is suitable for repurposing, and 2) the battery value is difficult to assess because the health and the chemistry are unknown.

The regulation proposes the use of labelling to clarify battery characteristics as well as the use of a battery passport, which will provide detailed information on the material supply chain, the use of the battery, and the state of health. This is potentially a revolutionary technology that can increase material sourcing transparency, expedite end of life processes, and help track the life of batteries.

Material sourcing and manufacturing requirements

The impacts upstream from the EVs represent the majority of impacts, and over the next several decades there will need to be materials mined to supplement the recycled content. The EU law has laid out steps to decrease those impacts, including supply chain due diligence and carbon footprint limits.

Supply chain due diligence: EVs are a more sustainable alternative to gasoline vehicles, but we must continue to address the impacts associated with sourcing battery materials. The regulation seeks to reduce sourcing impacts through implementing a framework based on several principles, including the Ten Principles of the United Nations Global Compact and the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas.

Essentially, the companies will be required to identify and address risks in the battery supply chain that infringe on the protection of human rights, including human health, protection of children, and gender equality. While the rules are stricter than those in the US, Amnesty International recently stated that the policies only provide safeguards against harm and don't provide access to remedies such as compensation if their rights are infringed on.

Battery carbon footprint: The life cycle carbon footprint of the battery is required to be included on the label of the battery, easily communicating this information to consumers. In addition, an assessment will be completed to determine maximum carbon thresholds for EV batteries.

Europe is paving the way- will the United States follow?

The US has not enacted any of the policies that were listed above. Instead, they have taken a different approach of dispersing federal funds for battery recycling and repurposing research, development, and demonstration projects. Battery repurposing and recycling in the US is reliant on these processes being profitable and does not provide policy safeguards that ensures if the economics don't work out, the battery is still eventually recycled. Ideally, the federal government would follow the EU's lead and enact similar policies to ensure optimal resource recovery and a sustainable and circular battery economy.

Currently, the US does have the potential to increase the availability of information to help circularity through the implementation of current law. The Inflation Reduction Act (IRA) sets requirements for sourcing EV battery minerals in the clean vehicle tax credit. There will need to be tracking of these batteries to ensure they meet the requirements. This presents an opportunity to draw on the example of the battery passport, which can help tracking and make repurposing and recycling more efficient. Ford is piloting a battery monitoring system as we speak, and policy can help speed up this adoption process.

California, the leader of US EV adoption, is also leading the US in progress towards EV battery recycling requirements. A state appointed advisory group released a report last year with policy recommendations to increase recycling. While their recommendations represent a leap forward beyond the business as usual by requiring recycling and increased information sharing, the EU policy goes much further by including the full battery life cycle and requirements such as recycled content standards and material recovery requirements.

As the California legislative session kicks off, we look forward to seeing how EV battery recycling regulation develops. Stay tuned for opportunities to support California and US battery recycling policies.

Posted in: Transportation
Tags: Battery Electric Vehicle, climate change, lithium ion batteries, recycling

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About the author
MORE FROM JESSICA
Jessica Dunn is a senior analyst in the Clean Transportation Program, specializing in lithium-ion battery sustainability. She conducts research on material circularity and reducing battery impacts through repurposing and recycling.

Guiding Principles for EV Battery Recycling Policy

February 27, 2023 | 8:00 am

Jessica Dunn
Senior Analyst

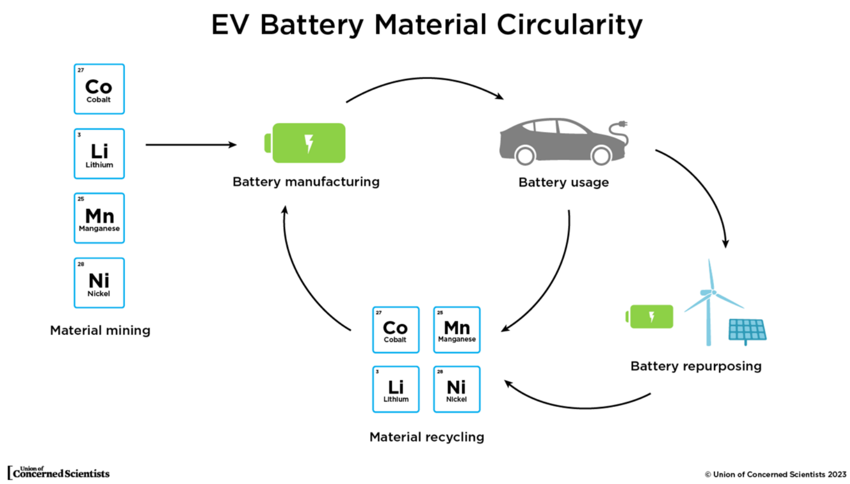
Electrifying our transportation system is essential for mitigating emissions that cause climate change and adverse health impacts. This electrification will require a lot more batteries and therefore a lot more

minerals. Recovering these materials from retired electric vehicle (EV) batteries is an alternative source to mining. Essentially, the materials recovered through battery recycling can replace future material supply that would otherwise need to be extracted from the earth to meet demand.

Estimates show that in 2050, the United States can meet about half of EV demand for cobalt and nickel and a quarter of lithium with minerals recovered through recycling. While EVs already result in less greenhouse gas emissions than the gasoline alternative, using these recycled materials substantially lowers impacts associated with material sourcing.

Prior to recycling, the battery retired from use in an EV can be used in a second-life application. This means it is either reused in another vehicle or it is repurposed for use in a stationary storage application. Eventually, the battery will reach its end of life and should be recycled, recovering minerals to then go back into the battery manufacturing stream.

The circular process starts at manufacturing, flows to the first use in an EV, is repurposed for a second life, recycled, and then eventually the minerals are back to manufacturing. This is referred to as material circularity or the circular economy.



Battery policy agreed upon in the European Union implements circular economy principles and is the most ambitious battery policy to date. It has the potential to increase the recycling of batteries and the use of recovered materials through extended producer responsibility and recycling requirements. In the US, California is also exploring recycling and material circularity policy. In 2022, a report was released by the California Electric Vehicle Battery Recycling Advisory Group which outlines policies the group believes the California legislature should implement.

Policies discussed and proposed by these groups have the potential to increase the reuse, repurposing, and recycling of batteries, as well as mitigate impacts associated with end-of-life processes and increase battery sustainability. As policies develop, we at the Union of Concerned Scientists have outlined the following high-level principles that we will use to guide our policy positions.

Guiding principles

1. Increased battery recycling and material circularity is necessary for a sustainable battery industry.
2. The producer (in most cases, the vehicle manufacturer) should be responsible for ensuring EV batteries are reused, repurposed, and eventually recycled.
3. The battery recycling process should minimize environmental impacts and have a high rate of material recovery, especially for lithium, nickel, and cobalt.
4. Prior to recycling, the battery should be reused, refurbished and/or repurposed, if it is safe and has remaining capacity.
5. The battery end-of-life should be considered during the design of the EV.
6. Information about the battery's health over time should be accessible when the battery is in the vehicle and after its removal.
7. Government funding should continue to support research and development of battery repurposing, reuse, and recycling.

Let's dive into these principles a bit further

Increased battery recycling and material circularity is necessary for a sustainable battery industry.

Recycling EVs already on the road is the most sustainable way to source materials. Embedded in these batteries is a highly concentrated amount of minerals that can be recovered through recycling. Newer recycling processes report recovery rates of 95% and low pollution impacts. This is a substantially better alternative than incineration-based techniques which do not currently recover any of the lithium and do emit greenhouse gases and particulate matter.

Once recovered, these minerals can be used to manufacture new batteries, therefore reducing the need for new mining. Overall, the decreased mining can make EVs more sustainable and lessen the risk of mishandling through inadequate storage or landfilling.

The producer (in most cases, the vehicle manufacturer) should be responsible for ensuring EV batteries are reused, repurposed, and eventually recycled.

Currently, the United States does not require EV battery recycling. While recycling is occurring, there is the potential for market dynamics to not catch all retiring batteries, therefore leading to improper disposal. Some newer batteries aren't using cobalt and nickel, which are traditionally the highest value minerals in EVs. This trend is beneficial because it results in lower cost and more environmentally friendly EVs. But on the flip side, the recycling of batteries without these minerals isn't currently profitable.and therefore may not be recycled if there isn't regulation requiring it.

One potential policy solution is to define a central party responsible, such as producers, for ensuring batteries are recycled. *Defining responsibility can increase the recycling rate and incentivize planning and efficiency.*

The automotive manufacturers are best suited for this position, following the typical policy structure called Extended Producer Responsibility (EPR). By centralizing responsibility to the automotive manufacturer, it not only ensures the battery is recycled, but also incentivizes the producer to design the battery and EV in a way that makes recycling easier and cheaper.

This has been implemented for EV batteries in the European Union and was proposed by the California Advisory Group (the report uses the term 'producer take-back'). A type of extended producer responsibility is used for ensuring the recycling of several products in California, including mattresses, paint, and carpet.

The battery recycling process should result in low environmental impacts and have a high rate of material recovery, especially for lithium, nickel, and cobalt.

Mineral recovery through recycling old batteries is significantly cleaner than mining new materials, and it is important that policies maximize the environmental benefits of recycling. This can be done through required material recovery rates and environmental impact reporting. Technologies are advancing and several new recycling companies state a 95% material recovery rate. This best available

technology should be used, and the use of incineration-based techniques that do not recover lithium should not be allowed.

Prior to recycling, the battery should ideally be reused, refurbished and/or repurposed, if it is safe and has remaining capacity.

Eventually, all batteries should be recycled. But prior, many batteries can be used in the environmentally advantageous second-life application such as reuse, refurbishing, and repurposing. Reuse and refurbishing refer to reusing batteries in the same application, but in a different car. Repurposing refers to using the battery in a different application, such as for stationary storage to support renewable energy generation. Read this excellent blog if you would like to learn more.

The battery end-of-life should be considered during the design of the EV and the battery.

When an EV is retired, the battery is removed from the vehicle and then typically further disassembled. If the disassembly is planned for during the design of the EV and the battery, the process can become safer and more efficient. Examples of potential deconstruction process improvements through EV and battery design includes the use of binders instead of adhesives and standardization among pack design. Disassembly is currently a manual process, but if batteries are standardized and built to be taken apart, smart robots could instead do this job.

If extended producer responsibility is established, design for disassembly and recycling is naturally incentivized.

Information about the battery's health over time should be accessible when the battery is in the vehicle and after its removal.

The battery health refers to the capacity and efficiency of the battery, something that slowly degrades over time and with use. This indicator is typically represented as a percentage and communicates the battery's percent maximum available capacity in comparison to when the battery was new. It is important for EV owners to know the health

of their battery, an indicator that is required starting in 2026 for EVs in California.

It is also important for battery health to be accessible once the battery is removed from the car. The battery health is a key determinant in deciding if the battery should be reused, repurposed, or sent directly to recycling. If the battery is in good health (i.e. relatively high capacity and efficiency), it should be reused or repurposed for a second-life prior to recycling.

Currently, if there is no visual damage, battery repurposers test the health by monitoring it through a complete charge and discharge or a specially designed testing process. This is expensive and time-consuming, but if this information was provided without extensive testing, repurposing can be expedited, and costs reduced.

Government funding should continue to support research and development of repurposing, reuse, and recycling.

As we transition away from the gasoline vehicle to the more environmentally friendly EV, battery recycling and material circularity should be priority. As discussed in a prior blog, there have been funds dedicated towards recycling research, development, and demonstration. While this funding is essential to developing a more sustainable battery industry, we also need policy that requires and ensures a circular battery economy.

What's next for battery recycling policy

At UCS, we want to see that all EV batteries are safely recycled and the materials recovered are used in the manufacturing of next generation batteries. These materials are an essential part of meeting upcoming demand and decreasing the need for mining.

US policy should follow the example of the European Union by implementing extended producer responsibility, requiring high material recovery rates, and increasing access to battery information. Stay tuned for more blogs that dive into these principles.

Posted in: Transportation
Tags: Battery Electric Vehicle, electric vehicles, Lithium-ion batteries, recycling, Recycling Clean Energy Technologies

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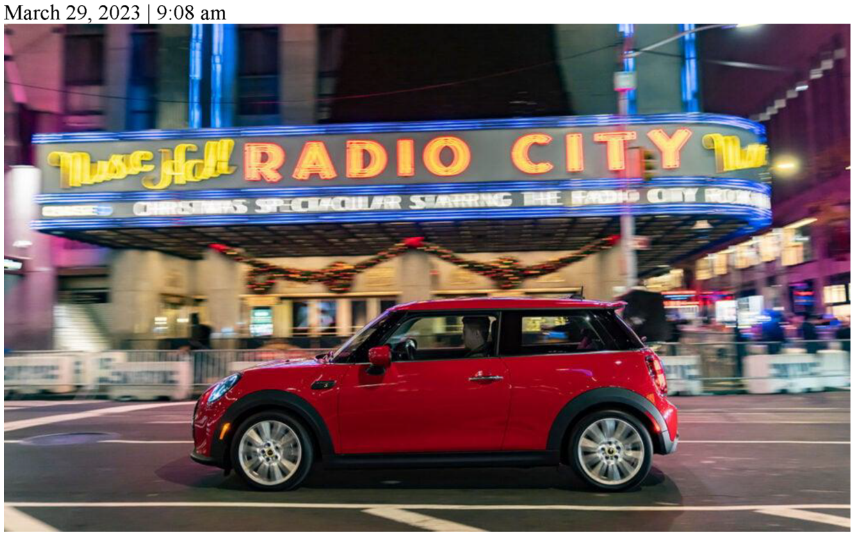
About the author
MORE FROM JESSICA
Jessica Dunn is a senior analyst in the Clean Transportation Program, specializing in lithium-ion battery sustainability. She conducts research on material circularity and reducing battery impacts through repurposing and recycling.

Why Do We Need EV Battery Recycling Policy?

March 29, 2023 | 9:08 am



Jessica Dunn
Senior Analyst

Our petroleum-based transportation system has led to health and climate impacts felt throughout the world. Electrifying transportation is a valuable tool we can use to reduce those impacts.

This transition will require an increase of minerals used in batteries that power our electric vehicles (EVs), trucks, and buses.

When these electric transportation modes retire, the batteries' usefulness continues. Even with diminished capacity, they can be reused, refurbished, or repurposed and then eventually recycled. The materials recovered from recycling can be used to manufacture new batteries, therefore reducing the amount of newly mined materials necessary to meet upcoming mineral demand.

The EV battery recycling business is just now kicking off, and because of the high value materials in lithium-ion batteries, the economics of this early industry look good. Batteries are being recycled, which has led some to make the case that there is no need for a strict recycling policy because the market will take care of itself. However, the positive economics of battery recycling may not last forever, nor will there be a nickel (get it?) to be made from every EV battery.

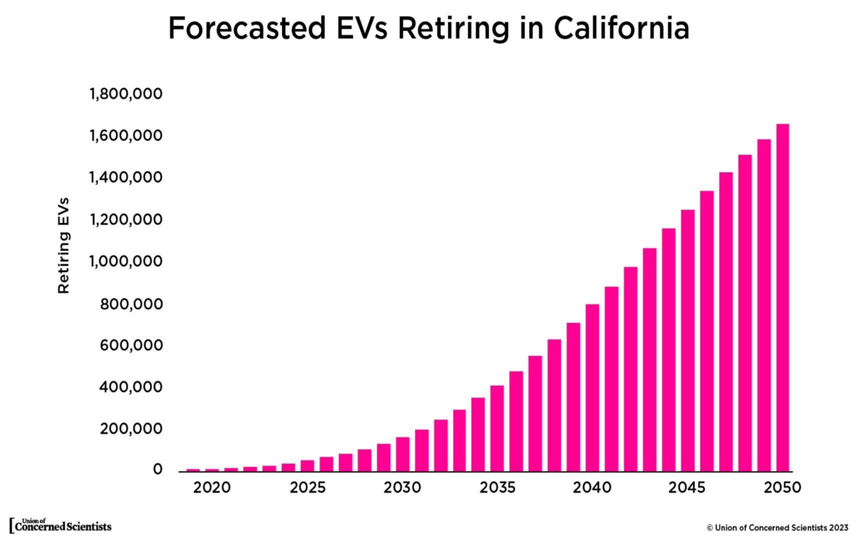
Recycling may not always be profitable for lithium-ion batteries that don't contain cobalt and nickel, batteries that are damaged, or for small volumes of batteries located in remote locations. Considering there is no recycling requirement for retired EV batteries in the US, when the cost of recycling or repurposing a battery is greater than the profit generated, there is risk that the batteries will be landfilled or mishandled.

To avoid this very real possibility, we need an extended producer responsibility recycling requirement. This means being clear about who is on the hook for unprofitable or otherwise unwanted EV batteries. The California legislature is beginning to take on EV battery recycling with Senate Bill 615 which is currently in initial draft form. So, we've decided now would be a good time to explain the problem and the need for a fool-proof solution.

While EVs retiring today are a trickle, this will increase exponentially

The number of batteries retiring today is relatively small in comparison to the number of batteries that will be retiring in the future. This is because EVs have only been a small fraction of auto sales over the last decade. As California transitions to 100% zero emission vehicle sales by 2035, there will be more EVs on the road and batteries eventually ready for recycling.

As the number of retiring batteries increases there is the potential for more batteries to slip through the cracks and not be recycled. An extended producer responsibility can help ensure high recycling rates with the safe and high recovery of materials.



Forecasted retirement of EVs sold in California. This calculation is based off the EV sales for California to meet the Zero Emission Vehicle requirement component of the Advanced Clean Cars II regulation. The survival rates and vehicle sales are based off the California Air Resources Board's Emission FACtor (EMFAC) model.

Yes, EV batteries can be recycled

Batteries can be recycled and there are companies doing so in North America. One US based recycling company has reported that they will take all batteries, even if they are not profitable to recycle. This is part of their research to identify where batteries are retiring and design efficient collection routes.

Once there is a larger availability of batteries from retiring EVs, recyclers can be a bit pickier as to the batteries they collect. They will likely make the strategic decision to choose those with positive economics, like the batteries that contain cobalt and nickel. Unfortunately, batteries like lithium-ion-phosphate (LFP) that don't contain these two valuable materials currently represent a cost to recycle. Since LFP is only a fraction of retiring supply, it doesn't seem to be a problem yet, but their market share is increasing. As more EVs retire, and as technology changes, recycling companies will likely prioritize batteries of higher material value, better health, and a shorter distance to travel.

Since it can't be guaranteed that recycling all EV batteries will be profitable, it is essential that we ensure a future where even these get recycled and handled safely to avoid improper disposal or them wasting away in landfills.

Instances where there is a disincentive to recycle

Scenario 1: Higher than average cost to collect and transport.

The costs associated with recycling includes the collection and transportation of the battery (about 29%), the dismantling and disassembly (about 37%), and then the recycling process (about 34%). The collection and transportation costs vary based on whether the battery is damaged, the distance to a recycling facility, and the volume of batteries shipped.

Damaged batteries have an increased risk of fire and as a result require extra precautions to ship. This includes additional packaging that must be custom made and comply with the United Nations standards.

Shipping costs per battery also increase with longer distances to travel and when only a few batteries need to be transported. This typically occurs when they are located in remote areas and there aren't enough to fill a truck. In this scenario, the truck with the special Class 9 hazardous permit is transporting only a couple batteries, therefore operating at partial capacity.

These shipping costs can be decreased with an efficiently designed collection network that optimizes collection points and the infrastructure already in place, such as the currently operating dismantlers and dealerships. Manufacturers are in the prime position to do this centralized planning to ensure that operations are in place for all batteries to be recycled and reap benefits from economies of scale.

Scenario 2: The LFP lithium-ion battery has low revenue from material recovery.

Revenue from selling the minerals that can be recovered from the battery make up the profit from recycling. Batteries that are currently retiring have high amounts of cobalt and nickel, two very valuable minerals. These minerals have been instrumental in EVs success, allowing batteries to be smaller while enabling EVs to go further. There are some alternatives, including lithium-iron phosphate (LFP), that do not contain either of these minerals. LFP hasn't historically been used in EVs sold in the US because the batteries have to be bigger than the nickel and cobalt alternatives to provide the same amount of energy. This is changing as technology develops and EVs become more prevalent.

Tesla has begun producing a lower range and less expensive EV that uses an LFP battery. Ford, Rivian, and Volkswagen also have plans for using LFP. Since these batteries contain lower value materials, they are also less valuable to recycle. My research and others evaluating recycling economics finds that recycling LFP is not currently profitable, therefore creating a disincentive to eventual recycling that may lead to low recovery rates.

Manufacturers can reduce the costs associated with recycling. Extended producer responsibility would incentivize designing these batteries to be more safely and efficiently disassembled which would result in decreased costs of recycling. As mentioned above, the dismantling and disassembling of the battery is estimated to represent about 37% of recycling costs. This is a substantial portion that varies by manufacturer and model because it is based on the time it takes for people to complete the process by hand. The process is lengthy because the battery is not designed to be disassembled and due to lack of standardization, the batteries cannot be taken apart by robotics.

Decreasing the cost of recycling through designing for disassembly has the potential to drive the recycling cost of LFP batteries down, which contain a valuable source of lithium. Recycling technologies in development could also lead to profitable recycling of LFP, therefore representing another potential area of investment for manufacturers that would be incentivized to make LFP recycling profitable.

All EV batteries need to be recycled

A strong recycling policy is essential to ensure that all EV batteries are safely recycled so that the materials can be recovered. If recycling requirements are not enacted, there is the possibility of batteries not being recycled if it is not profitable to do so. This could be either due to the batteries being damaged, in a remote locations, or of lower mineral value.

In addition, if the responsibility of recycling is placed on automotive dismantlers, there is the possibility that these batteries with a disincentive to recycle are pushed into the unlicensed and unregulated dismantling market. This market processes approximately 30% of retiring cars in the US and presents a large environmental and safety risk.

We suggest that an extended producer responsibility program with a recycling requirement is enacted to ensure all batteries are recycled and to drive recycling costs down. This is essential for reducing the amount of mining needed to electrify our transportation system over

the next several decades. This policy is an important aspect in meeting our long-term goals of creating a low impact and circular transportation system.

Posted in: Transportation
Tags: electric vehicles, Lithium-ion batteries, recycling

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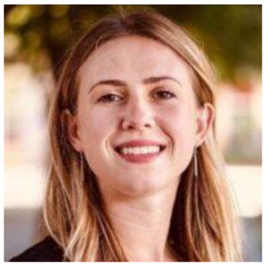
About the author
MORE FROM JESSICA
Jessica Dunn is a senior analyst in the Clean Transportation Program, specializing in lithium-ion battery sustainability. She conducts research on material circularity and reducing battery impacts through repurposing and recycling.

Why New DOE Battery Recycling and Repurposing Investments Are Crucial to The Future of EVs

November 21, 2022 | 9:39 am



Jessica Dunn
Senior Analyst

It’s been one year since passage of the Bipartisan Infrastructure Law (BIL), which included provisions to further clean transportation. Importantly, the BIL invests in electric vehicle (EV) battery recycling and repurposing– important strategies for increasing the sustainability of EVs.

The Department of Energy recently announced 10 recycling and repurposing projects that will receive a total of $73.9 million in funding. These projects could be key contributors to the technological innovation and scale up necessary to increase domestic recycling and make second-life stationary storage more accessible.

Currently, transportation is the largest contributor to climate-changing emissions. EVs can significantly reduce the sector’s emissions and set us on a path to reach our climate goals. While EVs deliver major climate emission benefits compared to gasoline vehicles, the recycling and reuse of EV batteries will help ensure the transition to EVs is sustainable over the long term.

Before recycling, batteries in good condition can be repurposed into a second-life application such as stationary storage. Second-life storage extends the lifespan of EV batteries while also helping decarbonization efforts– stationary storage is becoming more necessary as more of our electricity comes from renewable sources and as climate impacts threaten grid reliability. For example, storage is used to support solar photovoltaic systems by charging mid-day when the sun is strong and then discharging in the evening when energy demand peaks. In addition, California has begun exploring the option of using stationary storage as a backup resource when electricity is turned off to prevent wildfires.

When batteries reach the end of their life, they can all be recycled. The materials recovered can be used in the manufacturing of new batteries, resulting in large sustainability gains. The recycled materials replace the need for newly mined materials, therefore lessening the amount of mining necessary for the clean energy transition and creating a domestic supply.

These nascent industries are expanding rapidly and the Bipartisan Infrastructure Law investments are carefully aimed at addressing key challenges in repurposing, recycling, and the uptake of EVs.

What second-life projects were funded?

The Bipartisan Infrastructure Law funds went to five different second-life demonstration projects. The parties involved in these projects are wide ranging, including Universities, National labs, Utilities, auto manufacturers, well established companies, and startups.

Second-life demonstration projects include providing access to energy storage in underserved communities and EV charging in rural areas, as well as tech development that increases access to information and control over battery operations.

One project is aimed specifically at using these repurposed batteries to increase the accessibility of EV charging in rural areas. The stationary storage will be used as a charging station to provide more options for drivers to charge and provide relief from increased electricity demand on the grid. The effort will provide EV charging infrastructure in a multistate region (including Tennessee, Ohio, Virginia, Kentucky, West Virginia, Kansas, and Texas) and aide in the electrification of underserved rural communities.

Several of these projects are focused on technological improvements that will increase the efficiency and safety of second-life storage. Improvements begin with determining the battery health — this is a necessary estimation used for assessing if the battery is suitable for a second-life application. This estimation process is critical but lengthy. A second-life company received funding for technology that can drastically speed up the process, estimating the battery's health in two minutes.

After the batteries have been tested and diagnosed as safe for repurposing, they are combined to make a larger storage system. This storage system is a mix of batteries with varying levels of capacity and the performance is restrained by the lowest performing cell. The

charging and discharging of the cells are typically controlled in unison, restricting the capability of batteries and degrading them at a higher than preferable rate. Technology that enables more refined control of battery operations and knowledge of cell health was proposed in three of the five fund recipients. These innovations have the potential to increase the efficiency, lifespan, and safety of second-life storage.

What about battery recycling projects?

The other half of funded projects are focused on the development of recycling processes. Recycled materials have the potential to greatly decrease environmental and social impacts associated with batteries. Through their recycling and recovery, the need for newly mined materials can be reduced and the materials can continue to be used within the economy.

One recycling technique, called hydrometallurgical processing, has made great strides demonstrating high recovery rates of critical materials (think cobalt, nickel, manganese, and lithium) that can be used to manufacture new batteries. The technology is already operating at industrial scale and ready for expanded capacity. This funding will be used to continue improving this recycling process and build facilities in Nevada and Ohio.

The further development of a new recycling process, typically called direct cathode recovery, was also funded. This process recovers the battery materials in a form that is further along the manufacturing process. Essentially, instead of recovering the constituent materials like hydrometallurgical recycling does, direct recycling recovers these materials in their combined and processed form. The material recovered from using the direct cathode recovery process can more readily be reused, reducing the number of energy intensive steps in the manufacturing process.

A step in the right direction

This historic investment will greatly increase the repurposing and recycling innovation and infrastructure in the United States. It's a

necessary step in the direction towards a more circular, low impact, and domestic electric vehicle economy.

Posted in: Transportation
Tags: climate change, electric vehicles, EV batteries

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About the author
MORE FROM JESSICA
Jessica Dunn is a senior analyst in the Clean Transportation Program, specializing in lithium-ion battery sustainability. She conducts research on material circularity and reducing battery impacts through repurposing and recycling.

House Committee on Energy and Commerce

April 26, 2023, Hearing

"Exposing the Environmental, Human Rights, and National Security Risks of the Biden Administration's Rush to Green Policies"

Responses to Submitted Questions for the Record

Mark P. Mills

Senior Fellow, Manhattan Institute

The Honorable Mariannette Miller-Meeks, M.D.

In Iowa, we also have abundant wind with nearly 60% of our electricity coming from wind power. Wind developers have invested more than $23 billion in Iowa, and the industry supports nearly 4,000 jobs in the state. As Mr. Mills discusses in his testimony, China has a large market share in producing and refining the critical minerals we need for wind. While this committee needs to do more work to weaken China's grip on critical mineral supply chains, I am glad to have the wind energy industry alongside us working to on-shore its supply chains. Approximately 57% of the content of land-based wind turbines installed in the U.S. are domestically manufactured. Imports of wind equipment by and large come from our allies with only 5% coming from China.

1. Mr. Mills, like you, I am not in favor of a forced expansion of renewable energy nationwide, even if wind development works well for Iowa. Can you speak to some of the areas the wind energy industry needs to improve to drive healthy growth, and ways Congress can provide support?

ANSWER

First, if I may stipulate, wind turbines installed in windy regions, like Iowa, are operationally and economically sensible additions to electricity supply. However, the magnitude of the additions that makes sense for any given region is increasingly distorted by what amounts to a forced expansion of wind installations because of various state mandates requiring utilities to reach specific shares of electricity supply from wind (and solar), and also a *de facto* forcing of wind over other generation choices through state and federal tax incentives favoring wind. These policies lead to distortions in normal utility planning that used to be directed primarily at optimally meeting the twin goals of reliable and low-cost power for citizens. The wind industry, perhaps understandably, has supported or lobbied for such preferences.

Regarding the specific question about things the wind industry could do to help with healthy growth: Apropos the domestic sourcing of 57% of land-based turbines—and setting aside the fact that the Administration's plans and policies are heavily tilted towards off-shore projects which will be dominantly foreign-sourced—even domestic land-based machines are heavily dependent on imports for critical components and essential materials. We note that the DOE report, *Land-Based Wind Market Report: 2021 Edition*, which contains the 57% figure for domestic sourcing, also observes that imports account for 50% - 70% of turbine blades and hubs, 25% - 40% of towers, though only about 15% for the nacelle assembly. But that DOE report also states: "These figures understate the wind industry's reliance on foreign suppliers, because significant wind-related imports occur under trade categories not captured in this figure."

One example of something that's knowable is that nearly all the critical neodymium used in wind turbine electric components is foreign-sourced (see for example DOE 2022 report on "Rare Earth Permanent Magnets: Supply Chain Deep Dive Assessment"). Because the mineral sourcing issue is the same for the wind industry as it is for numerous other critical "energy minerals" used in solar and battery technologies, business leaders in all these domains could more vigorously

engage the challenges in providing information transparency. Otherwise, policymakers are at a disadvantage in understanding the options for addressing the realities of import dependencies.

The Honorable Russ Fulcher

Power experts in the Northwest have recommended the need for more power generation for the first time in years. If we're talking solar and wind, it is roughly 3,400 Megawatts per year. If it is natural gas, for example, it is only 800 Megawatts per year. In fact, the Northwest Power Council said that replacing 3,400 average Megawatts of existing hydropower or nuclear power generation would require nearly 5,500 average Megawatts of new wind and solar, as well as 2,000 Megawatts of natural gas. And yet, the Department of Energy estimates wind turbine blade waste could amount to 200 K to 370 K tons every year from now to 2050. The International Renewable Energy Agency estimates that global solar panel waste could reach 78 Mi tons by 2050. Does it make any sense to move so aggressively on such unreliable baseload energy sources, while undermining traditional sources that are baseload reliable, given the amount of waste being generated by these renewable sources and without a plan to address such waste? I can point to traditional sources of power in the Northwest - such as hydro, geothermal, and nuclear sources that are renewable, baseload reliable, and where we either don't have waste or have addressed the waste issue.

1. It is my understanding that the EPA considers certain solar panel waste to be hazardous. And yet, the Biden Administration continues to drive forward, not being clear on disposal of such materials. Is CERCLA (the Comprehensive Environmental Response, Compensation, and Liability Act) prepared to address disposal once these energy technologies reach their end-of-life stage?

ANSWER

It doesn't make economic or environmental sense to push, using subsidies and mandates, a greater reliance on wind and solar without a full understanding of the consequences of and solutions for the end-of-life waste for all energy machines, especially the quantities of wind and solar hardware now proposed. There challenges go beyond that fact of solar/wind waste entailing waste with metals toxicity, and the non-recyclability of turbine blades. There is also the fact of an unprecedented 1,000% increase in volume of conventional materials (concrete, steel, plastics, etc.) needed to build wind and solar to deliver the same unit of energy to society compared with conventional energy system. This latter factor means there will be a similar increase in total waste quantities. In addition, recent studies suggest the lifespan of solar and wind hardware is likely to be shorter than assumed in forecasts which will also mean increased volumes of waste appearing sooner than expected. The CERCLA, and other similar efforts, are important for addressing remediation of waste issues *ex post facto*, but what is needed now are actions to deal with the known inevitability of future waste volumes from the coming end-of-life of wind and solar installations, and to bring regulatory parity with conventional energy systems.

Center for American Progress
1333 H St NW
Washington DC 20010

August 30, 2023

Chair Bill Johnson
Subcommittee on Environment, Manufacturing, and Critical Minerals
Committee on Energy and Commerce
U.S. House of Representatives
2125 Rayburn House Office Building
Washington DC 20515
Attn: Kaitlyn Peterson, Legislative Clerk

Dear Chair Johnson:

Thank you for the opportunity to testify at the hearing before your subcommittee on April 26, 2023. The Honorable Mariannette Miller-Meeks, M.D. asked an additional question for the record:

> "Mr. Higgins, who is looking out for the "wealthy" children who mine Cobalt in the Congo?"

Please find my response enclosed.

Sincerely,

Trevor Higgins
Senior Vice President for Energy and Environment
Center for American Progress

Attachment

Child labor (which is by definition forced) and other human rights violations are a real and serious concern for cobalt mining in the Congo.

Section 307 of the Tariff Act of 1930 (19 U.S.C. § 1307) prohibits the import of goods made in whole or in part with the use of forced labor, including child labor. Following the removal of the consumptive demand exception via the Trade Facilitation and Trade Enforcement Act of 2015, there is no legal way to import a product made using forced labor into the United States. CBP is responsible for enforcing this prohibition. Recently, DHS stood up the interagency Forced Labor Enforcement Task Force.[1]

Notably, the Inflation Reduction Act created several incentives (including enactment of 23 USC 45X for advanced manufacturing and amendments to 23 USC 30D for the purchase of new clean vehicles) that will support the production and processing of critical minerals in the United States and limit the global market for critical minerals processed by foreign entities of concern.

[1] U.S. Department of Homeland Security, "Forced Labor Enforcement Task Force" available at https://www.dhs.gov/forced-labor-enforcement-task-force

Responses by the Hon. Daniel Simmons to Questions for the Record:

The Honorable Rick W. Allen:

1. **Mr. Simmons, you referenced a study in your testimony that the critical mineral input for a lithium-iron phosphate battery has increased by 393% from April 2021 to April 2022. Do you expect prices for critical minerals to continue to rise, thus increasing costs for solar energy, wind energy and electric vehicles?**

Answer:

It is incredibly difficult to estimate future prices of commodities. Increasing amounts of renewable technologies, along with electric vehicles and stationary batteries will dramatically increase the demand for critical minerals. Unless there is a massive increase in supply, prices will surely increase, and in order to massively increase supply, huge new investments will be necessary which will be reflected in price.

To have the most control over our economic future, it is critical that we increase the mining and processing of critical and other important minerals in the United States. This is certainly possible. A decade ago, people complained that we couldn't drill our way to more energy security, but we did just that. Today, the United States is in a much better position with respect to oil because we dramatically increased our oil production. We need to do the same with minerals.

2. **Could you elaborate on the impacts of the rush to produce electric vehicles and expand renewable energy on our electrical infrastructure system?**

Answer:

Over the last 100 years, piece by piece, we built the electric grid that powers the United States. The grid is incredibly complex. On the grid, supply and demand have to be balanced at all times or there will be blackouts or brownouts.

The grid was built around the idea of dispatchable power—sources of electricity that can be programmed on demand at the request of grid operators responsive to the demands of consumers. Wind and solar generation are fundamentally different because they are not dispatchable without batteries. It is a growing challenge for the electric grid as more non-dispatchable generation becomes attached to the grid.

Another challenge is that wind and solar resources are not located near population (and demand) centers. To facilitate the large-scale use of wind and solar technologies, we need much more electricity transmission than we currently have. To reach the Biden administration's goal of a zero-carbon grid by 2035, U.S. generation capacity would have to triple compared to its 2020 level and power line capacity would have to double or triple, according to a report from the National Renewable Energy Laboratory (NREL). Princeton University researchers, however, believe that grid capacity estimate maybe too low, requiring increases that are 2 to 5 times higher than today's levels by 2050.

A large increase in electricity transmission will increase the cost of running the electric grid. We are already seeing electricity rates increase even as we add a large amount of low-cost generation in the form of wind and solar. This is a concerning development.

The electric grid has evolved over 100 years. Moving too quickly to dramatically change the grid will result in high costs for consumers. We are already seeing electricity rates increase even when the cost of generation has decreased. This is a concerning trend that deserves more study to understand why rates are increasing.

The Honorable Russ Fulcher

1. **What are the national security benefits of buying local—producing critical minerals domestically or in allied countries with reliable partners?**

Answer:

There are certain critical minerals that are necessary for our natural security. For example, DOD needs certain critical minerals for high-tech electronics and for next-generation aircraft. The United States has many of these critical minerals, but the federal government limits access to minerals. For example, the Biden administration's Army Corp of Engineers recently revoked a Clean Water Act permit for the NewRange copper and nickel mine in Minnesota. Without access to minerals domestically, it is difficult to assure access to the necessary minerals needed for national security.

To mineral imports in perspective, at the peak of the U.S. oil dependency, we relied upon the nations of the Middle East for about 23% of our oil. China is the largest processor of copper, nickel, cobalt, lithium, and rare earths—processing between 35 percent and 85 percent of these minerals. This is not good for our national or energy security.