S. HRG. 118–167

BOTTLENECKS AND BACKLOGS: HOW CLIMATE CHANGE THREATENS SUPPLY CHAINS

HEARING

BEFORE THE

COMMITTEE ON THE BUDGET
UNITED STATES SENATE

ONE HUNDRED EIGHTEENTH CONGRESS

FIRST SESSION

October 25, 2023

Printed for the use of the Committee on the Budget

www.govinfo.gov

U.S. GOVERNMENT PUBLISHING OFFICE

54–121 WASHINGTON : 2024

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BOTTLENECKS AND BACKLOGS: HOW CLIMATE CHANGE THREATENS SUPPLY CHAINS

WEDNESDAY, OCTOBER 25, 2023

COMMITTEE ON THE BUDGET,
U.S. SENATE,
Washington, DC.

The hearing was convened, pursuant to notice, at 10:06 a.m., in the Dirksen Senate Office Building, Room SD–608, Hon. Sheldon Whitehouse, Chairman of the Committee, presiding.

Present: Senators Whitehouse, Merkley, Kaine, Luján, Grassley, Johnson, Braun, Kennedy, and R. Scott.

Also present: Democratic Staff: Dan Dudis, Majority Staff Director; Alexandra Gilliland, Climate Policy Advisor; Dan RuBoss, Senior Tax and Economic Advisor and Member Outreach Director.

Republican Staff: Chris Conlin, Deputy Staff Director; Krisann Pearce, General Counsel; Jordan Pakula, Professional Staff Member; Ryan Flynn, Staff Assistant.

Witnesses:

Dr. Scott Kelly, Head of Environmental Analytics, Risilience

Dr. Adam Rose, Research Professor, Sol Price School of Public Policy, and Senior Research Fellow, Center for Risk and Economic Analysis of Threats and Emergencies, University of Southern California

Ms. Kathy Fulton, Executive Director, American Logistics Aid Network

Dr. David Barker, Partner, Barker Companies

Dr. Robert McNally, President, Rapidan Group

OPENING STATEMENT OF CHAIRMAN WHITEHOUSE [1]

Chairman WHITEHOUSE. All right. Let me call this hearing of the Budget Committee to order, and thank the witnesses for being here. My apologies for the delay. It is a busy morning here in the Capitol, and I appreciate that all of you had to get through heightened security to be here punctually, so thank you for that, and my apologies for the evidently necessary inconvenience.

We have had 10 hearings so far this year regarding various serious risks that climate change poses to the federal budget. And of course, to American families and businesses, and in some cases to the economy at large. Today's hearing will examine another threat from climate change, which is disruption of global supply chains

[1] Chart submitted by Chairman Whitehouse appears in the appendix on page 32.

that can cause economic disruptions, product shortages, and higher prices for businesses and consumers, which should properly be called climate inflation.

Our global economy relies on a network of interdependent supply chains, and the products may be a simple soybean, or may, like my iPad here, comprise thousands of parts sourced from all around the globe. If you think of the interconnected systems that enable the production and distribution of cell phones, the raw material extraction, the manufacturing of thousands of individual components, the assembly of those components into a signal device, and the distribution of those devices worldwide, it's pretty astonishing.

Supply chains support almost $20 trillion each year in global trade, and are foundational to our everyday lives, yet almost no one thought about them until the COVID–19 pandemic laid bare fragilities in the system. Almost overnight we saw how shocks can disrupt supply chains, triggering cascading effects, both upstream and down.

Just as the pandemic wreaked havoc throughout our supply chains, climate change is poised to do the same, only much more frequently. In fact, it has already begun. We are seeing climate disruptions in the procurement of raw materials. At our hearing on climate change and the agricultural sector there was bipartisan agreement that extreme weather is damaging crop yields, and increasing food prices.

Last year Hurricane Ian, for instance, devastated Florida's orange trees, driving up the cost of orange juice. Climate fueled droughts and heatwaves have made growing chicken feed more expensive, which contributed to higher egg prices. Drought and wildfires in Spain have cut olive oil production in half, and catapulted prices to record highs.

Hotter and dryer climates are stunting cocoa harvests, and making cocoa, an essential ingredient in chocolate more expensive than it has been in decades. The added costs of climate change now have a seat at kitchen tables around the world.

Climate upheaval is also affecting supply of the critical minerals used in electronics. Extreme weather events threaten mining infrastructure, and it is estimated that 30 to 50 percent of the world's copper, gold, iron ore and zinc are produced in areas that are now facing water shortages that will affect production. Raw material scarcity, decreases in material quality and higher raw material prices all translate into harder to source components, and higher prices for consumers.

We're seeing similar climate caused disruptions in manufacturing. In China last August, a record breaking drought reduced hydropower production so much that factories lost power, crippling production of automobiles and electronics. In Puerto Rico in 2017, Hurricane Maria damaged or destroyed dozens of medical device factories.

Outright destruction of manufacturing facilities in an immediate consequence of extreme weather, but heat stress, or lack of water for production can also cause pauses. Most manufacturing facilities weren't built to endure the climate extremes, and climate shifts we see today. And of course, once in a blue moon disasters are now chronic.

Transportation is experiencing its own climate triggered disruptions. The Panama Canal is an essential link in our global supply chains. In 2022, more than 14,000 ships, $270 billion in cargo passed through. But this year brought the worst drought in a century, and in August water levels were too low for ships to pass. As a result, August wait times were 4 times what they were in June, with boats waiting as long as 21 days to pass.

Things are still not back to normal. The drought persists, and daily transit limits are expected through the end of the year. The Mississippi River, which transports 60 percent of United States (U.S.) grain exports, is experiencing similar problems. This is the Mississippi River in September of 2021. This is the river in 2023, and all the white that you see here is exposed bottom and sand.[2]

For the last 2 years extreme heat and drought have brought water levels dangerously low, limiting barge shipments, and causing shipping costs to soar. Today the cargo rate from St. Louis southward is almost 80 percent higher than the 3–year average.

Carbon Disclosure Project (CDP), one of the premier organizations quantifying the effects of climate change, has analyzed data from over 8,000 suppliers. They estimate that environmental risks in supply chains will cost companies $120 billion by 2026, costs companies will pass on to consumers in higher prices, climate inflation.

As sea levels and temperatures rise, and extreme weather becomes more frequent and more intense, the effects of climate change on supply chains will only get worse. The White House Council of Economic Advisors recently warned that climate change will make supply chain disruptions more common. That, and I quote them here, "as networks become more connected, and climate change worsens, the frequency and size of supply chain related disasters will grow."

More bottlenecks and backlogs, more delivery delays and empty shelves, higher prices, climate driven disruption causing climate driven inflation. Some of the economic threats that we've warned about can come as crashes that can hit suddenly, and spread systemically across the whole economy.

Supply chain disruptions are more likely to cause perhaps local shocks, but nationally will steadily erode buying power as prices rise. If you care about inflation, you had better care about climate disruption. And to you, my Ranking Member, Senator Grassley.

OPENING STATEMENT OF SENATOR GRASSLEY [3]

Senator GRASSLEY. Thank you, Mr. Chairman, and as the Chairman knows, I take a little bit different approach to the real problem of global warming and climate change. This morning the Budget Committee holds its 12th hearing in ten months on climate change. Over the course of these hearings we've heard sensationalists and their alarmist rhetoric used to mislead the public on climate change, and draw support for top down policies.

We've heard broad, unsubstantiated assertions of impending disaster and destruction. Claims that aren't supported by robust re-

[2] Chart submitted by Chairman Whitehouse appears in the appendix on page 83.
[3] Prepared statement of Senator Grassley appears in the appendix on page 34.

view of the science. Hearing after hearing Democrats have chosen not to invite a single climate change scientist as a witness. I prefer to do just the opposite.

I want to learn from and legislate based upon discussions with both my constituents and experts like climate scientist Patrick Brown. He recently exposed how academia demands scientists omit key facts and tout certain climate narratives in order to be published in high profile journals.

And of course, we all know, publication advances a person in academia. These publications, skewed by predetermined conclusions, are then used by activists to push a far-left agenda. Dr. Brown hit the nail on the head stating that this dishonesty, "distorts a great deal of climate science research, misinforms the public, and most importantly makes practical solutions more difficult to achieve."

And remember those practical approaches have created a situation where the United States is at the 2005 level of greenhouse gases going into the air. I believe better than any other country. Europe was ahead of us.

I think Europe slipped a little bit recently. So, what Dr. Brown has said, as examples of other people that approach it the same way, that's exactly what has happened here in the United States Senate, using non-scientists to spread alarm, and tout distorted climate research.

That happens to be a disservice to our constituents. This has pushed us further from finding practical solutions to adapt to climate change, and those are the solutions that I'm looking for. Our country is in dire need of energy permitting reforms to reduce emissions, save the taxpayer's dollars, and secure our energy grid.

Politics drives us away from reaching these solutions. What's worse is that we're $33 trillion in debt. Take out the savings from the Supreme Court striking down the Biden student loan bailout, and the deficit last year was nearly $2 trillion. That's a larger deficit, as a share of the economy, than all but 5 years since the end of World War II.

Americans can't afford groceries and gasoline, and from Iowa to Rhode Island, inflation is reducing the purchasing power of all Americans, yet this Committee didn't write a budget for this fiscal year, and it's unlikely to do so for the coming year.

Moreover, despite bipartisan interest, this Committee has been very slow in working to reform our broken budget process. It's time that we start doing the people's work.

While unrelated to climate change, supply chains for many different goods, face immediate threats. Putin, waging war in Ukraine. President Xi threatening to invade Taiwan and using the Uyghurs for slave labor. Hamas recently killed over 1,000 Israeli citizens, sparked war in the Middle East.

Beyond the horrific impacts on those in the midst of these events, they pose risks to global supply chains for necessities such as a food and energy. If we're going to discuss supply chains, this Committee should discuss our most pressing domestic and international concerns, that's why I'm proud to welcome Mr. McNally.

Mr. McNally has dedicated his career to analyzing the global energy supply chains, and its relationships with both geopolitical and climate policy threats. Prior to founding his own consulting firm, he worked on both the National Economic Council, and National Security Council, serving as President George W. Bush's top domestic and international advisor there in the White House.

I'm also pleased to welcome a fellow Iowan. A sixth generation Iowan, Dr. David Barker. Prior to serving on the Iowa Board of Regents and building his real estate business, Dr. Barker taught economic courses at both the University of Iowa, and the University of Chicago. He also served as an economist at the Federal Reserve Bank in New York, which I consider a prestigious position to be working at.

Democrats on this Committee have consistently expressed their beliefs that climate change will cause devastating shock to the global economy. We're likely to hear more of the same today. Dr. Barker, I'm looking forward to hearing your testimony on the relationship between temperature and Gross Domestic Product (GDP) growth.

Your economic analysis will allow us to put aside the politics of climate change, and discuss what today is telling us. Thank you, Mr. Chairman.

Chairman WHITEHOUSE. Thank you very much, Senator Grassley. We have five witnesses today. Dr. Scott Kelly is Head of Environmental Analytics, and Senior Vice President of Model Development and Analytics at Risilience, a climate analytics company.

Prior to that he served as Chief Economic Advisor to the Parliamentary Commissioner for the Environment in New Zealand. Dr. Kelly, welcome, and we look forward to your testimony.

After Dr. Kelly we have Dr. Adam Rose who is a Research Professor at the University of Southern California (USC), Sol Price School of Public Policy, and a Senior Research Fellow at USC Center for Risk and Economic Analysis of Threat and Emergencies. Prior to that he worked in the applied economics departments at Pennsylvania State University, and West Virginia University. Dr. Rose, thank you also for being here.

Next, we have Kathy Fulton, who is the Executive Director for the American Logistics Aid Network. She is also a founding member of the Federal Emergency Management Agency's (FEMA) Supply Chain Analysis Network, and a founding member of the Private Sector Emergency Management Association. Ms. Fulton, thank you for being here.

Next, we have the 6th generation David Barker, who is also a partner in Barker Companies, a real estate company. A regent on the Board of Regents of the State of Iowa, and has taught as an adjunct professor at the University of Iowa, and the University of Chicago.

He worked as an economist at the Federal Reserve Bank of New York, where he conducted research on real estate and banking. Dr. Barker, thank you for being here. I think six generations puts you pretty much back to the founding of Iowa, doesn't it? Impressive.

Finally, we will hear from Robert McNally, who is the Founder and President of Rapidan Energy Group, a Washington based oil market policy and geopolitical consulting firm. Mr. McNally has previously worked as an international energy consultant, a senior White House policy official, and a hedge fund strategist. Mr. McNally, we welcome you too.

Dr. Kelly, over to you for your remarks. Each of you has 5 minutes for prepared remarks, and your full statements will, without objection be made a part of the record.

STATEMENT OF DR. SCOTT KELLY, HEAD OF ENVIRONMENTAL ANALYTICS, RISILIENCE [4]

Dr. KELLY. Good morning, Senator Whitehouse, Ranking Member Grassley, and other Senators with us today. It is an honor to be here today on behalf of Risilience, a company using sustainability intelligence to help business quantify nature and climate related risk and opportunities for their strategic advantage.

The U.S. derives substantial economic value from global trade. In 2022 the U.S. Bureau of Economic Analysis estimated that exports contributed $3 trillion to U.S. GDP. While imports on the other hand, provide many of the raw materials, commodities and products that are required for economic production, and a healthy and robust economy.

The U.S. economy is dependent on a complex global web of interconnected supply chains, while the network of global trade routes may appear robust from the outside, supply chains are vulnerable to the physical effects of climate change. A meta-analysis of peer reviewed research found that supply chains relying on specialized products and key infrastructure are at acute risk of serious disruption from climate related weather events.

The direct impact of extreme weather events can cascade through supply chains, affecting the supply of commodities and goods and to sectors and regions across the economy, leading to increased cost to business and the broader economy. And as we saw during the COVID–19 pandemic, when supply chains were disrupted, there was a sharp increase in global commodity prices.

Research completed by the Federal Bank have similarly concluded that the disruptions to supply semiconductors during this period directly led to an increase in prices, with significant macroeconomic implications. Evidence from past events shows that major damage to ports across the world from climate related hazards is already occurring, and such impacts are predicted to increase in the future due to cascading climate risks.

Planning for such hazards is not systematically incorporated into adaptation planning, which leaves supply chains exposed and vulnerable to climate risks. One example of a specialized product supply chain is that of the microchip industry. Taiwan is the world's largest producer of microchips, accounting for over 60 percent of the global supply of semiconductors, and about 90 percent of the world's most advanced microchips.

As a small island nation in the middle of the South China Sea, Taiwan is highly vulnerable to the impacts of climate change. The island is located on the typhoon belt, and it's frequently hit by storms which cause widespread flooding and damage to factories. Research shows that the strength of typhoons has considerably increased over the last four decades, caused by an average increase of 0.55 degrees in sea surface temperature.

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[4] Prepared statement of Dr. Kelly appears in the appendix on page 37.

There is growing consensus among climate scientists that global warming may prime the atmosphere to produce fewer, but stronger storms, while fewer typhoons would be a welcome relief, stronger storms cause more damage. Fewer storms also give rise to water scarcity, due to more droughts, which also has an impact on the fabrication of microchips.

The fabrication of microchips is an energy intensive process. It is also highly water dependent, and requires large quantities of water for cleaning and etching silicon wafers. Both of these critical imports are vulnerable to the effects of climate change. One manufacturing plant located in southern Taiwan's Science Park alone consumes 138,000 cubic meters of water per day. This is equivalent to the daily use of a city of nearly 0.5 million people.

Microchips are a vital component in many durable goods, such as iPhones, vehicles, and military hardware. According to the St. Louis Fed's estimate, microchips are used as an input into one-quarter of all manufacturing sectors, which in turn account for 39 percent of all manufacturing output.

Even though microchips typically account for only a small fraction of total input costs, scarcity of microchips can halt production. The long lead time, and high investment costs required to develop new chip fabrications centers therefore raise concerns about vulnerabilities to the economy, and to national security.

In a 2022 survey by the Commerce Department, it was found that the inventory of semiconductors in the U.S. had fallen from 40 days in 2019, to less than 5 days in 2021. This means that disruptions caused by climate impacts in Taiwan could have substantial knock-on effects in the U.S.

It's not just the lost productivity of U.S. firms, and the furlough of U.S. workers, it's also the cascading impacts on exports that depend on microchips within production processes. In sum, multiple sectors across the U.S. economy could be severely disrupted with consequential economic impacts.

The manufacture and supply of microchips is just one example for how the growing physical risks from climate change will impact the trade of critical goods from across and within U.S. borders. U.S. corporations are starting to realize the business imperative of mitigating and adapting to climate risks, and accelerating their progress towards net-zero.

The U.S. government can help to support this process by incentivizing companies to build resilient supply chains and promoting the disclosure of these material financial risks, as these can have wide-ranging impacts across the U.S. and global economy. Thank you, and I welcome questions.

Chairman WHITEHOUSE. Thank you, Dr. Kelly. Dr. Rose.

STATEMENT OF DR. ADAM ROSE, RESEARCH PROFESSOR, SOL PRICE SCHOOL OF PUBLIC POLICY, AND SENIOR RESEARCH FELLOW, CENTER FOR RISK AND ECONOMIC ANALYSIS OF THREATS AND EMERGENCIES, UNIVERSITY OF SOUTHERN CALIFORNIA[5]

Dr. ROSE. Chairman Whitehouse, Ranking Member Grassley, members of the Committee. My name is Dr. Adam Rose, and I'm a research professor at the University of Southern California. I'm also a research team member on the Defense Advanced Research Project Agency's Resilient Supply and Demand Networks Program, an effort to improve the resilience of strategic supply chains.

I'm honored to appear before the Committee to provide input into the discussion of climate change impacts on supply chains. My testimony pertains to an ongoing study, Supply Chain Impacts of Mississippi River Fertilizer Shipment Disruptions on Agricultural Production and the U.S. Economy, which I coauthored with Professor Zhenhua Chen of The Ohio State University, Professor Fred Roberts of Rutgers University, and retired Coast Guard Captain, Andrew Tucci.

The research is being sponsored by the U.S. Department of Homeland Security Center for Accelerating Operational Efficiency at Arizona State University, and is being carried out at the Department of Homeland Security (DHS) Center for Risk and Economic Analysis of Threats and Emergencies (CREATE), at the University of Southern California, and the DHS Command, Control, and Interoperability Center for Advanced Data Analysis at Rutgers University.

Our research is focused on complex supply chain disruptions where multiple events combine to have compound or cascading impacts across economic sectors or geographic areas. Currently, we are working on a case study that examines compound disruptions affecting barge traffic on the Mississippi, which is vital to agriculture and other industries.

Any such impact would spread throughout the economies of the Mississippi River states, and the nation as a whole. The first of the compound disruptions is drought, which is currently in its second consecutive year on the river, with water levels at historical lows. The most likely cause of the situation is climate change.

The second disruption is the failure of Lock and Dam 27 near St. Louis. The Lock and Dam network on this river and others are part of America's aging infrastructure, and is especially vulnerable to climate change driven events such as heat, floods, and drought.

Our third disruption pertains to an interruption of fertilizer imports through New Orleans, which could also be due to climate change since this city is a typical bullseye for hurricanes. We estimated the economic impacts using state of the art tool known as computable general equilibrium modeling, which characterizes the economy as a set of interrelated supply chains, or a supply web.

Here are our major findings in terms of the impact to the combination of disruption in terms of gross domestic product impacts. We project an annual national loss of $18.1 billion, with the vast

[5] Prepared statement of Dr. Rose appears in the appendix on page 40.

majority of the impacts incurred by the 5 upper Mississippi River states, Illinois, Iowa, Minnesota, Missouri and Wisconsin.

In terms of employment impacts we project a net loss of 51,000 jobs years. This figure would be higher except that in our scenario there's a need for more labor to have to load and unload more barges because each can carry a lighter load at lower water levels.

In terms of price impacts we project an increase in the Producer Price Index of 0.3 percentage points, and the Consumer Price Index of 0.25 percentage points. In an era of high inflation these seemingly small percentages are especially meaningful.

We believe that this research is important because impacts on agriculture affect the U.S. and world food security. While this consideration doesn't get as much attention in the U.S. as in developing countries, it is a problem for low income families, and many people of color in our country.

While we don't expect disruptions like this every year, they are likely to increase in frequency and magnitude as climate change accelerates. This will impact the production of critical goods and services, seaports, and other infrastructure, thereby disrupting supply chains in the U.S. and among our trading partners.

I also note that the climate change impacts I've reported today only pertain to fertilizer supply chain impacts on the Mississippi River. This commodity represents only 6 percent of all barge traffic on the river, so our estimates are only a small part of the total national impacts that climate change is likely to have on this transportation route and other inland waterways.

In particular, the estimates do not account for the impacts to shipments of corn, wheat, and other grains on the river, which would increase the impacts just reported considerably. Our research team is also examining compound disruption scenarios in the Port of New York/New Jersey, and the Ports of Los Angeles/Long Beach stemming from additional stressors, including sea level rise and wildfires. We expect the impacts from these compound disruptions to be in the tens of billions of dollars.

I reported in depth on only one of the myriad of supply chain disruptions that will be caused by climate change. In fact, given the high degree of interdependence between sectors of the U.S. economy, and our economy's connection with those in most every other country on the globe, it is only a very small portion of the potential total negative impacts.

Many people will be affected through loss of jobs and profits, but most widely, every consumer in the U.S. will see their purchasing power diminished by inflation and caused by increased production cost shortages and delays of goods and services. Thank you.

Chairman WHITEHOUSE. Thank you, Dr. Rose. Ms. Fulton.

STATEMENT OF KATHY FULTON, EXECUTIVE DIRECTOR, AMERICAN LOGISTICS AID NETWORK [6]

Ms. FULTON. Chairman Whitehouse, Ranking Member Grassley, members of the Committee, thank you for the invitation to testify. I'm Kathy Fulton, and I'm the Executive Director of the American

[6] Prepared statement of Ms. Fulton appears in the appendix on page 42.

Logistics Aid Network, or ALAN. We're a nonprofit formed in response to the supply chain failures of Hurricane Katrina.

Our organization has the privilege to support businesses, nonprofits and emergency management agencies. Increasingly, this includes support for disasters resulting from climate related hazards. As a native of Louisiana, now living in Florida, I'm familiar with disasters, and the impacts and costs they bring to supply chains.

My comments today are my own, but would not be possible without the input from the vast network of individuals and organizations that comprise ALAN. I'll speak about three items related to the impact of climate disasters on supply chains. First, ways in which supply chains are disruptive.

Second, the sources of supply chain costs, and finally, ways in which supply chain stakeholders are addressing risk from a changing climate. Disasters disrupt supply chains in three primary ways, by restricting supply, the ability to provide a resource or service, by affecting demand, or the ability of an end consumer to access a resource or service in the manner or location they do pre-disaster, and by disrupting coordination mechanisms, like information and finances that connect supply with demand.

Modern supply chains feature capacity concentrations, which enable them to push high volumes at high velocity. These concentrations drive efficiency and cost savings by providing common resources, like shared infrastructure, and a skilled labor pool.

Many of you will recognize capacity concentrations within your own states. The blue economy in Rhode Island, farms in Iowa, warehouses and ports, and other locally and regionally important concentrations. When capacity concentrations are disrupted, the impacts can ripple far beyond the communities where they're located.

For example, IV saline bag production slowed due to power outages after Hurricane Maria. That disruption in supply delayed medical procedures around the U.S. and around the world. Supply chains are also disrupted by shifts in demand, like when 6 million Floridians evacuated after Hurricane Irma. This mass migration saved lives, but also created demand for resources and services in new locations.

Businesses, government organizations, and nonprofits all scrambled to meet the increased needs created by this shift. Finally, disruptions to coordination mechanisms can be as straightforward as downed communication systems, which prevent businesses from checking out customers in stores, or placing orders with suppliers. When businesses cannot exchange information or funds, the physical movement of goods stops as well.

These supply chain disruptions have a real cost to our economy, to communities, to individuals and families. I'll share a few examples. Businesses experience costs from lost or damaged inventories, like this July when a tornado destroyed a Pfizer pharmaceutical warehouse in North Carolina.

They experience lost sales due to facility closures, such as small businesses in southwest Florida experienced after Hurricane Ian. Businesses spend more when established transportation routes have delays, like the drought reducing the number of ships allowed through the Panama Canal.

And finally, businesses experience added costs to support employees by providing time off and funds, so that those employees could take care of their homes and families first. Each impact to a business also means an impact to an individual who works in, or is served by that business. And for individuals and families who are already vulnerable, the effects are amplified.

To reduce risks from climate change, businesses are taking long-term actions like diversifying their supplier base, or switching to cleaner energy, and short-term actions to protect assets and workforce. These adaptations require investments of time and money, and supply chains must continue to function while adjusting.

There's no rip and replace solution, and no individual business can bear the adaptation burden alone. Anticipating and adapting to the challenges of climate change will require a whole of nation effort, with sustained private-private and private-public conversation, education and preparation, focused on supply chain resilience.

I've cited a 2020 National Academies study, which provides a thoughtful roadmap for advancing such activities. Businesses lead and drive change when the risk and benefits are clear, quantified and supported by evidence. The hearings hosted by this Committee could form the foundation for studying the costs of climate change on supply chains.

But without a clear understanding of the potential cost of failing to adapt, or the potential benefits of such adaptations, it may be business as usual for supply chains until the pain of extreme events forces action. I hope my comments today have been helpful, and I look forward to your questions.

Chairman WHITEHOUSE. Thank you very much, Ms. Fulton. Dr. Barker.

STATEMENT OF DR. DAVID BARKER, PARTNER, BARKER COMPANIES [7]

Dr. BARKER. Chairman Whitehouse, Ranking Member Grassley, and members of the Committee, thank you for inviting me here today. If nothing is done to reduce greenhouse gas emissions temperatures will rise by 3 to 4 degrees, and global GDP will be 2.6 percent lower in 2100 than it would be if there is no climate change.

That is an estimate endorsed by the Intergovernmental Panel on Climate Change (IPCC), and in line with estimates from the only economist to win a Nobel Prize to work on climate change. Assuming real growth of 2.1 percent between now and then, GDP in the year 2100 will be 5 times higher than it is today. A 2.6 percent reduction of year 2100 GDP would mean that instead of being 5 times higher, GDP will be 4.9 times higher, that is not a catastrophic outcome.

It is reasonable to wonder if this argument is flawed because climate change might affect the rate of growth of GDP because of supply chain disruptions or other effects. If for example, GDP grew at a rate of 1.5 percent instead of 2.1 percent, the compounded effect of lower growth would be very large by the year 2100.

[7] Prepared statement of Dr. Barker appears in the appendix on page 48.

Eminent economists from Harvard, the Massachusetts Institute of Technology (MIT), and The Federal Reserve, have tested this hypothesis and report large effects of temperatures on growth. Their results have received glowing media coverage, and many academic citations. I proved that their results are wrong. One paper claimed that higher temperatures reduced growth rates in poor countries. South Korea was poor in 1960, the beginning of their sample, and the authors classified South Korea as poor throughout the analysis.

I discovered that if South Korea is classified as poor when it was poor, and rich when it was rich, the results nearly disappeared. When I reclassified all countries this way, the results disappeared completely. The authors of another paper would not provide replication code, but I wrote the code from scratch, and discovered that their results were not statistically significant.

All countries are weighted equally in this analysis, so St. Vincent in the Grenadines, one-eighth the size of Rhode Island, has the same weight as China. As a result, small countries with unusual circumstances affect the results. For example, 1994 in Rwanda, was a year of genocide and economic collapse. It was also a bit warmer than usual, leading the statistical model to conclude that temperature affects GDP.

That seems unlikely, and looking at the monthly data, the warmest months of that year in Rwanda occurred after the genocide, and so could not have caused it. The papers failed many other robustness checks that I performed. Research this flimsy should not have passed the peer review process, and should not have been published in academic journals.

The term statistical significance, suggests that a result is meaningful, and not the result of pure chance. A normal standard for a result to be taken seriously is that the odds are less than 1 in 20 that the result is from pure chance. But policymakers and the public can be misled if a researcher tries 20 different model specifications, and publishes the 1 that happens to produce a result.

In my opinion, political and ideological pressures to confirm the importance of climate change has caused the peer review process to break down, allowing questionable results to be published in elite academic, economics journals. Even if these results were valid, none of the papers I examined deny that adaptation could mitigate the effects they claim to find.

Robust supply chains exist in a variety of climates around the world, and significant adaptation will certainly occur over the next 80 years. The papers find no effect of changes in precipitation on GDP, casting further doubt on the likelihood that significant supply chain disruptions will affect GDP caused by climate change.

It was a good idea to test whether temperature fluctuations have affected GDP growth. The problem is that the results that were claimed do not hold up. My conclusion is that the records of temperature and economic growth that I have examined do not support the hypothesis that supply chain disruptions caused by climate change are likely to cause reductions in per capita GDP growth, thank you.

Chairman WHITEHOUSE. Thank you, Dr. Barker. Dr. McNally.

STATEMENT OF ROBERT MCNALLY, PRESIDENT, RAPIDAN ENERGY GROUP [8]

Mr. McNally. Chairman Whitehouse, Ranking Member Grassley, members of the Budget Committee, I'm honored you've invited me today to this important hearing. This testimony reflects my views, and not that of Rapidan Energy Group. Oil is, and for the foreseeable future will remain, the life blood of modern civilization, by virtue of the fact that 97 percent of the vehicles on the planet run on it.

Oil's commercial use starting in 1859 lifted humanity from five millennia of squalor, darkness and immobility. Now after the last 4 years critical oil and gas supply chains have endured major, if fortunately so far, short-lived geopolitical disruptions. They include on September 14, 2019, Iranian drones and missiles attacked the Saudi Abqaiq processing plant, the world's most vital energy facility, accounting for 6 percent of global supply.

Unlike a pipeline or a port, you can't easily replace a processing plant. Now oil is fungible and globally traded, so a disruption there means high gas prices here. Had Iran destroyed that facility it would have caused a severe lasting oil price spike I estimate by about 33 percent, likely throwing the U.S. into a recession and the world into a wider, regional war.

Fortunately, Iran inflicted light and reversible damage. Two, on May 7, 2021, Russian based ransomware attackers forced a shutdown of the 3 million barrel a day, 5,500-thousand-mile-long Colonial Pipeline. It supplies half the gasoline and diesel to the east coast, supports 90 military bases and installations and 7 major airports.

The attack differed critically from the thousands of prior cyber attacks on U.S. persons, businesses and government agencies, and now for the first time they directly disrupted physical flows of energy required for social order and national security of the United States. Fortunately, Colonial restarted the pipeline after 6 days, albeit after paying the attackers a ransom.

Three, Russia's invasion of Ukraine on February 24, 2022, triggered sanctions that the International Energy Agency (IEA) advised could disrupt up to 3 million barrels a day of Russian oil exports. Russia is one of the top three oil and gas producers and exporters.

In response, oil prices spiked by 32 percent in 13 days, from $97 to $128 a barrel. Crude oil prices rose again despite Surface Plasmon Resonance (SPR) releases, pushing pump retail gasoline prices to a record last year $5 a gallon. They fell back only when that Russian oil didn't go off the market.

Finally, while the conflict initiated by this month's Hamas savage attacks on Israel does not yet directly threaten oil supply, there is substantial risk that fighting will spread to include Iran's proxy, Hezbollah and Lebanon, other regional actors. The Middle East, we get 40 percent of crude oil exports, 18 percent of our refined product exports, a good deal of our Liquified Natural Gas (LNG) from the Middle East.

[8] Prepared statement of Mr. McNally appears in the appendix on page 53.

Now policy considerations. Again, luckily these Abqaiq and Colonial Pipeline attacks were massive, but short. And so far, neither Russia nor Hamas has disrupted oil, but we should not bank on such luck in the future. These supply disruptions underscore the ongoing vulnerability of energy production in distribution systems essential for our security and living standards.

They suggest several policy considerations. First, attend carefully to cyber threats to critical energy infrastructure, including petroleum production, transportation system and electric grids. We have more work to do to deter and respond. Second, consider the current and new geographic concentrations of energy supplies, production and trade.

China's dominance of critical materials, rare earth elements, and decarbonized supply chains is well known to you. Third, build and bolster defenses against severe energy supply interruptions, and resist frittering them away. Draining the SPR for non-emergency purposes is a dangerous policy error. I recommend Congress rectify it soon by appropriating funds to replenish it.

Finally, avoid sweeping bans, mandates and other policies that impose burdensome costs without clear and publicly acceptable benefits. I can think of no more dangerous development for U.S. energy security than the International Energy Agency's advice since 2020, to ban all new investment in upstream oil and gas projects.

Such policies will exacerbate supply chain bottlenecks arising from tightening supply and demand fundamentals in coming years, resulting in more extensive and economically painful oil and gas price spikes.

Ideally, Congress and the White House will support domestic energy production and minimize supply chain risk while developing sound, cost-benefit based strategies and policies to address climate change. Thank you.

Chairman WHITEHOUSE. Thank you very much. Let me begin if I may with Ms. Fulton. You said that your organization, the American Logistics Aid Network was started in response to the upheavals of Hurricane Katrina. Who started it? Who were your original like clients and sponsors?

Ms. FULTON. Thank you for the question, Senator. We were formed by industry associations who represent logistics and supply chain service providers.

Chairman WHITEHOUSE. Industry and business associations formed you.

Ms. FULTON. Yes, sir.

Chairman WHITEHOUSE. Are industry and business associations your ongoing clients and supporters?

Ms. FULTON. Absolutely. Yes, sir.

Chairman WHITEHOUSE. And why is it that industries and businesses are interested in funding and supporting your work, and your services?

Ms. FULTON. Businesses recognize that disasters disrupt their consumer base, so their clients are affected by disaster, and they want to make sure that their clients and their employees, the people who work for them, can continue to operate, so they rely on us, they rely on our organization to help get communities restarted, to get those communities the supplies and support that they need.

Chairman WHITEHOUSE. Do your industry and business community supporters come to you and say why are you wasting your time on climate related disasters? That's a bunch of bunk and hokum?

Ms. FULTON. No, sir. They do not.

Chairman WHITEHOUSE. And why do you think they don't do that.

Ms. FULTON. Businesses recognize that whether the risk is short-term from a short-term disruption or a long-term disruption, they have to be prepared to respond.

Chairman WHITEHOUSE. For what it's worth, we're seeing it on the defense side as well. We've heard from the former commander of naval station Norfolk, near and dear to Senator Kaine's heart, that there's a timestamp on that very important naval facility because of sea level rise and flooding risk, so thank you for your work.

Dr. Rose, you focused really on fertilizer and the Mississippi, but you did it—I think you said, as a case study, correct? And is it your view that the fertilizer Mississippi case study has import throughout supply chains and for a whole variety of industries and risks?

Dr. ROSE. Yes. It's a good example of what we face with other commodities as I've said. We focus on the fertilizer shipments, and the problems with the barges not being able to carry the loads due to low river waters. But if we also included the higher cost of grain shipments, it would increase our estimates significantly.

It's just one of many examples of transportation issues that we face that are exacerbating the problems due to climate change.

Chairman WHITEHOUSE. You said it was one of a myriad, I think.

Dr. ROSE. Yes.

Chairman WHITEHOUSE. In your testimony. Are there any in particular, that aren't the one you studied, that you would flag as particular risks that we should be paying attention to?

Dr. ROSE. Well we should also be concerned about the wildfire risks to supply chains. One of our speakers, Dr. Barker, mentioned that there was no study that found that rainfall variability had a negative effect on the economy. I beg to differ with that.

The variability in rainfall, for instance, is the major reason we've got more excessive, more frequent, more excessive wildfires in the western U.S. We have periods of heavy rainfall which stimulate lush growth, and then we've got periods of drought where those dry out and they're just tinder for wildfires. Those wildfires are especially devastating for the people in those communities, and parts of supply chains that some of these wildfires are even of concern now to people in the ports of Long Beach and Los Angeles.

Chairman WHITEHOUSE. Dr. Kelly, you mentioned that supply chains are vulnerable around the world. Same or similar question to Dr. Rose's. Are there particular vulnerabilities that you would highlight as ones that are of particular concern, or that should be of particular concern to the Committee, to the Congress, and to the business community?

Dr. KELLY. Thank you for the question, Senator. Yes. Like I mentioned in my testimony concentration risk in supply chains is important. I think it's important that the U.S. recognizes critical supply chains, such as advanced battery technology, the pharmaceutical industry, and critical components to the production of the commodities within the U.S. economy.

When doing this analysis you can look across the globe and identify hot spots where physical risk is occurring, to know where best to target and diversify supply chains to minimize the long-term risks. Thank you.

Chairman WHITEHOUSE. My time has expired. Let me turn it over to Senator Grassley, then Senator Kaine.

Senator GRASSLEY. Before I ask my first question I see that Dr. Barker wanted to respond to Dr. Rose. Why don't you do that?

Dr. BARKER. Thank you, Senator Grassley. I did not say that there were no studies indicating that rainfall, variability of rainfall had an effect. I was saying that the studies that I reviewed found that there was no effect of rainfall on GDP growth.

Senator GRASSLEY. Okay. Mr. McNally, I'm going to start with you. We've heard many politicized climate change narratives throughout our 12 climate change hearings, and unfortunately the politicalization of climate change isn't limited to the halls of Congress.

How have international institutions, let's say like the International Energy Agency allowed climate alarm to compromise their missions? And then in your professional opinion, which is a greater threat to global energy security and the U.S. economy, climate change or top down climate policy?

Mr. MCNALLY. Thank you, Senator Grassley. The International Energy Agency was formed after the Arab oil embargo 50 years ago this month, with a security mission, organize the collective use of strategic reserves, and then help us understand what's going on in oil and gas markets, including data and forecasts, and they have a bunch of hard-working talented folks doing that, and their job is difficult.

Unfortunately, and the saddest thing I've seen in my career professionally as a barrel counter, and as someone who's spent most of his career trying to predict what's going to happen, not influence it. Starting in 2020, the IEA stopped producing what we call current policy scenario, or business as usual forecasts. Basically, a base case that assumes policy in place today.

They do that under environmental pressure because we're showing too much oil demand, and too much oil supply. But by doing that they deprive you in the Senate and Congress of the tool you need to use to make cost benefit assessments of policy options.

You also dupe the world into thinking that we're heading towards peak demand really soon, and that's very dangerous. And from that, they then come out and said there should be no new investment in oil and gas supply. Again, I think I can think of nothing more dangerous and disastrous for our near term and medium term energy outlook, and national security outlook than were we to effectively make peak supply real by banning investment in new oil and gas production.

And in my view, no question, although I'm not a climate scientist, nor a climate modeler, when I see things like President Biden's call to outlaw the use of gas and coal and electricity by 2035, or ban the sale, or mandate the restriction sale of internal combustion engine (ICE) cars, cancel the Keystone Pipeline, much less the IEA is called to ban all upstream investment.

I have no question that those policies would be much more costly than any reasonable benefits we'd get in any other area, including climate policy.

Senator GRASSLEY. Dr. Barker, you've discovered faulty economic methods used to spread climate alarm, and then revealed them to the world. What statistical tricks should objective listeners look to, or look out for to differentiate climate change propaganda from economic accuracy?

And then why do you think economists and others use these tricks in the first place?

Dr. BARKER. Thank you, Senator Grassley. Well some of the easy ones that we see in the popular media are talking about costs of climate change without putting them in context, either as a percentage of GDP, or with growth. I mean if we're projecting costs out many decades in the future, we need to think about what those costs are relative to the growth that we expect to see between now and then.

Another is that studies that I've looked at that claim that there is some kind of optimal temperature for economic production, have difficulty with the fact that a lot of poor countries happen to be also very warm countries. Now people have debated for many years why that's the case, but we really don't know. And it's difficult to control for that and look at the actual effects of temperatures.

But many of these tricks are much harder to see. I mean for example, the papers I looked at used thousands of lines of code to shape the data, and assumptions are buried in those thousands of lines of code, or regressions that use 500 variables. And it requires a really close look to find some of the assumptions that are embedded in that work.

Why do they do these tricks? Well I think as an economist we know that incentives matter. And when the incentive is to publish, people publish, and conclusions that fit the dominant ideas are easier to publish than papers that challenge those ideas.

Senator GRASSLEY. Well Mr. Chairman, could I have 45 seconds to kind of close up here?

Chairman WHITEHOUSE. Please.

Senator GRASSLEY. We continue to receive testimony that relies on the extreme Representative Concentration Pathway 8.5 (RCP8.5) scenario. Climate scientist, Dr. Roger Pielke, testified in June that the real world is actually tracking below this extreme scenario. Dr. Pielke also said, "every day that we continue to prioritize the most extreme scenario in research and policy, is a day that we mislead ourselves."

So, in summation, we should both invite climate scientists who have the ability to speak to the validity of scientific assertions, and there isn't a single Senator or witness in this room who's qualified to do so right now. Thank you.

Chairman WHITEHOUSE. Thanks very much, Senator Grassley. I'll turn to Senator Kaine, but I'll first ask unanimous consent to put into the record of the hearing an article I wrote with Senator Graham entitled A World Without Fossil Fuels Funding our Enemies Would be a Safer World for America, in which we write that if you could transition the world away from fossil fuels, Americans would instantly be safer.

Oil and gas development has often been associated with autocracy and corruption. A world in which oil and gas money has less power is a world that will likely have less corruption, autocracy and terror. That world will be a safer world for America. Without objection that will be put on the record, and Senator Kaine is recognized.[9]

STATEMENT OF SENATOR KAINE

Senator KAINE. Mr. McNally, you testified in your opening comments that we should be wary about any policies that disrupt the energy markets in oil and gas. What do you think is the advisability of the United States using sanctions against nations like Russia, Venezuela, and Iran on their energy sector for bad behavior?

Mr. MCNALLY. Thank you, Senator Kaine. So tread very carefully. I think it's critical that when President Obama put sanctions on Iranian oil exports, he did so at a time in which U.S. shale oil production was surging. We were enabled, really, to contain oil prices while cutting off Iran's oil exports.

And one of the reasons why the Russian oil disruption did not occur last year was the Biden administration, to its credit, recognized that the European sanctions could cause a loss of 3 million barrels a day of Russian supply, so they led in creating a price cap mechanism, an off-ramp if you will for those sanctions.

One of the goals of that was to avoid that catastrophic loss of Russian oil, high oil prices that would hurt the economy and possibly public support for Ukraine. So those are two instances where it came into play.

Senator KAINE. So your thought is there's no one size fits all on sanctions, but just tread carefully if you impose sanctions on foreign nation's energy sector.

Mr. MCNALLY. Yes.

Senator KAINE. Thank you for that. This is a question for Dr. Fulton, Ms. Fulton, and it's about pharmaceuticals. It's a little bit of a Virginia story. We're well aware of the devasting impact that natural disasters can have on access to life sustaining medicines. Some of you have talked about some of the recent examples.

In 2017 Hurricane Maria hit Puerto Rico. That exacerbated a saline solution shortage. 2018 wildfires in the western part of the country triggered N95 mask shortages, and a number of you talked about the tornado destroying the Pfizer plant in North Carolina. That plant stored raw materials, packaging supplies, finished medications awaiting shipments to U.S. hospitals.

Events like these stress the importance of diversifying supply chains. We can and should bring production of critical components closer to our shores. One disaster shouldn't be able to take down a supply chain, particularly a supply chain in an area as important as medical products and pharmaceuticals.

That's why I was pleased that earlier this week, the Biden administration announced that Richmond-Petersburg, Virginia re-

[9] Document submitted by Chairman Whitehouse appears in the appendix on page 84.

ceived a designation as a regional tech hub for advanced biotech manufacturing. I was selfishly excited about this because I helped create the Virginia Biotech Research Authority when I was a City Councilman in the late 1990s.

I served on its Board as Mayor, I appointed its Board Members as Governor, and then I fought for the funding in both the American Rescue Plan, and the Infrastructure Bill to help support this initiative. Can you discuss the importance of a federal investment in diversifying our medical product and prescription drug supply chain, and why is this sector so vulnerable to potential climate risks?

Ms. FULTON. Yes. Senator Kaine, thank you so much for the question. And congratulations on the new designation for the Richmond and Petersburg area. Medical products and pharmaceuticals are currently heavily reliant on oversea sources, many of which are in areas that are vulnerable to climate disruptions.

The long transportation routes that these have to travel to get to the United States create challenges, especially when there are disruptions in global shipping. You asked about, you know, why are they vulnerable? What can federal investments do? I think the lessons learned from the pandemic really underscore why we need this type of federal investment.

You're going to create jobs through this, but it's also going to drive innovation and technological investments, which is going to make things more efficient and cost-effective for production standards. It is important in creating robust, secure and resilient medical and pharmaceutical supply chains, and reducing that reliance on the lengthy transportation routes.

Senator KAINE. Thank you. And Dr. Rose, a question for you, staying in the same space. I am the Chairman of the Western Hemisphere Subcommittee of the Foreign Relations Committee, and I have been with other colleagues in a bipartisan way, pushing the idea of more nearshoring of production closer to the United States.

Obviously, if we can get it in the United States that's great, but if we can get production of critical supplies and nations in the Western Hemisphere where we have trade agreements, where we're trying to help them grow their economies, I think that's all for the good. There are a number of steps underway to do that.

The Vice President is working with nations to try to build more supply chains there. The Chips Manufacturing Bill had an ability to do investments in chips production in the Americas to pull some of that back from China. I'll talk a little bit about—and this is my last question, about the value of looking at nearshoring, and bringing supply chains, if not completely back to the United States, at least back closer to the United States in the region that is our neighbor where we have trade agreements with virtually all the nations in the area.

Dr. ROSE. Well the first way it helps is it lowers transportation costs, rather than bringing things all the way from China. Second, it improves the security of supply because you're dealing with friendly countries. Third, it helps improve relations with our neighbors.

China is aggressively going throughout the globe investing in many countries, and they're in our backyard and could be even more so if we don't fill that vacuum. And finally, I'd say it's one way, especially with Mexico, to help with the border crisis, creating jobs in Latin America will slow immigration to the U.S.

Chairman WHITEHOUSE. Senator Johnson.

STATEMENT OF SENATOR JOHNSON

Senator JOHNSON. Thank you, Mr. Chairman. I'll start by saying what I always say. I'm not a climate change denier. I'm just not an alarmist, we'll adapt. We'll have to adapt. It was interesting a couple of months ago on August 14th, 1,609 scientists and professionals from around the world signed a world climate declaration saying there is no climate emergency.

This group was led by two Nobel Laureates, John Clauser, and Ivar Giaever. I hope I'm pronouncing that right. Both won their Nobel Prize in physics. I'd like to enter this declaration into the record. All the signers are listed here, and very impressive credentials. It's pretty short, so I'm going to take my time to read it.[10]

"There is no climate emergency. Climate science should be less political, while climate policy should be more scientific. Scientists should openly address uncertainties and exaggerations in their predictions of global warming, while politicians should dispassionately count the real costs as well as the imagined benefits of their policy measures.

Natural, as well as anthropogenic factors cause warming. The geological archive reveals that earth's climate has varied as long as the planet has existed, with natural cold and warm phases. The Little Ice Age ended as recently as 1850, therefore it is no surprise that we are now experiencing a period of warming. Warming is far slower than predicted.

The world has warmed significantly less than predicted by IPCC on the basis of modeled anthropogenic forcing. The gap between the real world and the modeled world tells us we are far from understanding climate change. Climate policy relies on inadequate models.

Climate models have many shortcomings and are not remotely plausible as policy tools. They do not only exaggerate the effect of greenhouse gases, they also ignore the fact that enriching the atmosphere's CO_2 is beneficial." I love this next one. "CO_2 is plant food. The basis of all life on earth. CO_2 is not a pollutant.

It is essential to all life on earth. More CO_2 is favorable for nature. Greening our planet. Additional CO_2 in the air has promoted growth in global plant biomass. It is also profitable for agriculture, increasing the yields of crops worldwide. Global warming has not increased natural disasters.

There is no statistical evidence that global warming is intensifying hurricanes, floods, droughts and such like natural disasters, or making them more frequent. However, there's ample evidence that CO_2 mitigation measures are as damaging as they are costly.

Climate policy must respect scientific and economic realities. There is no climate emergency. Therefore, there is no cause for

[10] Document submitted by Senator Johnson appears in the appendix on page 86.

panic and alarm. We strongly oppose the harmful and unrealistic net zero CO_2 policy proposed for 2050. Go for adaptations instead of mitigation. Adaptation works whatever the causes are.

Our advice is that science should strive for significantly better understanding of the climate system, while politics should focus on minimizing potential climate damage by prioritizing adaptation strategies based on proven and affordable technologies." They conclude, "to believe the outcome of a climate model is to believe what the model makers have put in.

This is precisely the problem of today's climate discussion to which climate models are central. Climate science has degenerated into a discussion based on beliefs, not on sound self-critical science. Should not we free ourselves from the naive belief and immature climate models?"

Net zero by 2050, according to a Bloomberg New Energy Finance study will cost \$21 trillion. \$21 trillion. In testimony before this Committee it's looking like we've already spent somewhere between \$5 and \$6 trillion. And I've asked the majority witnesses have we bent the curve down? Have we mitigated climate change having spent \$5 to \$6 trillion?

Do you think spending \$21 trillion is going to bend that curve down? We've also got out of the majority witnesses that there's no way that China and India is going to reduce its dependence on fossil fuel. In fact, a majority witness said, "Nor is America." 80 percent of our economy right now is powered by fossil fuels. That's not going to end any time soon. Isn't that correct, Mr. McNally?

Mr. MCNALLY. That is correct, Senator.

Senator JOHNSON. Dr. Barker, I mean I appreciate your testimony in terms of what I would call the corruption of science. One thing you didn't mention is the incentive of chasing grant dollars. I mean you're going to get many dollar grants from the federal government if you're publishing a paper that disputes the consensus? And by the way, I think 1,609 very eminently qualified scientists would at least bust the myth that climate change is a global risk is consensus.

These are some skeptical people, and that's really what science is all about. Isn't that true, Dr. Barker?

Dr. BARKER. That's true, Senator, and I have not received any government grants for debunking climate research.

Senator JOHNSON. I appreciate that. So Mr. Chairman, I would appreciate———

Chairman WHITEHOUSE. It will be admitted into the record, and your comments are appreciated.

Senator JOHNSON. Thank you much.

Chairman WHITEHOUSE. Senator Merkley.

STATEMENT OF SENATOR MERKLEY

Senator MERKLEY. Thank you very much, Mr. Chairman. I want to start with the challenge of the Panama Canal, and Dr. Kelly as you are well aware, we've had a big impact on ships running through the Panama Canal because of extended drought affecting the water levels inside the upscale locks, the higher locks.

And how will those delays affect the supply chains for the United States?

Dr. KELLY. Is this my question, or is it for———

Senator MERKLEY. Yes.

Dr. KELLY. So the physical risks of climate change are a global issue, and they affect the U.S. as well, so it's important that the U.S. understands and builds evidence to try and model the effects of disruption to these events as they occur from drought or extreme weather events.

We've seen, as my colleague, Adam Rose, has already testified from the Mississippi, that this has already caused severe disruptions. Disruptions to the global supply chain, where it's through the Panama Canal as we've seen disrupt imports into the U.S. through those routes through agricultural products, through key supply lines.

Senator MERKLEY. Thank you. I will note that there is a port in Oregon, it's a deep water port that we're trying to turn into a container port to enhance the ability to have port capacity on the west coast that could help alleviate some of the supply chain challenges. But it needs to make a grant in order to undertake it, so a message we're taking to the administration.

I do want to turn to the question of the challenge of many of our supply chains for solar panels are tied to China. And we had China restricting Gallion and Germanium chip components, and then most recently restricting graphite a couple days ago.

If we are to produce half of the electricity we need through solar panels to get to the 2035 goal of produce all electricity with renewables, if half of it comes from solar panels, we have to deploy 3 billion solar panels. What additional steps should we take to try to produce more solar panels here, avoid supply chain problems in deploying solar energy? Dr. Rose.

Dr. ROSE. Diversification is the first order of business in reducing risks, so reducing our dependence on China is paramount, so we need to look for alternative sources of supply. We need to find ways of simulating U.S. solar production.

Senator MERKLEY. Thank you. Mr. Chairman, our colleague from Wisconsin just read about a statement of some 1,600 scientists being concerned that we're over inflating the risks of climate change. I'll just note in my home state of Oregon, the increase in the fire season is very, very real. We've had six towns burn to the ground. That never happened in the past.

Of course, we saw what happened in Hawaii this year. The droughts are real. Our farmers are being hurt by massive impact on the reduced rainfall. They're getting less water from the snow pack, which has decreased an average of 2,240 inches in the Cascades over the last 90 years, and are being impacted by less water, groundwater, because it's not recharging, and because of ancient groundwater is a one-way path to depletion.

They're being impacted by our fishermen off the coast, by the warmer waters in the Pacific, very significantly more acidic, and warmer waters which produced a virus in the—or facilitated a virus in the starfish, something we've never seen before. Starfish wasting disease that led to the decimation of our kelp beds, and the kelp beds are significant to the ecosystem.

In other words, our farmers, our fishermen, our forestry industry, all the foundations of rural economy are being profoundly impacted on a very real basis by the changes that we've seen just in the last 30 years, so certainly this is not dependent upon international studies to tell us that there is a massive change in the world not seen in human history before.

And so I think we better accelerate our efforts to address that, not pretend and stick our head in the sand that there is no problem.

Chairman WHITEHOUSE. Few work harder than you, Senator Merkley. Thank you. Senator Braun.

STATEMENT OF SENATOR BRAUN

Senator BRAUN. Thank you, Mr. Chairman. I'd like to start off with a simple question, and just raise your hand.

All of you are familiar with the concept in finance of present value?

[Hands raised.]

Senator BRAUN. I figured so. Since I've been here no one understands that in this institution. That is why we borrow aggressively for the latest and greatest political idea that you think might parlay into a solution. And of course, if you understand present value, you know the significance, especially when interest rates are high, whatever you spend in the moment and to get that justified, you're going to have to have something in the future that is huge in consequence, in terms of that return on investment, or to justify why you'd want to spend and borrow the money in the present.

It would be different too, if we were dealing with capital, equity. We have no equity here. We borrow now 30 cents on every dollar we spend. Just 5 years ago that was 20 cents. I think you all understand how that cost of capital is going to really go up when you start pricing in the 5 percent that interest rates have gone up in the last year and a half.

I won't insult you with what is 1 percent, you make it easy, 30 trillion. Take 5 percent of that, and then start applying it to 42 trillion, that our fearless leader has us in debt in 5 years, 52 trillion in 9 to 10 years. That's a calamity that will far swamp anything that we've been talking about here.

And I'm a conservative that believes we need to be in the discussion of climate. I think if not, you're at least not going to be in a position where you have credibility to offer other things to do. But in light of that, and the fact that the biggest economies, other than ours, in the world, outside of the European Union (EU). And that's a collective group that seems to have trouble getting things in agreement.

They're building coal fired plants weekly in India and in China. So the fact that we've got something that to me is worth discussing, the physics and chemistry. You put greenhouse gases into the air, I think it warms things up. But the modeling that having an accurate sense of present value analysis, we've been off the mark for 20 years.

So that means if a disproportionate part of the equation is all the money you're spending and borrowing in the present when we've not knocked anything out of the park. So, I think my point would be maybe we ought to get back to budgeting. The fact that we haven't done that in 20-some years makes this very much an academic discussion.

It means we're talking about something that we know might occur, but there's been almost zero credibility on plugging in the benefits that would accrue from spending and borrowing all this money. I'd like again, a show of hands, do you think that makes sense what I've just said?

[Hands raised.]

Senator BRAUN. I see 4 out of 5 think you do. That is better than most on a panel. So, I guess my point is let's redirect the essence of the Budget Committee to doing what you're supposed to do. The other issues are ancillary, and especially when we've been so long on this idea of trying to find out what actually the consequence is.

To me we've given up our energy independence. We've done so many things that tilt the whole analysis, which finance pays the bills. Government, just because you've got the printing press in the basement, and your credit card gets renewed every year, you can't be borrowing now a $1 trillion every 6 months.

I do think we need to be engaged in the conversation, but I think we're going to have other issues, much more serious than what might occur that we've not modeled very well. And the only way you can have credibility putting that much emphasis on it now is if you can tell us there's a tipping point fairly soon down the road, or else we're just going to borrow and spend ourselves into a place that will be a lot worse than where the economy might go supply chain and all that, due to climate.

I'd like Mr. McNally to comment on it, and Dr. Rose. Let's start with Mr. McNally.

Mr. MCNALLY. Thank you, Senator. My clients ask me to predict what policymakers will do. And one reason why we predict there will not be sufficient action to arrest—to achieve net zero, is we look exactly at the problem you're describing.

The budget problems of our country could be solved, as I understand it, in a couple weeks of legislative time. They could be understood by an 11-year-old with decent math skills, and would not require getting China onboard or anything else. If, you know, solving global warming, a global central planning exercise is climbing Mount Everest, fixing the problems you've just described is a walk in Shenandoah. You know, the Skyline Drive, much easier to do mechanically, yet we can't do that. It's very difficult as you know, you and your colleagues know better than me it involves hard choices, but it's much more doable than solving, achieving net zero.

That's one reason why I'm cautious when advising investors about how much real action to expect on the climate front.

Senator BRAUN. Dr. Rose.

Dr. ROSE. Well I'm going to show my age. I started working on environmental problems 50 years ago, and interviewing businesses about how they were going to cope with air pollution control. And many of them told me it was going to bankrupt them, and we found over the years that businesses rallied when they're faced with regulation and costs, they find ways to meet those challenges with innovation, and different ways of doing things.

And we've found those innovations paid dividends over and over again. So, the projected costs that I think you've cited are exaggerated. You've underestimated the benefits that most scientists believe we're going to receive by reducing climate change.

There are tipping points. The scientific community has universally agreed that 2 degrees Centigrade, increase in temperatures, average temperatures from the industrial revolution base is as far as we need to go, and many of them don't think we should go past 5 degrees.

Senator BRAUN. Do you think the modeling has been good to date?

Dr. ROSE. Yes. Yes. The climate modeling has been. So, there've been people who have been cited. Senator Johnson mentioned 189 people signed a document led by two physicists. Well physicists aren't climatologists, so I could cite 18,000 scientists that would say climate change is a serious problem.

Senator BRAUN. Thank you.

Chairman WHITEHOUSE. Senator Luján.

STATEMENT OF SENATOR LUJÁN

Senator LUJÁN. Well good morning, Mr. Chairman. Thank you for holding this hearing as well, and to our Ranking Member and to his staff, thank you all so much, and for being here everyone. I want to talk about New Mexico a bit, and through the lens of my home state.

And I'm going to do this by talking about specialty crops. Specialty crops matter to economies, to the fabric of community, to culture. And in New Mexico our chili products and chili peppers, which are the best in the world, the best in the country. And if Governor Polis is watching from Colorado, I just want to remind him that their chili seed came from New Mexico.

But that aside, the question that I have is looking at the value of impacts due to climate, but on specialty crops like chili in New Mexico. The value of these peppers go far beyond their economic value. As I just said from a cultural perspective, a traditional perspective, the tourism aspects associated, one of the key parts of our state that makes us so unique.

Now my question to you, Ms. Fulton, is yes or no, doesn't a full cost accounting of the damages that climate change is causing to supply chains go beyond numbers like GDP and export value?

Ms. FULTON. Yes, Senator.

Senator LUJÁN. With the chili crops in New Mexico being a uniquely New Mexican specialty crop that supports not only the agricultural sector, but so many aspects of the state's economy, tourism, restaurants and all the rest. How does the United States make our supply chains resilient when considering specialty products that cannot be replaced as a result of what we're seeing with these heat conditions, less water, the drying of rivers, reservoirs, whatever it may be?

Ms. FULTON. Yes, Senator, thank you for the question. It's one of those wicked problems, right? You can't take the traditional route of saying you need to diversify your crop when it's a specialty crop and there is no replacement for it. And the suggestion to find an alternative product, Colorado aside, is certainly not an option, right?

So in the scenario you present, really getting to any useful solution is going to require innovation, collaborative problem solving from the whole community. It's collective action. It's convening to talk about challenges from multiple perspectives. It can't just be farmers. It has to include supply chain professionals. It has to include others, climatologists. It has to include a whole community.

It has to bring everyone to the table again to talk about these types of wicked problems.

Senator LUJÁN: Now your testimony focused on how climate driven extreme weather events impact supply chains. Unfortunately, in northern New Mexico, where we are working to recover from what was a horrific record setting fire. A fire that spread faster than anyone could predict.

The Hermans Peak wildfire last year is the largest in our state's history, and devastated local economies and I don't know that people will ever be able to fully recover. With the support of my colleagues, we were able to secure a significant fund and disaster aid specific for these families because of how this fire got started.

We were able to earn that support. Now one of the concerns that I have is more than a year later communities are still working to receive the aid to rebuild and recover. I don't know that FEMA is expeditious in the work that needs to be done with getting this funding out into communities. The reason I say that is without timely distribution of recovery aid, people and businesses may have to make other choices, such as relocating, or not reopening for business.

When this happens there is no supply chain to rebuild. It's completely gone. So my question, Ms. Fulton, is yes or no, should the government disaster recovery programs recognize the fragility of local economies and supply chains, and how to implement their aid programs?

Ms. FULTON. Yes, Senator.

Senator LUJÁN. And how should the government change its disaster response programs to recognize the importance of rapidly rebuilding damaged supply chains?

Ms. FULTON. So the best way to support communities after disaster is by supporting the restoration of those local supply chains. Without your supply chain there is no economy. And so, I cited a National Academies' report that talks about ways government can assist, getting out of the way, number one, and then rapidly funding restoration activities.

Reducing impediments to businesses so that they can reopen, so that community members have places to go and gather and work and live together. I do believe that there has been positive progress in this regard. The National Academies' report that I cite is one document. There's a FEMA Supply Chain Resilience Guide, which is also another important document that's been published within the past 5 years.

But I also worry that as the post-pandemic surge in supply chains wane, we get kind of back to normal, and I don't know if we'll ever be at normal. We're going to forget how important those local community supply chains are. And so, I just want to emphasize those sustained investments—without them we're not going to be able to nourish and hydrate, provide medical care and shelter for the people in our communities.

So thinking about supply chain resilience locally and broadly.

Senator LUJÁN. I appreciate that. Mr. Chairman, I have some other questions. I'll submit them into the record, and I do want to highlight Ms. Fulton's testimony surrounding the devastation in communities, especially the work that she's done in the area of hurricanes.

Our west we see all the debate around the Colorado River right now with the lack of water flow. The Rio Grande, which flows in New Mexico is going dry in some areas as well. And I say that just to remind us of the comprehensive nature east to west from sea to shining sea across the country.

How different natural disasters are impacting all communities with the devastation that we're all witnessing. Thank you again for this hearing, Mr. Chairman.

Chairman WHITEHOUSE. Thank you, Senator Luján. Senator Kennedy you're up.

STATEMENT OF SENATOR KENNEDY

Senator KENNEDY. Thank you Mr. Chairman, and thanks to all the members of our panel for being here today. Dr. Kelly, you are head of environmental analytics, is that right? And what's the name of your company?

Dr. KELLY. Risilience.

Senator KENNEDY. Risilience. You're a Ph.D.?

Dr. KELLY. That's correct.

Senator KENNEDY. Where did you do your work?

Dr. KELLY. At the University of Cambridge.

Senator KENNEDY. Okay. If you were king for a day, Doctor, and you were not fettered or constrained by any political considerations, can you just list for me—I don't think we'll have time for you to explain each one at length, but list for me the five things you would do, King, to make America carbon neutral by 2050.

Dr. KELLY. Thank you, Senator, for that question. The first and most important thing is to decarbonize the energy sector, so remove fossil fuels from the economy as fast as possible, transition to renewable energy. Then require businesses to disclose their climate related risks, so that the community can understand investors and shareholders can understand what those are, and make better investment decisions.

I would then work with the international community to make sure that the grid around the world is decarbonized. I would also work on agriculture, and agriculture and other sectors to make sure that we can——

Senator KENNEDY. Well, that's not very specific. Let me try it again. Give me the five things. You're King now, but for one day. Five new rules in the United States of America, so we'll be carbon free by 2050.

Dr. KELLY. I would put in a rule to make——

Senator KENNEDY. I got you'd get rid of oil and gas. That's the first one. The most specific.

Dr. KELLY. Require companies to disclose climate related risks.

Senator KENNEDY. Okay. That's two.

Dr. KELLY. I would invest in new technologies to decarbonize industrial processes to reduce emissions.

Senator KENNEDY. Okay, and what's four?

Dr. KELLY. Work with the international communities to——

Senator KENNEDY. Work with the community, okay. Is there another one?

Dr. KELLY. And to work with political leaders across.

Senator KENNEDY. Work with political leaders, yeah. You sound like a consultant. All right. Let's take—get rid of oil and gas, and what would you replace it with?

Dr. KELLY. Renewable energy.

Senator KENNEDY. What kinds?

Dr. KELLY. Wind and solar. Presently the most cost-effective.

Senator KENNEDY. Nuclear?

Dr. KELLY. I'm personally not in favor of nuclear.

Senator KENNEDY. You don't like nuclear. Okay. How much will it cost to, and over what period of time do we have to get rid of all oil and gas and go to wind and solar?

Dr. KELLY. So the good thing about wind and solar is that it's now more cost-effective than producing——

Senator KENNEDY. Over what period of time would we have to make this transition?

Dr. KELLY. Well we need to do it before 2050 to get to the U.S.——

Senator KENNEDY. If we do it before 2050 we'll be—I'm trying to understand what it—should I give up? Dr. Rose, can you give me if you were King for a day the three things you would do?

Dr. ROSE. I will start on something that you might find more attractive.

Senator KENNEDY. I'm not interested in "attractive," but I've been to so many of these hearings where people come and talk about catastrophe, and so what do we do about it, and you get nothing but nonsense. So if you could give me, this is your chance. Just three specific things, King, that you would do.

Dr. ROSE. All right. So I would invest in carbon capture and storage.

Senator KENNEDY. Carbon capture.

Dr. ROSE. I don't think we need to get rid of all fossil fuels immediately.

Senator KENNEDY. That's one. Number two?

Dr. ROSE. Number two, I would pass a renewable portfolio standard for the U.S., which calls for a shift to renewables and electricity generation. So I recently completed a study where——

Senator KENNEDY. Okay. I don't have time.

Dr. ROSE. All right.

Senator KENNEDY. What's number three?

Dr. ROSE. I would pass a cap and trade bill in the U.S. to find the least cost ways of dealing with climate change.

Senator KENNEDY. Tell me how that would work.

Dr. ROSE. You essentially place a cap on emissions. You give permits or allowances to entities, and you allow them to trade. That trading shifts the cost burden to the lowest cost, and these we found that that can save 70 percent of the potential costs of dealing with climate change, as opposed to passing it across the board.

Senator KENNEDY. You'd put a tax on carbon?

Dr. ROSE. Well it's different than a tax because you can freely grant these allowances, and then it's trade in, so it's not a tax. It's different than a tax.

Senator KENNEDY. How much do you think all of this will cost, your best guess?

Dr. ROSE. I don't have a dollar figure, but the figure is a lot lower than what I've heard on this side of the aisle today.

Senator KENNEDY. Well you think we ought to just do it and then worry about the cost later?

Dr. ROSE. No. I think we should do the studies.

Senator KENNEDY. What's your—I mean you advised the United Nations (UN) and you're at USC and that's a pretty good school.

Dr. ROSE. Right.

Senator KENNEDY. What's your best guess about what it will cost us to decarbonize by 2050?

Dr. ROSE. Well one thing I'd like to mention the gentleman at Brown that it's not the government paying this cost.

Senator KENNEDY. Yes, but can you give me a figure first?

Dr. ROSE. I would say it might cost us 2 percent of GDP per year.

Senator KENNEDY. Quantify that.

Dr. ROSE. So that's in terms of the U.S. to start, and that's a couple hundred billion dollars.

Senator KENNEDY. A couple of hundred billion?

Dr. ROSE [continuing]. To start, and then it will level off, and then eventually I think——

Senator KENNEDY. Wait, wait, wait. I don't know why I can't get straight answers. Okay. You all want to talk about the problem, but you never want to answer the question.

Dr. ROSE. No. I've been answering.

Senator KENNEDY. Well no you haven't. I'm just asking for a figure. Does anybody have a figure that it would cost to decarbonize by 2050? That's all I'm asking. Does anybody have one?

Dr. ROSE. So my answer is you start out with $200 billion, and you get down to a cost savings by 2040.

Senator KENNEDY. What would be the total cost by 2050 you think?

Dr. ROSE. At most a couple of hundred billion dollars by 2050 over 25 years.

Senator KENNEDY. So you think we can do—we can totally decarbonize America by a couple of hundred billion?

Dr. ROSE. Well I didn't say totally decarbonize, because remember I said——

Senator KENNEDY. Carbon neutral, you're right, you're right, carbon neutral. Does anybody disagree with that?

Dr. KELLY. That is probably fair. If that's a yearly figure I'm assuming.

Dr. ROSE. No, no, that's total. That was total.

Senator KENNEDY. $200 billion for the whole pack.

Dr. ROSE. For the total with some——

Senator KENNEDY. What is your figure, Professor?

Dr. KELLY. I'm not prepared to give a figure.

Senator KENNEDY. You don't know. You just want us to do it and pay for it later.

Dr. KELLY. It's a——

Senator KENNEDY. Do you have a figure ma'am?

Ms. FULTON. No sir. This is really out of my area of expertise.

Senator KENNEDY. Do either of you gentleman?

Mr. MCNALLY. Senator, I don't have a figure, and I wouldn't want to do the task you assigned me. But if you did, and I had to do that, I would take the Green New Deal and implement it. I would put the U.S. economy on a——

Senator KENNEDY. How much would it cost?

Mr. MCNALLY. It will cost our country our liberties, our economy, we'll have to nationalize.

Senator KENNEDY. How much will it cost?

Mr. MCNALLY. Our country.

Senator KENNEDY. Okay? Do you have an idea?

Dr. BARKER. I have seen estimates that are a much higher percentage of GDP than Dr. Rose has indicated.

Senator KENNEDY. I mean it's frustrating folks. I don't mean to be rude, but I can't tell you how many of these hearings I've been through. And you say the world is coming to an end, okay. All right. How much will it cost? Uh, uh, we don't know.

Mr. KELLY. One point is Senator, that the cost of doing——

Senator KENNEDY. Or, we're not sure. We need to get back to you. No fair-minded policymaker is going to embark on something that might cost the minimum of $200 billion—based on what I've read that's low. I don't know you won't just answer straight.

Mr. KELLY. It's a difficult question to answer because——

Senator KENNEDY. Of course it's difficult. That's what you're here for.

Mr. KELLY. Technology advances at different rates.

Senator KENNEDY. If you want us to just go start, and then worry about the cost later? Come on Professor, this isn't Cambridge. These are taxpayers paying the costs.

Mr. KELLY. We need to make hard decisions now to try and——

Senator KENNEDY. Well how much will they cost?

Mr. KELLY. We need to——

Senator KENNEDY. You don't even know. I'm done.

Chairman WHITEHOUSE. Thank you, Senator Kennedy. Just for the record, I've got to get to Finance. I have to wrap this up. Just for the record there are some pretty solid numbers out there that come from corporate financial firms that look at this stuff professionally.

Wood McKenzie has predicted $2.4 trillion annually in global decarbonization, but that is not net of the foregone expenditure in fossil fuel, so the net number dips a good deal lower, and the consultancy has estimated that if we continue on our present path without taking proper action against climate change, the cost of doing nothing will reach $178 trillion between now and 2070, was their figure.

Whereas if we do decarbonize then we get economic growth of $43 trillion between now and 2070, so the economic difference from taking this seriously and proceeding with decarbonization is $220 trillion roughly between now and 2070.

So, we're dealing with some pretty real numbers here by people who are actually paid to do this work, and put their professional reputations on the line to do this work, and have real clients, who depend on them for this work. So, let me express my appreciation to the panel.

If there are questions for the record we'd like to have them in by tomorrow at noon, and then those questions for the record will be distributed to the witnesses, and we would ask the witnesses to endeavor to reply promptly to any such questions for the record, so we can close the record of this hearing.

Thank you all very much for being here, and that will bring the end of this hearing.

[Whereupon, at 11:43 a.m., Wednesday, October 25, 2023 the hearing was adjourned.]

Opening Statement of Chairman Sheldon Whitehouse
Senate Committee on the Budget
"Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains"
October 25, 2023

Chairman Whitehouse's remarks, as prepared for delivery:

Ranking Member Grassley and members of the Committee, in ten hearings so far this year, we've laid out serious risks climate change poses to the federal budget, to American families and businesses, and to the economy at large. Today's hearing will examine yet another threat posed by climate change: disruption of global supply chains, causing economic disruptions, product shortages, and higher prices for businesses and consumers—climate inflation.

Our global economy relies on a network of interdependent supply chains. Its end products may be a simple soybean, or may—like this cellphone—comprise thousands of parts sourced from around the globe. Think of the interconnected systems that enable the production and distribution of a cellphone: the raw mineral extraction, the manufacturing of thousands of individual components, the assembly of those components into a single device, and the distribution of those devices worldwide.

Supply chains support almost $20 trillion each year in global trade and are foundational to our everyday lives. Yet almost no one thought about them until the COVID-19 pandemic laid bare the fragilities in our system. Almost overnight, we saw how shocks can disrupt supply chains, triggering cascading effects both upstream and down.

Just as the pandemic wreaked havoc throughout our supply chains, climate change is poised to do the same—only much more frequently. In fact, it has already begun.

Already, we are seeing climate disruptions in the procurement of raw materials.

At our hearing on climate change and the agricultural sector, there was bipartisan agreement that extreme weather is damaging crop yields and increasing food prices. Last year, Hurricane Ian devastated Florida's orange trees, driving up the cost of orange juice. Climate-fueled droughts and heatwaves made growing chicken feed more expensive, which contributed to higher egg prices. Drought and wildfires in Spain have cut olive oil production in half and catapulted prices to record highs. Hotter and drier climates are stunting cacao harvests and making cocoa—an essential ingredient in chocolate—more expensive than it has been in decades.

The added costs of climate change now have a seat at kitchen tables around the world.

Climate upheaval is also affecting supply of the critical minerals used in electronics. Extreme weather events threaten mining infrastructure, and it's estimated that 30 to 50 percent of the world's copper, gold, iron ore, and zinc are produced in areas that are now facing water shortages. Raw material scarcity, decreases in material quality, and higher raw material prices—all translate into harder-to-source components and higher prices for consumers.

We're seeing similar climate-caused disruptions in manufacturing.

In China last August, a record-breaking drought reduced hydropower production so much that factories lost power, crippling production of automobiles and electronics. In Puerto Rico in 2017, Hurricane Maria damaged or destroyed dozens of medical device factories.

Outright destruction of manufacturing facilities is an immediate consequence of extreme weather, but heat stress or lack of water can also pause production. Most manufacturing facilities weren't built to endure the climate extremes and climate shifts we see today, and once-in-a-blue-moon disasters are now chronic.

Transportation is experiencing similar climate-triggered disruptions.

The Panama Canal is an essential link in our global supply chains. In 2022, more than 14,000 ships—$270 billion in cargo—passed through. But this year brought the worst drought in a century, and in August, water levels were too low for ships to pass. As a result, August wait times were four times what they were in June, with boats waiting as long as 21 days to pass. Things are still not back to normal. The drought persists, and daily transit limits are expected through the end of the year.

The Mississippi River, which transports 60 percent of U.S. grain exports, is experiencing similar problems.

For the last two years, extreme heat and drought have brought water levels dangerously low, limiting barge shipments and causing shipping costs to soar. Today, the cargo rate from St. Louis southward is almost 80 percent higher than the three-year average.
CDP, one of the premier organizations quantifying the effects of climate change, has analyzed data from over 8,000 suppliers. They estimate that environmental risks in supply chains will cost companies $120 billion by 2026—costs companies will pass on to consumers in higher prices.

As sea levels and temperatures rise and extreme weather becomes more frequent and more intense, the effects of climate change on supply chains will only get worse. Recently, the White House Council of Economic Advisors warned that climate change will make supply chain disruptions more common; that "as networks become more connected, and climate change worsens, the frequency and size of supply-chain-related disasters" will grow.

More bottlenecks and backlogs. More delivery delays and empty shelves. Higher prices. Climate-driven disruption causing climate-driven inflation.

Some of the economic threats we've warned of are crashes, that can hit suddenly and systemically—across the whole economy. Supply chain disruptions are more likely to cause local shocks, but nationally will erode buying power as prices rise. If you care about inflation, you'd better care about climate disruption.

UNITED STATES SENATE
BUDGET COMMITTEE
RANKING MEMBER CHUCK GRASSLEY

Opening Statement by Senator Chuck Grassley of Iowa
Ranking Member, Senate Committee on the Budget
Hearing on "Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains"
Wednesday, October 25, 2023

VIDEO

This morning the Budget Committee holds its 12th hearing in 10 months on climate change.

Over the course of these hearings, we've heard sensationalist and the alarmist rhetoric used to mislead the public on climate change and draw support for top-down policies.

We've heard broad, unsubstantiated assertions of impending disaster and destruction. Claims that aren't supported by a robust review of the science. Hearing after hearing, Democrats have chosen not to invite a single climate scientist as a witness.

I prefer to do just the opposite.

I want to learn from and legislate based on discussions with both my constituents and experts like climate scientist Patrick Brown.

He recently exposed how academia demands scientists omit key facts and tout certain climate narratives in order to be published in high profile journals. And of course, we all know, publication advances a person in academia.

These publications, skewed by predetermined conclusions, are then used by activists to push a far left agenda.

Dr. Brown hit the nail on the head stating that this dishonesty "distorts a great deal of climate science research, misinforms the public and, most importantly, makes practical solutions more difficult to achieve."

And remember, those practical approaches have created a situation where the United States is at the 2005 level of greenhouse gases going into the air. I believe [that's] better than any other county. Europe was ahead of us, I think Europe slipped a bit recently.

So, what Dr. Brown has said as examples of other people that approach it the same way, that's exactly what's happened here in the Senate.

Using non-scientists to spread alarm and tout distorted climate research -- that happens to be a disservice to our constituents.

This has pushed us further from finding practical solutions to adapt to climate change, and those are the solutions that I'm looking for.

Our country is in dire need of energy permitting reform to reduce emissions, save taxpayer dollars and secure our energy grid. Politics drives us away from reaching these solutions.

What's worse is that we're $33 trillion in debt. Take out the savings from the Supreme Court striking down the Biden student loan bailout, and the deficit last year was $2 trillion. That's a larger deficit as a share of our economy than all but five years since the end of World War II.

Americans can't afford groceries and gasoline. From Iowa to Rhode Island, inflation is reducing the purchasing power of all Americans.

Yet, this Committee didn't write a budget for this fiscal year and it's unlikely to do so for the coming year. Moreover, despite bipartisan interest, this Committee has been very slow in working to reform our broken budget process.

It's time that we start doing the people's work.

While unrelated to climate change, supply chains for many different goods face immediate threats: Putin waging war on Ukraine. President Xi threatening to invade Taiwan and using Uighurs for slave labor. Hamas recently killed over one thousand Israeli civilians and sparked war in the Middle East.

Beyond the horrific impacts on those in the midst of these events, they pose risks to global supply chains for necessities, including food and energy.

If we're going to discuss supply chains, this Committee should discuss our most pressing domestic and international concerns. That's why I'm proud to welcome Mr. McNally.

Mr. McNally has dedicated his career to analyzing the global energy supply chain and its relationship with both geopolitical and climate policy threats.

Prior to founding his own consulting firm, he worked on both the National Economic Council and the National Security Council -- serving as President George W. Bush's top domestic and international energy advisor in the White House.

I'm also pleased to welcome a fellow Iowan, a 6th generation Iowan, Dr. David Barker. Prior to serving on Iowa's Board of Regents and building his real estate business, Dr. Barker taught economics courses at both the University of Iowa and the University of Chicago. He also served as an economist at the Federal Reserve Bank of New York, which I consider a prestigious position to be working.

Democrats on this Committee have consistently expressed their belief that climate change will cause devastating shocks to the global economy. We're likely to hear more of the same today.

Dr. Barker, I'm looking forward to hearing your testimony on the relationship between temperature increases and GDP growth. Your economic analysis will allow us to put aside the politics of climate change and discuss what the data is telling us.

Thank you, Mr. Chairman.

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Written Testimony
US Senate Budget Committee

Dr Scott Kelly
Wednesday 25th October 2023

Good morning Senator Whitehouse – Ranking member Grassley and other Senators with us today.

It is an honour to be here today on behalf of Risilience, a company using sustainability intelligence to help business quantify nature and climate-related risks and opportunities for strategic advantage.

The US derives substantial economic value from global trade. In 2022, the US bureau of economic analysis estimated that exports contributed $3 trillion to US GDP, while imports on the other hand provide many of the raw materials, commodities and products that are required for economic production and a healthy and robust economy. The US economy is dependent on a complex global web of interconnected supply chains. While the network of global trade routes may appear robust from the outside, supply chains are vulnerable to the physical effects of climate change.

A meta-analysis of peer reviewed research found that supply chains relying on specialised products and key infrastructure are at acute risk of serious disruption from climate-related weather events. The direct impact of extreme weather events can cascade through supply chains affecting the flow of commodities and goods to regions and sectors, leading to increased costs to business and to the broader economy[1]. And as we saw during the COVID-19 pandemic, when supply chains are disrupted, there is a sharp increase in global commodity prices[2]. Research completed by the Federal Reserve Bank of St Louis concluded that the disruption to the supply of semi-conductors during this period, directly led to an increase in prices with significant macroeconomic implications[3].

[1] Ghadge, Abhijeet, Hendrik Wurtmann, and Stefan Seuring. 'Managing Climate Change Risks in Global Supply Chains: A Review and Research Agenda'. *International Journal of Production Research* 58, no. 1 (2 January 2020): 44–64. https://doi.org/10.1080/00207543.2019.1629670.
[2] Bernanke, Ben, and Olivier Blanchard. 'What Caused the U.S. Pandemic-Era Inflation?' *Monetary Policy*, 2023.
[3] Leibovici, Fernando, and Jason Dunn. 'Supply Chain Bottlenecks and Inflation: The Role of Semiconductors'. *Economic Synopses* 2021, no. 28 (2021). https://doi.org/10.20955/es.2021.28.

Evidence from past events shows that major damage to ports across the world from climate-related hazards is already occurring and such impacts are projected to increase in the future due to cascading climate risks[4]. Planning for such hazards is not systematically incorporated into adaptation planning, which leaves supply chains exposed and vulnerable to climate risks.

One example of a specialised product supply chain is that of the microchip industry. Taiwan is the world's largest producer of microchips, accounting for over 60% of the global supply of semi-conductors and about 90% of the world's most advanced microchips. As a small island nation in the middle of the South China sea, Taiwan is highly vulnerable to the impacts of climate change. The Island is located on the typhoon belt and is frequently hit by storms which cause widespread flooding and damage to factories. Research shows that the strength of typhoons has considerably increased over the last four decades, caused by an average increase of 0.55°C in Sea Surface Temperature[5]. There is a growing consensus among climate scientists that global warming may prime the atmosphere to produce fewer but stronger storms[6]. While fewer typhoons would be a welcome relief, stronger storms cause more damage[7]. Fewer storms also give rise to water scarcity due to more severe droughts which also has an impact on the fabrication of microchips.

The fabrication of microchips is an energy-intensive process. It is also highly water-dependent and requires large quantities of water for cleaning and etching silicon wafers. Both of these critical inputs are vulnerable to the effects of climate change. One manufacturing plant located in the Southern Taiwan Science Park, alone, consumes 138,000 m^3 of water per day[8]. This is equivalent to the daily usage of a city of nearly half a million people[9].

Microchips are a vital component in many durable goods, such as iPhones, vehicles and military hardware. According to the St Louis Fed's estimate,

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[4] Er Kara, Merve, Abhijeet Ghadge, and Umit Sezer Bititci. 'Modelling the Impact of Climate Change Risk on Supply Chain Performance'. *International Journal of Production Research* 59, no. 24 (17 December 2021): 7317–35. https://doi.org/10.1080/00207543.2020.1849844.

[5] Pandey, Ravi & Liou, Yuei-An. (2022). Typhoon strength rising in the past four decades. Weather and Climate Extremes. 36. 100446. 10.1016/j.wace.2022.100446.
[6] Voiland, Adam," In a Warming World, Storms May Be Fewer but Stronger ", https://earthobservatory.nasa.gov/features/ClimateStorms (accessed 27 Sep 2023);
[7] Miller, Brandon, Kann et al. "Hurricanes are becoming more dangerous. Here's why", https://edition.cnn.com/interactive/2020/12/us/hurricanes-climate-change/ (accessed 27 Sep 2023)
[8] TSMC 2022 Sustainability Report p. 109. https://esg.tsmc.com/download/file/2022_sustainabilityReport/english/e-all.pdf
[9] Assuming average individual consumption of 282 litres per day based on 2021 estimates (Water Resources Agency)

microchips are used as an input into one-quarter of all manufacturing sectors, which in turn account for 39% of all US manufacturing output[10]. Even though microchips typically account for only a small fraction of total input costs, scarcity of microchips can halt production. The long lead time and high investment costs required to develop new chip fabrication centres therefore raises concerns about vulnerabilities to the economy and to national security.

In a 2022 survey by the Commerce Department, it was found that the inventory of semiconductors in the US had fallen from 40 days in 2019 to less than 5 days in 2021[11]. This means that disruptions caused by climate impacts in Taiwan could have substantial knock-on effects in the US.

It's not just the lost productivity of US firms and the furlough of US workers, it's also the cascading impacts on US exports that depend on microchips within production processes. In sum, multiple sectors across the US economy could be severely disrupted with consequential economic impacts.

The manufacture and supply of microchips is just one example for how the growing physical risks from climate change will impact the trade of critical goods across and within US borders. US corporations are starting to realise the business imperative of mitigating and adapting to climate risks and accelerating their progress towards net-zero. The US Government can help support this process by incentivizing companies to build resilient supply-chains and promoting the disclosure of these material financial risks, as these can have wide-ranging impacts across the US and the global economy.

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[10] Leibovici, Fernando & Dunn Jason, "Supply Chain Bottlenecks and inflation: the role of semiconductors" St Louis Fed Economic Synopses No 28, 2021, https://research.stlouisfed.org/publications/economic-synopses/2021/12/16/supply-chain-bottlenecks-and-inflation-the-role-of-semiconductors (accessed 10 Oct 2023)
[11] U.S. Department of Commerce. 'Results from Semiconductor Supply Chain Request for Information', 25 January 2022. https://www.commerce.gov/news/blog/2022/01/results-semiconductor-supply-chain-request-information.

U.S. Senate Budget Committee Testimony—Adam Rose (University of Southern California) 10/25/23

Chairman Whitehouse, Ranking Member Grassley, members of the Committee, my name is Dr. Adam Rose and I'm a research professor at the University of Southern California. I am also a research team member on the Defense Advanced Research Projects Agency's Resilient Supply-and-Demand Networks program – an effort to improve the resilience of strategic supply chains.[1]

I'm honored to appear before the Committee to provide input into the discussion of Climate Change Impacts on Supply Chains. My testimony pertains to an on-going study, "Supply-Chain Impacts of Mississippi River Fertilizer Shipment Disruptions on Agricultural Production and the U.S. Economy," which I've co-authored with Professor Zhenhua Chen of The Ohio State University, Professor Fred Roberts of Rutgers University, and retired Coast Guard Captain, Andrew Tucci.[2] This research is being sponsored by the DHS Center for Accelerating Operational Efficiency (CAOE) at Arizona State University, and is being carried out at the DHS Center for Risk and Economic Analysis (CREATE) at the University of Southern California and the DHS Command, Control and Interoperability Center for Advanced Data Analysis (CCICADA) at Rutgers University.

Our research is focused on complex supply chain disruptions, where multiple events combine to have compound or cascading impacts across economic sectors or geographic areas. Currently, we are working on a case study that examines compound disruptions affecting barge traffic on the Mississippi, which is vital to agriculture and other industries. Any such impact would spread to the economies of Mississippi River states and the nation as a whole.

The first of the compound disruptions is drought, which is currently in its second consecutive year on the River, with water levels at historical lows. The most likely cause of this situation is climate change. The second disruption is a failure of Lock/Dam 27 near St. Louis. The Lock and Dam network on this river and others are part of America's aging infrastructure, and is especially vulnerable to climate change driven events such as heat, floods, and drought. Our third disruption pertains to an interruption of fertilizer imports through New Orleans, which could also be due to climate change, since this city is a typical bull's-eye for hurricanes.

We estimated the economic impacts using a state-of-the-art economic tool known as computable general equilibrium modeling, which characterizes the economy as a set of interrelated supply chains, or a "supply web." Here are our major findings about the impact of this combination of disruptions:

GDP impacts: A national loss of $18.1 billion, with the vast majority of the impacts incurred by the 5 upper Mississippi River states (Illinois, Iowa, Minnesota Missouri, and Wisconsin).

Employment impacts: A net loss of 51,000 job-years. This figure would be higher except that, in our scenario, there is need for more labor to have to load and unload more barges because each can only carry a lighter load at low water levels.

[1] https://www.darpa.mil/news-events/2023-10-18

[2] Chen, Z., A. Rose, F. Roberts, and A. Tucci. 2023. "Supply-Chain Impacts of Mississippi River Fertilizer Shipment Disruptions on Agricultural Production and the Regional and National Economies," Center for Risk and Economic Analysis (CREATE), University of Southern California, and Command, Control and Interoperability Center for Advanced Data Analysis (CCICADA), Rutgers University, forthcoming.

Price impacts: An increase in the Producer Price Index of 0.30% and in the Consumer Price Index of 0.25%. In an era of high inflation these seemingly small percentages are very meaningful.

We believe that this research is important because impacts on agriculture affect U.S. and world food security. While this consideration doesn't get as much attention in the U.S. as in developing countries, it is a problem for low-income families and many people of color in our country.

While we don't expect disruptions like this every year, they are likely to increase in frequency and magnitude as climate change accelerates. This will impact the production of critical goods and services, seaports, and other infrastructure, thereby disrupting supply chains in the U.S. and among our trading partners.

I also note that the climate change impacts I've reported today only pertain to fertilizer supply-chain impacts on the Mississippi River. This commodity represents only about 6% of all barge traffic on the River, so our estimates are only a small part of the total national economic impacts that climate change is likely to have on this transportation route and other inland waterways. In particular, the estimates do not account for the impacts to shipments of corn, wheat, and other grains on the River, which would increase the impacts just reported considerably.

Our research team is also examining compound disruption scenarios in the Port of New York/New Jersey and the Ports of Los Angeles/Long Beach stemming from additional stressors, including sea-level rise and wildfires. We expect the impacts from these compound disruptions to be in the tens of billions of dollars.

I've reported in depth on only one of a myriad of supply chain disruptions that will be caused by climate change. In fact, given the high degree of interdependence between sectors of the U.S. economy and our economy's connection with those of most every other country on the globe, it is only a very small proportion of the total negative impacts. Many people will be affected thorough loss of jobs and profits, but, most widely, every consumer in the U.S. will see their purchasing power diminished by the inflation caused by increased production costs, shortages, and delays of goods and services.

Written Testimony of Kathy Fulton
Executive Director, American Logistics Aid Network

For the United States Senate Committee on the Budget

Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains
October 25, 2023

Chairman Whitehouse, Ranking Member Grassley, and members of the committee:

Thank you for the invitation to testify before the Committee today. My name is Kathy Fulton and I serve as the Executive Director of the American Logistics Aid Network, a 501(c)(3) non-profit organization formed by senior logistics and supply chain professionals to unify our industry's disaster relief efforts. Created in response to the supply chain failures of Hurricane Katrina, our organization has had the privilege in the last eighteen years to support communities and individuals across the United States. Our mission to save lives and reduce suffering for disaster survivors via well-coordinated logistics solutions affords us the opportunity to work with businesses, non-profits, and emergency management agencies across the United States as they prepare for, respond to, recover from, and mitigate against disasters of all types. These increasingly include those resulting from climate related hazards[1].

As a native of Louisiana now living in Florida, I'm no stranger to disasters and the impacts and costs they have on our country's supply chains and the people serving in and served by those supply chains. My comments today are my own but would not be possible without input from the vast network of supply chain and logistics practitioners, universities, board members, staff, and volunteers that comprise American Logistics Aid Network.[2,3]

I will focus my comments on three items related to the Impact of Climate Disasters on Supply Chains:

1. Ways in which supply chains are disrupted by climate disasters.
2. Sources of costs realized across supply chains due to climate disasters.
3. Ways in which supply chain stakeholders are already addressing the risks of a changing climate, and opportunities to implement cross-sector solutions to better prepare for the challenges ahead.

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[1]NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2023). https://www.ncei.noaa.gov/access/billions/, DOI: 10.25921/stkw-7w73
[2] https://www.alanaid.org
[3] A special thank you to Phil Palin of https://supplychainresilience.org and Dr. Jarrod Goentzel and his team at MIT's Humanitarian Supply Chain Lab. I am humbled to work with you.

WAYS IN WHICH SUPPLY CHAINS ARE DISRUPTED

Supply chains have long seen disruptions from disasters but only recently has the public taken interest in these disruptions. Not long after the beginning of the COVID-19 pandemic, supply chains garnered public attention when everyday items became difficult to find or experienced extended restocking timelines. When supply chains are running smoothly, most people do not think about them. Thankfully for most of us in the United States, being able to find what we need on the shelves of a grocery store or food pantry is like being able to flip a switch and see the lights go on. This abundance of access can be attributed to the agility of today's modern supply chains. But just like with power generation that enables us to turn on that light, there is an intricate set of activities that lead to any one of us being able to obtain food, or fuel, or water, when and where we need it.

This set of activities, commonly referred to as "the supply chain" is both complex and adaptive[4], composed of numerous physical locations, transportation routes, information flows, and financial transactions.

Disasters cause disruptions to supply chains in three primary ways:

- By disrupting supply, that is, restricting the ability to provide a resource or service;
- By disrupting demand, that is, hampering the ability of an end consumer to access a resource or service in the manner or location they do pre-disaster;
- Or by disrupting the coordination mechanisms, like information flows and financial transactions, that connect sources of supply with sources of demand.[5]

Contemporary supply chains feature capacity concentrations which enable them to push high volumes of items at high velocity in response to demand pull signals from consumers. While we often think of bottlenecks in the negative connotation, these concentrations of capacity are "planned bottlenecks". Like the neck of a bottle that controls the speed and direction of the flow of liquid from the mouth of the bottle, these locations are where businesses consolidate their activities; and where related businesses often spring up around them. These capacity concentrations drive efficiency, cost-savings, and timely fulfillment of demand by enabling access to common resources like shared infrastructure and a skilled labor pool.

Many of you will recognize capacity concentrations within your own states: the Blue Economy in Rhode Island, farming in Iowa, warehouses and ports in Southern California, petroleum refineries along the Gulf Coast, or any number of locally and regionally important concentrations.

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[4] Pathak, Surya and Day, Jamison and Nair, Anand and Sawaya, William J. and Kristal, Murat, Complexity and Adaptivity in Supply Networks: Building Supply Network Theory Using a Complex Adaptive Systems Perspective (2007). Decision Sciences, Vol. 38, Iss. 4: 547-580, Available at SSRN: https://ssrn.com/abstract=1079068

[5] Ozlem Ergun, Wallace J. Hopp & Pinar Keskinocak (2023) A structured overview of insights and opportunities for enhancing supply chain resilience, IISE Transactions, 55:1, 57-74, DOI: 10.1080/24725854.2022.2080892

When these capacity concentrations are disrupted due to extreme weather events, bottlenecks become chokepoints, and the impacts can ripple far beyond the communities in which they exist. Baxter, a leading manufacturer of hospital products, operates three large facilities in Puerto Rico which manufacture sterile saline solutions for intravenous usage. After Hurricane Maria, all three facilities in this capacity concentration lost power and had to reduce production to levels that could be supported by generators. This resulted in delayed medical procedures in the United States and around the world.[6] That is a disruption in supply.

Supply chains are also disrupted by shifts in demand. An example of a shift in demand would be evacuations in advance of a hurricane, such as Hurricane Irma, where over six million people left their homes.[7] This mass migration undoubtedly saved lives, but also created demand for food, fuel, shelter, and medical care in new locations, sometimes many states away. Businesses, government organizations, and non-profits alike scrambled to meet the increased needs created by this population shift.

Finally, disruptions to coordination mechanisms can be as straight-forward as downed communication systems which prevent businesses from checking out customers in their stores or placing orders with their suppliers. But there are also more complex disruptions, like when the New York Stock Exchange closed for two days due to Superstorm Sandy in 2012. When businesses cannot exchange information or funds with their trading partners, the physical movement of goods stops as well.

COSTS TO SUPPLY CHAINS FROM CLIMATE DISASTERS

Any of these supply chain disruptions have a real cost to our economy, to communities, and to individuals and families. Businesses must spend money to protect against future disasters and address unbudgeted costs related to disruption; and many experience the financial effects for years after. Governments take on the cost to rebuild infrastructure; individuals and families take on the costs of rebuilding their lives.

I will only address costs to commercial supply chains, where financial losses and added spending come from a variety of causes, such as:

- Lost or damaged inventories, exemplified by the July 2023 tornado that destroyed the warehouse of a Pfizer pharmaceutical plant in North Carolina;
- Lost sales due to facility closures, such as the many small businesses in Sanibel and Fort Myers experienced after Hurricane Ian in 2022;
- Extra spending on labor and transportation to move supplies to meet increased demands, such as in response to evacuation notices or pre-storm surge spending by

[6] National Academies of Sciences, Engineering, and Medicine. 2020. Strengthening Post-Hurricane Supply Chain Resilience: Observations from Hurricanes Harvey, Irma, and Maria. Washington, DC: The National Academies Press. https://doi.org/10.17226/25490.
[7] https://www.weather.gov/mfl/hurricaneirma

consumers. Extra costs also occur when established transportation routes experience delays; like what we are currently seeing with drought causing reduced number of ships allowed through the Panama Canal, and lower barge capacity to move grain and other goods down the Mississippi River. These costs come in the form of both lost revenues due to reduced equipment availability and fees and penalties from supply chain trading partners.

- Added costs to provide temporary equipment or structures after an event. A major medical care organization lost their facility in Lahaina during the August 2023 wildfires. To continue providing for the medical needs of the community they moved a mobile clinic from California via ocean transport.
- Added costs to repair or rebuild facilities, like businesses in Cathedral City, CA are doing after post-tropical cyclone Hilary swept through in August of this year.
- Increasing costs of insurance to help defray some of these losses; and finally,
- Extra costs to support employees. Every business will tell you that their number one priority following a disruptive event is to support their employees and communities. Indeed, supply chains do not function without people to operate the equipment, drive the trucks, or stock the shelves; nor without consumers who can access the products safely. Businesses take on the added costs of bringing in staff from other parts of the organization so that employees who have been affected can focus on their personal lives. Following Hurricane Ida (2021) in Louisiana, a major grocery retailer brought in employees from multiple states so that they could re-open to serve their communities. Businesses often also provide affected employees with additional benefits like temporary housing, financial support, and more so those employees can begin to recover their lives and livelihoods.

These examples address the direct costs created by disaster, but there are additional indirect costs that are amplified during disasters due to human reactions to uncertainty.[8] While these are difficult to measure, the symptoms are evident; think of empty store shelves prior to hurricanes or winter storms.

Each of these direct and indirect impacts to a business also means an impact to an individual who works in or is served by that business. And for those individuals and families who are already vulnerable, the effects are amplified. Supply chain failures – when supply and demand are mis-matched, can be life-threatening, such as the previous example of saline bag manufacturing disrupted by Hurricane Maria.

<u>BUSINESS ADAPTATIONS IN RESPONSE TO CLIMATE RISK</u>

Increasingly, businesses are seeking to adapt their supply chains to reduce their exposure to the risks of climate change. They are taking broad, long-term actions, like diversifying their supplier base, or switching to cleaner sources of energy. Supply chain decision makers are taking climate

[8] Sterman, John D. Business Dynamics: Systems Thinking and modeling for a Complex World. Irwin/McGraw-Hill, 2009.

change into consideration when deciding where to place new factories, offices, and warehouses[9], as well as in planning inventory management strategies.[10]

Companies are also addressing current and immediate risks, like adding backup power generation, flood protection, or other mitigation measures. This includes grocery retailers who have invested in back up power generation in response to public safety power shutoffs driven by drought and fire risk in California or regular threats from hurricanes in the Southeast. Adaptations are also being made to protect workforce, as in the example of UPS agreeing to provide air conditioning for delivery drivers working in extreme heat[11]. Businesses take these protective, adaptive measures so they can continue to serve their customers and remain profitable while doing so.

However, the number of businesses thinking broadly about adaptations is still small, with a recent survey by PricewaterhouseCoopers[12] finding that less than one-fifth of firms "have implemented initiatives to protect their workforce or physical assets from the impacts of climate risk." In many ways this limited response makes sense. Today's supply chain designs have emerged from large capital expenditures over the last fifty to sixty years, while the risks of climate change have only risen to the board room level discussions in the past two decades. Investments have led to supply chains having a certain amount of native resilience; but that resilience fails when a capacity concentration is hit hard.

Supply chains need to continue to function while adjusting to new risks. There is no rip-and-replace solution to reduce or completely remove risk, nor can an individual business bear the adaptation burden alone.

A 2020 National Academies of Science, Engineering, and Medicine consensus study of Hurricanes Harvey, Irma, and Maria[13] identified four recommendations for strengthening supply chains in a post-catastrophic context. These included (1) "Build system-level understanding of supply chain dynamics as a foundation for effective decision support" and (2) "Support mechanisms for coordination, information sharing, and preparedness among supply chain stakeholders".[14]

Whether physical or operational, adapting effectively will require a system-level understanding of supply chain dynamics. We see this in the move for organizations to study and map their suppliers, and their suppliers' suppliers, as far up the supply chain as possible. Where they

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[9] https://blog.naiop.org/2022/10/how-supply-chain-and-logistics-drive-site-selection/
[10] https://www.bloomberg.com/graphics/2023-opinion-apple-supply-chain-climate-change/
[11] https://about.ups.com/us/en/newsroom/press-releases/people-led/ups-statement-agreement-with-teamsters-on-heat-safety.html
[12] https://www.pwc.com/gx/en/issues/esg/how-climate-adaptation-can-both-protect-and-grow-your-business.html
[13] https://www.nationalacademies.org/our-work/building-adaptable-and-resilient-supply-chains-after-hurricanes-harvey-irma-and-maria
[14] The other two recommendations were directed towards the actions and education of emergency management agencies.

identify threats from climate change or other sources, they work to de-risk by identifying alternate suppliers. These efforts to identify and qualify new sources of supply take time and investment.

This is where the second recommendation comes in: coordination, information sharing, and preparedness among supply chain stakeholders have been shown to improve post-disaster community outcomes.[15] Complex systems are better understood when gaining the perspective of multiple observers and actors; and adaptation is more effective when measures are aligned across and between supply chains. Achieving supply chains capable of meeting consumer demand despite climate obstacles will require partnerships and trust building beyond just data sharing.

Anticipating and adapting to the challenges of climate change requires a collaborative, cross-sector, "whole-of-nation" effort, one in which our country has not yet meaningfully engaged. Understanding how best to direct those collective actions calls for dedicating time, research, and investment. We need sustained private-private and private-public conversation, education, practical mitigation and preparation focused on supply chain resilience. The National Academies study provides a thoughtful roadmap for advancing such conversation and collaboration.

Businesses are willing to lead and drive change when the risks or benefits are clear, quantified and supported by evidence. The hearings hosted by this Committee could form the foundation for a holistic study on the cost implications of climate disasters on supply chains. But without a clear understanding of the potential costs of failing to adapt, or the potential benefits such adaptations can bring, it may be "business as usual" for supply chains until the consequences of extreme events force action.

I hope my comments today have been helpful. I look forward to your questions.

[15] https://www.vestedway.com/

Testimony by David Barker at the Senate Committee on the Budget hearing on Wednesday, October 25, 2023, entitled "Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains."

Introduction

Thirty-eight trillion dollars is a lot of money. That is the amount the IPCC predicts that climate change will cost the world economy by the year 2100 if nothing is done to reduce greenhouse gas emissions.[1] A careful reader of the IPCC report will notice that this would be a loss of 2.6% of world GDP in 2100.[2] Assuming real growth of 2.1% between now and then, GDP in 2100 will be 5 times higher than it is now.[3] A 2.6% reduction of 2100 GDP would mean that instead of being 5 times higher, GDP per capita would be 4.9 times higher, which is not a catastrophic outcome.[4]

It is reasonable to wonder if this argument is flawed because climate change might affect the rate of growth of GDP through supply chain disruptions or other effects. If, for example, GDP grew at a rate of 1.5% instead of 2.1%, the compounded effect of lower growth would be very large by the year 2100. Robust supply chains are critical to economic growth, and disruption of supply chains might be one way that higher temperatures could affect growth. It is a reasonable hypothesis to test.

The Academic Literature on Climate Change and Economic Growth

Three eminent economists from Harvard, MIT and Northwestern, Melissa Dell, Benjamin Olken and Benjamin Jones, published a paper in 2012 (DJO) claiming to show that higher temperatures reduce the rate of growth of per capita GDP in poor countries.[5] Their work was the basis of many subsequent papers on the economics of climate change. Last month I published a paper in a peer reviewed economics journal, Econ Journal Watch, in which I argued that these results are flawed.[6]

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[1] IPCC. 2018. Global Warming of 1.5°C. Cambridge, UK: Cambridge University Press. p. 256.
[2] Ibid.
[3] See Maddison Project. 2000. Maddison Project Database 2020. Groningen Growth and Development Centre, University of Groningen (Groningen, Netherlands) for data showing the average world growth rate of per capita GDP. An estimate of world economic growth of 2.1% through 2100 can also be found in Christensen P, Gillingham K and Nordhaus W 2018 Uncertainty in forecasts of long-run economic growth Proc. Natl Acad. Sci. 115 5409–14.
[4] These estimates are consistent with the DICE model created by William Nordhaus. See Nordhaus, William. 2018. Projections and Uncertainties About Climate Change in an Era of Minimal Climate Policies. American Economic Journal: Economic Policy 10(3): 333–360 and W. Nordhaus, Revisiting the social cost of carbon, PNAS, 114 (2017), 1518-1523.
[5] Dell, Melissa, Benjamin F. Jones, and Benjamin A. Olken (DJO). 2012. Temperature Shocks and Economic Growth: Evidence from the Last Half Century. American Economic Journal: Macroeconomics 4(3): 66–95.
[6] Barker, David. 2023. Temperature Shocks and Economic Growth: Comment on Dell, Jones, and Olken. Econ Journal Watch 20(2):234–53

The flaws are related to what is often called a crisis of replicability in some areas of scientific research, and more specifically, what is known as p-hacking.[7] The letter P refers to probability. In statistical analysis, a p-value tells us the probability that a result obtained with statistical analysis could have been found because of random chance instead of an actual effect. A common standard is 5%. In other words, if there is less than a one in twenty chance that a result comes from random chance, then the result is taken seriously. But if a researcher runs a model 20 times using different specifications, the odds are that at least one of these specifications will show statistical significance, even if there is no true result. Publishing this result without disclosing that other specifications were tried can be very misleading.

The problem of p-hacking is compounded by publication bias, which means that academic journals are more likely to accept papers that show an effect of something, rather than those that fail to show an effect. As a result, researchers who depend on publications for tenure and post-tenure review are incentivized to produce what appear to be statistically significant results.

Whether it is intentional or not, p-hacking can be overcome through robustness checks, meaning that different specifications and data can be checked to see if they produce similar results. I performed a number of robustness checks on papers claiming to show effects of temperature on economic growth.

In DJO, countries were categorized as rich or poor based on the first year of the sample, which went from 1960 to 2003. In other words, if a country was below the median of all countries in 1960, it was categorized as poor for the entire sample. I discovered that if South Korea, which was very poor in 1960 and very rich in 2003, is classified as poor when it was poor and rich when it was rich, the results nearly disappeared. When I reclassified all countries this way, the results disappeared completely.

There were other arbitrary aspects of their model specification that, when changed, reduced the statistical significance of their results. I also found that, using an alternative data source, there was no effect of temperature on growth. Looking at monthly instead of annual temperatures I also found no evidence supporting their hypothesis.

In DJO and other papers purporting to show a relationship between temperature and growth, all countries are weighted equally. This means that St. Vincent and the Grenadines, one eighth the size of Rhode Island, has the same weight as China. As a result, small countries with unusual circumstances affect the results. For example, 1994 in Rwanda was a year of genocide and economic collapse. It was also a bit warmer than usual, leading the statistical model to conclude that temperature affects GDP. Looking at monthly data, the warmest months of that year in Rwanda occurred after the genocide, and so could not have caused it.

With this method of equal weighting, large countries with varied climates are assigned a single average temperature each year, which can also be misleading.

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[7] For an explanation of p-hacking, see Friese M, Frankenbach J. p-Hacking and publication bias interact to distort meta-analytic effect size estimates. Psychol Methods. 2020 Aug;25(4):456-471.

DJO claimed that temperature might affect economic growth by causing political unrest. Correcting their untenable classification method and removing a few unusual observations was enough to eliminate this result.

Another paper that was first published by the Federal Reserve Bank of Richmond and later in an academic journal, claimed that higher temperatures in the United States have lowered growth of state GDP.[8] Their result came from using an extreme estimate of warming multiplied by a statistically insignificant coefficient that changes sign when estimated with a different source of data. The results are sensitive to removal of a small number of observations and an attempt to deal with non-linear effects shows that if anything, warmer temperatures increase economic growth.[9]

It is interesting to note that the Federal Reserve has devoted considerable attention to climate change. A query of the Fed's listing of recent publications related to climate change returns hundreds of research papers, press releases and policy statements.[10] In May of 2023 twenty-seven Fed economists participated in a conference on climate change hosted by the San Francisco Fed.[11]

Another paper published in 2021 by the Board of Governors of the Federal Reserve System also claimed to find a relationship between temperature and world economic growth.[12] It used complicated statistical techniques, but I showed that its results were not statistically significant, and using simulated data I showed that the paper's model could be easily tricked into showing an effect when no effect existed.[13]

Discussion

Even if these results are valid, none of the papers I examined deny that adaptation could mitigate the effects they claim to find. Robust supply chains exist in a variety of climates around the world, and significant adaptation will certainly occur over the next 80 years The papers find no effect of changes in precipitation on GDP, and the DJO data show no statistically significant increase in the volatility of temperature or rainfall, casting further doubt on the likelihood of significant supply chain disruptions.[14]

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[8] Colacito, Riccardo, Bridget Hoffmann, and Toan Phan (CHP). 2019. Temperature and Growth: A Panel Analysis of the United States. Journal of Money, Credit and Banking 51(2–3): 313–368.

[9] Barker, David. 2022. Temperature and U.S. Economic Growth: Comment on Colacito, Hoffmann, and Phan. Econ Journal Watch 19(2): 176–189.

[10] https://www.fedsearch.org/board_public/search?text=%22Climate%20change%22%20OR%20%22%20global%20warming%22%20OR%20%22CO2%22

[11] https://www.frbsf.org/wp-content/uploads/sites/4/SystemClimate_Final-Agenda.pdf

[12] Kiley, Michael. 2021. Growth at Risk from Climate Change. Finance and Economics Discussion Series 2021-054. Board of Governors of the Federal Reserve System (Washington, D.C.).

[13] Barker, David. 2023. Temperature and Economic Growth: Comment on Kiley. Econ Journal Watch 20(1): 69–84.

[14] The DJO data do not rule out an increase in temperature or precipitation volatility that is more localized than at a national level.

I have examined other papers that are prominently cited, including by the IPCC, and found similar problems, as well as new problems. Estimates of non-linear effects of temperature on growth, for example, are particularly susceptible to being led astray by unusual observations.

The papers failed many other robustness checks that I performed. Research this flimsy should not have passed the peer review process and should not have been published. In my opinion, political and ideological pressure to confirm the importance of climate change has caused the peer review process to break down, allowing questionable results to be published in elite academic journals.

The papers I critiqued were given glowing coverage in the media, and some of them are in the top 1% of the academic economics literature, measured by citation counts. They were published in top journals and the authors are some of the most celebrated economists in the world. Those journals have not acknowledged problems in the articles they have published, and the popular media have no interest in correcting stories they wrote when the research came out. Econ Journal Watch gave all authors of the papers I critiqued the opportunity to respond in print, but none have so far accepted the invitation. I appreciate this opportunity to point out the weaknesses in current research on the economic effects of climate change.

The economists who wrote these papers had a good idea, which was to test whether episodes of high temperatures in the past caused lower GDP growth. The mechanisms that are hypothesized, such as higher temperatures reducing the productivity of outdoor workers or interfering with supply chains as trucks overheat and other equipment is stressed, or higher temperatures leading to more extreme wind or fire, are reasonable things to test. But the evidence from the record of temperature variation and economic growth does not support the hypothesis that climate change will negatively affect economic growth. In fact, some studies show net positive effects of warming for the United States, and by extension for the federal budget, although this conclusion is subject to the same criticisms I have outlined.

A recent paper in Ecological Economics opens by saying: “A large discrepancy exists between the dire impacts that most natural scientists project we could face from climate change and the modest estimates of damages calculated by mainstream economists.”[15] Some alarmists have departed from conventional economic views to make extreme predictions. For example, the World Economic Forum claims that without stronger action to reduce greenhouse gas emissions, there will be “runaway climate change that makes the world all but uninhabitable.”[16] Some are critical of the work of economists on climate change, believing that tipping points may lurk in the future that are not clear from analysis of past data.

My research does not address possible tipping points that might mean greater effects of climate change on GDP, but other economists have examined this possibility. William Nordhaus, for example, has studied the potential for a melting of the Greenland ice sheet, and has found that it

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[15] Rising, James A, Charlotte Taylor, Matthew C. Ives, Robert E.T. Ward. 2022. Challenges and innovations in the economic evaluation of the risks of climate change. Ecological Economics 197: 1-13.
[16] World Economic Forum. 2022. The Global Risks Report 2022 17th Edition. Geneva:World Economic Forum. p. 31.

would have only a minor impact on his estimate of the social cost of carbon.[17] Many mainstream credentialed economists share the view that the effects of climate change on GDP are likely to be far more modest than extreme predictions that receive more media attention. Some have even proposed that the costs of reaching the Paris targets would be greater than the benefits.[18]

Conclusion

The records of temperature and economic growth that I have examined do not support the hypothesis that supply chain disruptions caused by climate change are likely to cause reductions in per capita GDP growth. Because federal revenue is closely tied to GDP, it follows that my results cast doubt on the idea that climate change will have an impact on the United States Budget by reducing federal tax revenue.

Links to my papers:

https://econjwatch.org/articles/temperature-shocks-and-economic-growth-comment-on-dell-jones-and-olken

https://econjwatch.org/articles/temperature-and-economic-growth-comment-on-kiley

https://econjwatch.org/articles/temperature-and-us-economic-growth-comment-on-colacito-hoffmann-and-phan

[17] Nordhaus, W. Economics of the disintegration of the Greenland ice sheet. Proc. Natl. Acad. Sci. USA 2019, 116, 12261–12269.
[18] Tol, Richard (2023). Costs and benefits of the Paris climate targets. Forthcoming, Climate Change Economics.

Prepared Testimony of Robert McNally, President, Rapidan Energy Group

Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains
United States Senate Committee on the Budget
October 25, 2023
Washington, DC

Chair Whitehouse, Ranking Member Grassley, distinguished Members of the Senate Budget Committee, my name is Robert (Bob) McNally. I am the founder and president of Rapidan Energy Group, an independent Washington, DC-based energy advisory firm. I am honored that you have invited me to contribute to your important hearing today. This testimony reflects my views and not those of Rapidan Energy Group.

I have worked for 32 years at the intersection of energy markets, policy, and international politics. Except for service in the Peace Corps and as President George W. Bush's energy advisor from 2001–2003, I have spent my career providing clients with analysis and forecasts of market, policy, and geopolitical trends and events in the energy sector, specializing in the global oil market. Neither Rapidan nor I represent or lobby for any person, group, or company.

I am delighted the Senate is turning its attention to supply chain and bottleneck challenges and honored to contribute to your deliberations by suggesting some cautionary notes and lessons from recent oil and gas market supply disruptions and risks.

Oil is the lifeblood of modern civilization. Its widespread commercial use starting after 1859 lifted humanity from millennia of squalor, darkness, and immobility. Over the past four years, critical oil and gas supply chains have endured major, if fortunately short-lived, geopolitical disruptions. They are:

2019 Iranian attack on the world's most critical oil facility. On September 14, 2019, Iranian drones and missiles struck two Saudi Arabian oil facilities. One, the Abqaiq crude processing plant, is the world's most vital energy facility, accounting for about 6% of global oil supply. Unlike a port or pipeline, Abqaiq cannot be easily replaced or circumvented. The Iranian attack was the most extensive *volume* disruption from a single historical event. When oil markets opened in Asia on the Sunday evening following the attack, oil prices jumped by 15% in one day, the biggest percentage since oil futures began trading in 1988.

Nearly all Saudi crude must be processed at Abqaiq to prepare for export and refining into petroleum products. Since oil demand is highly insensitive or inelastic to price changes, the sudden and prolonged loss of nearly 6% of supply would have caused a massive oil price spike (I would estimate by around 33%) to reduce consumption by a similar percentage, likely inducing a recession.

Had Iran destroyed those facilities, it would have caused a severe and lasting oil price spike, likely throwing the US and world economies into a tailspin and triggering a wider regional war. Since oil is fungible, widely traded, and globally priced – a supply chain disruption anywhere causes a price spike everywhere, including right here at home. Being a net energy exporter provides some macroeconomic and national security resilience to international supply disruptions but not to price spikes, which act like a sudden tax on consumers and businesses, driving up the cost of personal transportation and goods and services.

Fortunately, Iran chose to inflict light and reversible damage, and Saudi Aramco was able to restore production quickly. The world dodged a bullet.

The 2021 Colonial Pipeline cyber attack was the most significant energy attack on the homeland in history. On May 7, 2021, Russian-based ransomware hackers forced a shutdown of the Colonial Pipeline. This major artery transports gasoline, diesel, and jet fuel from refineries in Texas to the East Coast, as far north as New York. This attack differed critically from the thousands of prior cyberattacks on US persons, businesses, and government agencies in that, for the first time, foreign attackers directly disrupted physical energy flows vital for the social order and national security of the United States. The pipeline supplies 45-50% of East Coast liquid fuel supplies, 90 military bases and installations, and seven major airports. Fortunately, Colonial restarted the pipeline after six days, albeit after paying the attackers a ransom.

The 2022 Russian invasion of Ukraine caused gasoline prices to spike to record levels. Russia's invasion of Ukraine on February 24, 2022, triggered sanctions that the International Energy Agency (IEA) advised could disrupt three mb/d of Russian oil exports through the rest of that year – some 810 mb in total. In response, oil prices spiked by 32% in 13 days, from $97 to $128 per barrel. On March 1, 2022, the IEA announced a 60 million barrel (mb) collective stock release, and on April 7, it increased the release by 120 mb. Combined with earlier United States Strategic Petroleum Reserve drawdowns unrelated to the Ukraine emergency, the IEA estimated some 240 mb would be released over six months.

But these strategic stock releases only offset about 30% of the feared loss of Russian supply. So, oil prices soon spiked again, reaching $121 per barrel in early June. Since global crude oil prices are the most important determinant of domestic US gasoline prices, consumers saw retail pump prices soar to a record $5 per gallon last summer. Tight post-pandemic refining capacity also contributed to this gasoline price spike. Oil prices retreated only after the feared Russian supply loss failed to materialize, partly due to G7 Price Cap mechanics intended to enable Russian oil exports to continue while crimping Russia's revenues.

Despite no material loss in Russian crude exports as initially feared, the US continued drawing down the SPR by the total 120 mb originally announced as part of its response to Russia's invasion of Ukraine. Considering also the non-emergency SPR release in November 2021 and congressionally mandated sales, the volume of crude in the SPR has fallen by nearly half, or 287 mb, since President Biden took office. The SPR now holds 351 mb – its lowest level in 40 years.

Fortunately, there is a bipartisan sense that the SPR releases have gone too far, and we should restore our protection against severe supply interruptions. The Biden administration worked with Congress to cancel prospective, congressionally-mandated SPR sales and has sought to begin refilling the SPR should crude oil prices fall below $80 per barrel. As noted below, Congress should bolster these small steps by appropriating funds to replenish the SPR.

2023 Hamas attack on Israel and the associated risk of expanded regional conflict and energy disruption. Hamas's war against Israel raises the risk of a regional conflict that could disrupt large amounts of oil and LNG exports. The Biden administration has said Tehran is complicit in the savage attacks on October 7, 2023, and believes Iran-backed proxies intend to escalate attacks against US personnel and vessels if the conflict continues. While the conflict in Gaza does not threaten oil supply, there is a substantial risk that fighting will spread to include Iran's proxy, Lebanese Hezbollah, and other regional actors, including Yemen-based Houthi fighters, if not Iran itself. A Middle East regional conflict would put at risk 40 percent of global crude exports and 18 percent of refined product exports passing through the Strait of Hormuz to world markets.

Even the *perceived* risk of losing Gulf energy exports would cause oil prices to rise sharply, reflecting a risk premium. Soaring crude oil prices are always unwelcome for consumers and many businesses. Moreover, with the Federal Reserve attempting to engineer a soft economic landing amid the highest inflation rates in 40 years, our present circumstances make high energy prices even more problematic.

Turning to gas market impacts, with the temporary shutdown at Israel's Tamar gas field and the East Mediterranean Gas (EMG) Pipeline, the Israel-Hamas conflict is already affecting Israel's domestic gas market and exports to Egypt. A multi-month shutdown of these facilities would delay the restart of Egypt's LNG exports (offline since June), marginally tighten global LNG balances this winter, and put some upward pressure on global natural gas prices.

The risk of further supply disruptions would increase if the conflict expanded in the region. Lebanese Hezbollah, unlike Hamas, can target offshore infrastructure and has done so in the past. If the war spreads to the Gulf, it could restrict shipping through the Strait of Hormuz—a choke point for more than 20% of global LNG supply. Ras Laffan, the world's largest LNG liquefaction facility, is located in the Arabian Gulf, and its exports to Asia and Europe must transit the Strait of Hormuz.

Policy considerations

Luckily, the massively disruptive Abqaiq and Colonial Pipeline attacks ended quickly. And so far, neither Russia's invasion of Ukraine nor Hamas's attack on Israel has caused an energy supply interruption for the United States. But we should not bank on such luck in the future. These supply disruptions underscore the ongoing vulnerability of energy production and distribution systems essential for our security and living standards. They suggest the following policy considerations regarding both hydrocarbon and decarbonized energy supply chains and bottlenecks:

First, attend carefully to cyber threats to critical energy infrastructure, including petroleum production, transportation systems, and electric grids. Congress must ensure the US has appropriate laws and procedures to effectively deter adversaries from attacking our critical infrastructure and responding to such attacks.

Industry and government's responses to the Colonial pipeline attack fell far short. For example, the federal government was neither informed nor consulted about Colonial Pipeline's decision to pay the ransom, despite FBI recommendations, nor was it consulted beforehand about Colonial Pipeline's decision to protect the pipeline systems by shutting it down temporarily. For further detail on this topic, including specific recommendations, please see this working paper by the Forum for American Leadership, a non-profit foreign policy and national security advisory group whose Energy Security working group I chair, entitled *Eight Necessary Steps to Defend US Critical Energy Infrastructure from Cyber Attacks*.

Second, consider the current and new geographic concentrations of energy supplies, production, and trade. The geographic concentration of oil and gas production in the Middle East and major transit choke points from that region to global markets (the Strait of Hormuz, Bab-el-Mandeb, and the Suez Canal) have challenged US foreign policy since the Arab Oil Embargo fifty years ago this month. The sabotage of the North Stream natural gas pipelines last September and the potential act of sabotage this month on a 95-mile-long natural gas pipeline connecting Finland and Estonia show that the Baltic has recently become another supply chain risk for our European allies.

As we seek to develop and scale up new energy sources, consider potential vulnerabilities arising from geographic concentration and dominance by hostile nations. China's dominance of renewable power and electric vehicle supply lines is a familiar challenge. On this topic, I recommend the FAL working paper, *Arsenal of Energy: How to Bolster U.S. Energy Security and Aid our Allies Confronting Authoritarian Aggression*, which includes specific suggestions to address supply chain risks arising from decarbonization.

Third, build and bolster defenses against severe energy supply interruptions and resist frittering them away. Recent energy supply chain crises underscore the folly of draining our SPR to pay for non-energy expenses or in a vain attempt to control gasoline prices. Draining the SPR for non-emergency purposes is a dangerous policy error. I recommend that Congress rectify it soon by appropriating funds to replenish it.

Regarding rare earth elements, Congress should consider establishing a strategic rare earths reserve and restricting the use of rare earth elements from China in advanced defense technology in the United States.

Finally, the US should avoid policies that would exacerbate an already tight and volatile energy market. Policies that cause abrupt increases in energy costs or loss of supply will harm consumers, the economy, and social peace.

My firm, Rapidan Energy Group, carefully monitors global energy and climate policies. We find that policies that increase energy costs often spark unrest. Most often, governments respond to this unrest by reversing the policy. Examples include France's brief attempt to impose a carbon tax on diesel fuel that triggered the "Yellow Vest" social protest and, more recently, Germany's dilution and delay to a planned ban on natural gas-fired home heaters.

Moreover, last year's energy price spikes due to Russia's invasion of Ukraine were a stress test for many governments' willingness to impose or maintain energy taxes and supply restrictions. We found most governments, including in Europe and the US, responded to this stress test by increasing fuel subsidies, lowering fuel taxes, or attempting price controls to insulate consumers from these energy costs. The Biden administration, which took office determined to implement sweeping restrictions on domestic oil and gas production, temporarily responded to last year's oil price spikes by asking shale companies and OPEC+ producers to increase output while greenlighting a new Willow upstream oil project in Alaska. But with the crisis having passed, the administration has unfortunately reverted to sweeping anti-oil and gas supply policies, such as removing nearly all the National Petroleum Reserve in Alaska from leasing. [1]

I recommend avoiding policies that impose burdensome costs without clear and publicly acceptable benefits. In addition to the Biden administration's hostility toward new oil and gas investments, I can think of no more dangerous development for US global and energy security than the International Energy Agency's advice since 2020 to ban new investment in greenfield oil

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1 Friedman, Lisa. (2023, September 7). Biden Approved a Big Oil Project. Now, He's Cracking Down on Drilling. *New York Times.* https://www.nytimes.com/2023/09/07/climate/biden-drilling-climate-oil.html

and gas projects. These policies will exacerbate supply chain bottlenecks arising from tightening supply and demand fundamentals in the coming years, resulting in more extensive and economically painful oil and gas price spikes. Ideally, Congress, the Biden administration, and the IEA will support domestic energy production and minimize supply change risks while developing sound, cost-benefit-based strategies and policies to address climate change.

In closing, I recommend two other relevant FAL working papers that bear on today's hearing: *Congress is Key to Restoring Realism in US Energy Policy* and *Blueprint for a Serious and Sound Climate Policy*.

Questions for the Record
from Senator Charles E. Grassley
for Dr. Scott Kelly
Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains
October 25, 2023
Senate Budget Committee

<u>Question #1:</u>
Your testimony expressed that allegedly stronger and more frequent typhoons in the South China Sea could lead to increased disruptions of the Taiwanese microchip industry. Do you believe that climate change is currently the most sizable threat to the microchip supply chain? Where does the threat of a Chinese invasion of Taiwan and the ongoing various military maneuvers fall on your list?

Thank you for your question Senator Grassley. I'm not qualified to comment on the likely threat from a Chinese invasion of Taiwan or the disruption that various military maneuvers in the South China sea may have on microchip fabrication. What I can say is that Taiwan, and the broader SE Asia region is among the most exposed to the effects of climate change, and faces significant political and economic challenges to cope with and adapt to climate related risks. This is coupled with the fact that the chip industry is highly vulnerable to climate change, given its concentration in particular geographies and dependence on water and energy for production which are both vulnerable to extreme event-driven outages. While climate change might be overshadowed by other threats in the near term, it is among the most existential risks to the area over the medium to long-term. Finally, owing to the concentration of risks of semi-conductor production in Taiwan, diversifying suppliers and logistics and onshoring production will mitigate dependencies of chip production in a small geographical area in a volatile region. Thus, building a resilient microchip supply chain to protect against the physical risks of climate change may also go some way to protect the microchip supply chain against a Chinese invasion of Taiwan

Questions for the Record
from Senator Chris Van Hollen
for Dr. Scott Kelly
Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains
October 25, 2023
Senate Budget Committee

Question #1:
We know that chips production is a water and energy intensive process. As we're seeking to onshore domestic chips production to safeguard global supply chain concerns, how can we work to ensure that we're manufacturing these materials in the most efficient manner?

Thank you for this question, Senator Hollen.

There are many opportunities to improve the efficiency of chip production both in terms of water and energy. The most appropriate options will depend on a range of factors linked to the site location, manufacturing processes, technologies, and prevailing financial and economic conditions.

On the question of water, the first thing to consider is the quantity of additional water consumption requirements a new chip fabrication plant will need, both today and under future climatic conditions. Certain parts of North America are expected to experience more intense droughts based on the latest climate modelling. Given the fabrication of semi-conductors is a water intensive process, choosing the best location for building a fabrication plant must therefore consider the additional water stress that a new plant or expansion to an existing plant may have on the surrounding area. The modelled impacts of future climate change contributing to water stress within an area should therefore be assessed before any decision is made to build a new fabrication facility. Ideally, new fabrication facilities should only be considered in areas that are expected to have low future water stress.

Other opportunities for improving water efficiency are from optimising the manufacturing process. Potential options include the implementation of a closed loop-water system to capture, treat and reuse water within the manufacturing process. Other options include dry processing and green chemistry. Dry processing refers to the use of gasses or the use of plasma technology to etch, clean or deposit materials on semiconductor wafers. Plasma etching is a form of dry processing that uses high energy plasma to selectively remove material from the semiconductor wafer. Green chemical processes such as atomic layer deposition (ALD) and atomic layer etching (ALE) can be more precise and use less water than traditional methods.

On the question of energy efficiency, it is important to invest in the latest and most efficient equipment and technology, to optimise the production process and reduce wasted energy as far as practicable across the facility. This could include the installation waste heat recovery systems, an energy management system to monitor and manage energy consumption and improving the thermal performance of the building itself. Finally, to avoid carbon emissions and improve energy security, investment in onsite renewable energy generation should also be factored into the development of new fabrication plant.

<u>Question #2</u>:
The CHIPS for America Fund provides $11 billion for research and development in semiconductor manufacturing. We have an opportunity to use some of this funding to address the efficiency of the sector – do you have any recommendations for how we can create a climate-resilient supply chain?

There are several ways to build a more resilient supply chain.

1. Increase onshore production. Increasing the domestic production of microchips will reduce the concentration risk from existing major microchip manufacturers, namely from Taiwan.
2. Source supplies from areas that have low physical risk from climate change. Identify locations of production in the world that are at the least risk from physical climate change.
3. Diversify existing suppliers. Increasing the number of suppliers across a larger geographic region will reduce risks from extreme events and increase resilience to future climate change.
4. Diversify existing supply routes. The supply route of critical parts and commodities can be just as important as where the product or commodity is sourced. Sea ports represent a bottleneck in supply chains where a damaged port can seriously impede the transport of goods through the economy.
5. Increase inventory and buffers for critical components so that inventory can be drawn down when supply chains are impacted.
6. Encourage existing manufacturers to reuse and recycle old components to increase the supply of parts available while also minimising waste.
7. Require manufacturers to assess and disclose their material climate related risks. The active disclosure of climate related risks increases awareness through stakeholders, addressing the issue of asymmetric information allowing for improved decision making by key stakeholders.

Questions for the Record
from Senator Wyden
for Dr. Adam Rose
Bottlenecks and Backlogs: How Climate Change Threatens Supply chains
October 25, 2023
Senate Budget Committee

Question #1:

Climate-induced events like storms and wildfires have hammered our supply chain infrastructure, and are only predicted to become more frequent. As we've experienced in the Covid-19 crisis, the impacts of supply chain disruptions are far-reaching and severe. Congress needs to use all the tools at its disposal to prevent the worst effects of the climate crisis and mitigate its worst effects. That's why I'm proud to support a project to develop a container terminal in the International Port of Coos Bay in Oregon that can increase our West Coast shipping capacity by 10%.

How might a container terminal at Coos Bay, which is located in a lower-risk wildfire corridor and has less exposure to tropical storms than much of Southern California, alleviate disruptions your team has projected and allow suppliers to de-risk their supply chains?

Answer:

I'm not really an expert on the network of ports, their individual operations, or the extended infrastructure needed to contact them with the rest of the supply-chain. All I personally can really say at this time is the following:

1. New US ports or expansions of existing ones can help alleviate supply-chain disruptions, especially if those ports are relatively insulated from the effects of climate change.

2. Larger ports are needed to support the development of offshore wind energy (see the attached paper).

3. Ports can generate a large number of direct and indirect jobs in their host regions.

The Electricity Journal 35 (2022) 107167

Contents lists available at ScienceDirect

The Electricity Journal

journal homepage: www.elsevier.com/locate/tej

The co-benefits of California offshore wind electricity

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ARTICLE INFO

Keywords:
Offshore wind
Value proposition
Co-benefits
Job impacts
Environmental justice
Input-output analysis

ABSTRACT

California has set forth an ambitious goal of generating all its electricity from carbon-free technologies by 2045. Offshore wind (OSW) presents several attractive system, economic, and environmental attributes to help the state achieve these goals. Inclusion of OSW into the clean electricity generation portfolio could contribute significantly to total resource cost savings. In addition, OSW offers several major co-benefits. Its high and consistent capacity factor and generation time profile complements that of solar and helps enhance renewable electricity generation reliability. OSW could also be instrumental in early retirement of costly and pollution-heavy natural gas plants and lead to substantial job creations. Moreover, California could reap additional economic co-benefits from the development of a local wind energy industry. Additionally, OSW has the potential to advance environmental justice through reduction of ordinary air pollutants in urban areas and by bringing economic opportunities to lagging areas. At the same time, there are multiple challenges that must be addressed for OSW to reach its full potential. Our analysis is intended also to serve as a template for studies elsewhere by providing a comprehensive framework for estimating co-benefits, taking account of important local conditions, and identification of challenges and how they might be overcome.

1. Introduction

California has set forth an ambitious goal of generating all of its electricity from clean and carbon-free technologies by the year 2045. The state had been planning for this target to be met primarily by several renewable sources like solar, land-based wind, geothermal and biomass, along with other zero-carbon technologies. Offshore wind (OSW) energy has more recently proven to be a technologically feasible and economically viable option in other locations. Therefore, momentum has increased to include California's OSW energy as a complement to its current renewable energy and storage resources.

Given the long time-horizon of California's electricity planning, it is prudent to be flexible about the range of technological options. OSW has several relative advantages and can complement other renewable alternatives. Currently, OSW is being included in California's 2019–2020 Integrated Resource Plan (IRP) modeling for the first time by the California Public Utility Commission (CPUC, 2020). The CPUC has also directed the California Independent System Operator (CAISO) to assess the transmission capacity and requirements for large-scale OSW as part of a policy analysis of the Transmission Planning Process (TPP).

The current U.S. presidential administration has formally expressed its support for speeding up the development of OSW to the level of 30 GW nationally by the year 2030, including committing sizable funding for loans to the industry and for increases in seaport capacity to accommodate the shipment of the necessary large equipment components. This commitment to OSW appears staunch as well, given that the U.S. Departments of the Interior and Commerce recently approved construction of the Massachusetts Vineyard Wind Project, the first utility-scale OSW farm in the United States (BOEM, 2021). Furthermore, the Biden administration announced on May 25, 2021, an initiative to accelerate California OSW development. Specifically, the Departments of the Interior and Defense have delineated a central coast development area known as the "Morro Bay 399 Area". The Interior Department has also stated that it will engage in efforts to advance a potential OSW area on the northern coast of California adjacent to Humboldt County (White House, 2021).

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https://doi.org/10.1016/j.tej.2022.107167
Received 23 May 2022; Accepted 26 May 2022
Available online 27 June 2022

California has recently made tremendous strides in the effort to make Pacific OSW a reality. On September 23rd, 2021, California Governor Gavin Newsom signed into law AB 525, which creates a directive for state agencies to deliver plans for the establishment of OSW in the state's coastal waters (Bulijan, 2021). This state bill is contained within a much broader climate package as part of the California Comeback Plan (Office of Governor Gavin Newsom, 2021). It mandates the California Energy Commission (CEC) to set OSW energy production targets for 2030 and 2045 and determine the maximum feasible capacity of OSW before June 1, 2022. The legislation also outlines the needed infrastructure improvements (such as port space and transmission lines) to allow for OSW generation and distribution. The bill, moreover, requires the CEC to coordinate with the other relevant state and federal agencies, and other stakeholders, to identity suitable sea space, develop a permitting roadmap, and assess potential impacts on coastal resources and groups of peoples (California Legislative Information, 2021). The passing of this bill comes as the nation as a whole is preparing for an imminent OSW future (Davenport, 2021).

The California Energy Commission (CEC) recently recognized the potential of OSW and worked with the federal Bureau of Ocean Energy Management (BOEM) to identify the best sites in the state, as identified in the President's May 25th announcement. A recent draft report by a Joint Agency group composed of the CEC, CPUC, and California Air Resources Board (CARB) indicated that, under several scenarios including the "core study scenario," 10 GW of OSW is required to meet the 100% clean energy goal in the state by 2045 (CEC/CPUC/CARB, 2021). The report estimates that this addition of OSW would contribute toward total resource cost savings of $1 billion. At the same time, the 10 GW represents only about 5% of the estimated OSW potential capacity in the state.

In addition to providing economic gains to ratepayers, OSW in California can offer several major co-benefits (Rose et al., 2021). The purpose of this paper is to estimate these additional gains. A large number of direct net job gains will accompany OSW development, even after accounting for displacement of other sources of electricity. Moreover, these construction and operation/maintenance jobs on-site have multiplier effects on the rest of the state's economy. Furthermore, many of the direct job gains would likely be in areas of the state that are lagging economically, thereby promoting income equity. OSW promises reductions in ordinary air pollution and greenhouse gas emissions when accomplished through the displacement of fossil-fuel installations in urban areas, which would also yield environmental justice co-benefits. OSW represents a valuable complement to other renewable energy sources in terms of electricity reliability as well. Also, an early start on OSW development could help California become a leader in OSW technology and support industries up the supply chain, as well as allow the state to become an important transshipment point for trade in this technology with other Pacific Rim countries.

All of this is not to deny that issues still need to be resolved relating to planning, including the permitting process and environmental compliance, the need for a significant amount of investment in transmission lines, and the need to address a diverse set of stakeholder concerns. We also address these concerns and note the progress underway in addressing them.

Offshore wind development will need to consider many localized features, including wind speed, water depth, solar radiation competitiveness, transmission line accessibility, proximity of support industries, availability of nearby specialized ports, and especially state and local government regulations. Our analysis, however, is intended to be of broader interest by serving as a template for studies elsewhere by providing a comprehensive framework for the analysis of co-benefits, specification of how these are affected by important local conditions, and identification of challenges and how they might be overcome.

Section 2 presents the analytical framework used to evaluate electricity generation technologies, including both the consideration of the "value proposition" relating to delivering electricity and other broader co-benefits. OSW development potentials in California and operating experiences in other states/countries are introduced in Section 3. Section 4 summarizes the important role of OSW in providing flexible and reliable clean electricity resources. The direct benefits and co-benefits of OSW are evaluated in Sections 5 and 6. More detailed job creation potentials of a 10 GW OSW build-out in California and the development of in-state wind energy manufacturing cluster are presented in Section 7. Section 8 discusses major challenges of OSW development. Sections 9 and 10 conclude the paper by providing a summary of our findings.

2. Analytical framework and methodology

Many factors are typically considered in evaluating electricity generation technologies. The major one is the "value proposition," which is the cost of generating electricity without a given technology minus the cost of generating it with the technology. In other words, it is the cost savings to the system from adopting the technology. This is an example of cost-effectiveness analysis (CEA), which essentially compares the new candidate to the current or projected mix of technologies to determine whether it is competitive in delivering a given amount of electricity. CEA is a special case of benefit-cost analysis (BCA), because it does not require consideration of any benefits beyond delivering a target level of electricity. If the revenues from producing electricity are juxtaposed to the costs, it would also be analogous to the private-sector profitability criterion.

This narrow characterization of the value proposition, however, has evolved to include other considerations relating to delivery of electricity. One of these is "reliability," which differs across energy resources and technologies in terms of variations in daily or seasonal input flows and the prevalence of scheduled and unscheduled downtimes of the technology that transforms the raw energy into electricity. In this case, the value proposition becomes even simpler because the candidate technology need only be compared to the cost and reliability of the next one or two resources/technologies it is intended to replace and not the entirety of the electricity production mix. Still another basic extension is to cast the analysis in "portfolio theory," where diversification is a key risk reduction strategy, and any new candidate technology can contribute to this apart from a narrower value proposition or the reliability consideration.

Public policy decisions, on the other hand, are based on many other considerations. Beyond the narrow benefit of delivering electricity, these have come to be known as "co-benefits." One of the first examples of this concept was that of "joint-product" production, as in the case of multiple-purpose river development, which factored in the value of flood control and recreational services in evaluating hydroelectric dam projects (Krutilla, 1958). More recently, there has been a focus on the co-benefits of reducing greenhouse gases and ordinary pollutants with the use of clean energy technologies. One way of factoring this into the basic CEA or BCA criteria is to value the social costs (health, property, ecological) of the pollutants and add them to the cost of the technology that generates the pollutants in making the comparison of energy alternatives. An alternative approach is to consider the reduction of these broader *societal cost* of pollution as a direct *social benefit* of the candidate renewable/clean energy technology. Other co-benefits include: job creation and its multiplier effects on the overall economy, improvements in equity/justice, enhanced national security, technological innovation, and attainment of broader economic development goals.

Many of these co-benefits are not always fully appreciated by those who interpret CEA or BCA in a narrow sense. However, their acceptance has been increasing over the years. The societal cost of pollutants has resulted in the inclusion of price "adders" in electric utility rate-making (see, e.g., Burtraw et al., 1995; Akin-Olçum et al., 2021). More recently, there has been a renewed push to include "economy-wide" (multiplier or multi-market) effects (EPA, 2017; Farrow and Rose, 2018). Also, recently, there has been a move to analyze disaster risk reduction, including long-term disruption of utility infrastructure, in terms of a "resilience triple-dividend." In addition to including the direct benefits of lowering potential losses, it adds two general categories of co-benefits— reduction of uncertainty, which improves the business climate, and inclusion of externalities and joint products (Surminski and Tanner, 2016; Rose, 2016).

Employment impacts from the potential development of OSW represent a major category of co-benefits of climate action plans including specific energy technologies (Rose and Wei, 2012; Wei and Rose, 2014; Wei and Rose, 2016; Mamkhezri et al., 2021). This is sometimes a controversial topic characterized by extreme claims that rushing renewables will be a panacea or will bankrupt the economy.

Yet another co-benefit is the potential to attract OSW-related industrial clusters to California. These would further reduce production costs through agglomeration effects and increase the size of multipliers of the supply chain by displacing imported sources of OSW equipment with local production.

Finally, we consider regulatory obstacles and supportive measures and inducements relating to a range of stakeholders, including electricity generators, electricity grid system operators, investors, developers, trade unions, the general population, and governments at all levels. Along the way, we examine positive and negative aspects of OSW development in California, and identify ways to enhance the positive and reduce the negative ones, mainly through the fostering of development of wind energy manufacturing capacities and clusters within the state.

3. Background

California has implemented a number of policy goals intended to transition the state into a green economy, notably including Senate Bill (SB) 100, which aims at achieving a 100% clean electric grid by 2045. The target in California SB 100 is expected to be met primarily by renewable generation sources like onshore wind, onshore solar, and geothermal, along with other zero-carbon technologies like existing hydroelectric and energy storage (see SB 100, 2018). Wind energy has a potentially strong presence in California, as it has proven to be a technologically feasible and economically viable resource elsewhere. Moreover, formal steps have been taken and public and private sector support has been increasing to include OSW as a complement to the state's current renewable energy portfolio standard (RPS) (CPUC, 2020; SB 100 Joint Agency, 2021).[1]

California is on track to meet its goal of 60% renewables by 2030. However, under the SB 100 Core scenario, which factors in high electrification demand, California will need to install around 50 GW of cumulative renewable capacity to meet the 2030 goal, and greater than 150 cumulative GW to satisfy the 2045 goal of complete carbon neutrality (CEC et al., 2021). Additionally, California is expected to require two to six times current renewable generation capacity by 2050 in order to meet the state's separate GHG emission reduction goals outlined in AB 32, which indicates the potential need for 100–150 GW of new capacity (Hull et al., 2019; Mahone et al., 2018). Meeting these decarbonization goals will necessitate a large overhaul of the current electric system and a diversified energy mix in California.

OSW is an attractive alternative for several reasons, as evaluated by Wang et al. (2019), Collier (2020), and Brightline Defense (2020), and as included in policy discussions by the SB- 100 (2018), CEC (2021), CPUC (2020), Amul et al. (2020), and Chiu (2021). In California, there is an extensive coastal wind resource base. OSW in five potential OSW development areas in California has the potential to generate up to 21 GW of electricity in perpetuity (Collier, 2020). This could contribute up to 12% of California's anticipated renewable electricity growth by 2045. Total OSW technical potential in California is considered to be approximately 200 GW; therefore, the state could possibly accommodate even larger net capacities than what these studied sites would offer (Optis et al., 2020).

Appendix A provides a summary of the OSW operations in other states and countries.

4. Role of OSW in meeting the need for flexible clean resources in California

4.1. Extent of the resource base

Studies to date have focused on five potential areas totaling 21 GW of viable OSW resource in California, capable of providing around 25% of state electricity needs in perpetuity (CPUC, 2020; Beiter et al., 2020c; Collier et al., 2019).[2] The total space potentially available for the first round of offshore wind development, according to the recent White House announcement, would enable roughly 4.6 GW.

In the 2019–2020 Integrated Resource Planning (IRP) process in California, OSW was included as a candidate resource available starting in 2030. Modeling conducted by the CPUC selected OSW as part of a least-cost 2030 energy portfolio, but only under the strictest GHG target of 30 million-metric-tons (MMT). Specifically, 1.6 GW is selected (primarily from the Morro Bay call area) under the assumption that no new out-of-state onshore wind (OOS) is available. If 3 GW of OOS wind resources in Wyoming and New Mexico are made available, selected OSW capacity falls to only around 6 MW. Still, these figures are only a fraction of the technically viable OSW resources across the five sites listed above (CPUC, 2019). It is important to note, however, that the CPUC and the CAISO are currently working to update the cost and resource assumptions for OSW by incorporating the latest projections from NREL and transmission cost information that will be available in early 2022 with completion of the OSW sensitivity in the TPP. These updates will potentially improve the performance of OSW in future cycles of the IRP.

4.2. Niche role based on some superior qualities

OSW energy generation has several superior qualities that warrant its further evaluation by California's energy planning agencies. Winds off the coast of California are steady and generally blow throughout the day, offering the potential for consistent electricity generation. OSW also experiences higher and more stable capacity factors than terrestrial wind sources (Hull et al., 2019). Additionally, offshore wind shows a tendency to peak between 6 PM and 9 PM, and this daily peak coincides with the hours when net energy demand ramps up quickly. In contrast, solar generation typically peaks around noon, and onshore wind peaks around midnight (Wang et al., 2019; Hull et al., 2019). There is a daily challenge of balancing the electricity grid, and this issue is exacerbated by vanishing solar generation in the evenings as power consumption rises (Collier, 2017). The evening "ramp" is typically met by natural gas plants either powering back on or increasing generation, thereby increasing GHG and local air pollutants.

[1] Offshore wind was made available as an optional "candidate" resource for the first time in the state's 2019–2020 IRP process, which helps to coordinate the expansion of carbon-free energy by load-serving entities (Amul et al., 2020). Since the release of the 2019–2020 (IRP) report, the CPUC has been collaborating with the BOEM and the National Renewable Energy Laboratory (NREL) to further explore offshore wind's potential in California's resource portfolio. OSW has also been included in core modeling scenarios in the 2021 SB 100 joint agency report, and the modeling has determined that offshore wind (up to 10 GW) is selected for resource planning purposes when made available.

[2] The total resource potentials for the three BOEM designated call areas, Humboldt, Morro Bay, and Diablo Canyon, are estimated to be 1.6 GW, 2.4 GW, and 4.3 GW, respectively. The other two major study areas, Cape Mendocino and Del Norte, have total resource potentials of 6.2 GW and 6.6 GW, respectively (Amul et al., 2020; Beiter et al., 2020c).

OSW generation has the potential to eliminate this energy imbalance. OSW is also more suitable to operate in tandem with solar than onshore wind resources due to its capacity factor and stability advantages (the fact that OSW capacity factors are less volatile than other renewables). These advantages may also help reduce the state's future reliance on costly grid scale lithium-ion battery storage (Hull et al., 2019). The desirable generation attributes of OSW can therefore help in providing energy diversification for a high-electrification future.

OSW turbines can thus also be expected to operate at greater capacity for a larger percentage of time than onshore wind, which can offset relatively higher installation costs. The reliability of wind speed also reduces wear on the turbine and limits plant downtime, reducing the need for backup generation (BOEM, 2017). Furthermore, unlike solar PV, OSW maintains a similar levelized avoided cost of energy (LACE) at increased scale because generation is spread more evenly throughout the day. All of these positive characteristics of OSW power will be increasingly valuable to the grid, especially given the upcoming decommissioning of currently operational energy resources like the Diablo Canyon nuclear power plant (American Jobs Project, 2019).

4.3. Potential of OSW to replace other generation

OSW could further reduce the need for back-up gas generation to balance variable renewables. Offshore wind's capacity value may also offset the need for the CAISO or load-serving entities to maintain Resource Adequacy (RA) contracts with gas plants, enabling quicker retirement of peaking plants than otherwise would be retained for reliability needs. Furthermore, Collier et al. (2019) postulates that the addition of 8 GW of offshore wind would replace the need for approximately 7 GW of battery storage and 14 GW of solar, as well as precipitate the retirement of an additional 5 GW of combined-cycle (NGCC) gas plants by 2045.

A recent NREL study (Beiter et al., 2020a) has also indicated that under 2 GW and 7 GW hypothetical offshore wind rollout scenarios on the east coast, OSW capacities can primarily displace NGCC generations, providing 4% and 13.5% of total energy consumption in ISO-NE, and 1.4% and 5.1% in NYISO. However, the increased variability in the net load of OSW generation does cause NGCC plants to experience increased starts and decreased hours on-line. The variability can also lead to more frequent starts, and at higher costs, for natural gas combustion-turbine plants.

In CPUC SB 100 2045 framing study scenarios (CPUC, 2019), three scenarios were explored that reflect varying decarbonization strategies: high electrification, high biofuels, and high hydrogen. All scenarios assume the GHG policy constraint of 86 MMT by 2050. In considering the high electrification scenario, the sensitivity that includes OSW as a candidate resource enables the largest retirement of gas-fired power plants (5.2 GW), equal to around one-eighth of California's current natural gas generation capacity.

5. The basic value proposition – direct benefits

We begin with the evaluation of OSW cost-effectiveness. Total OSW System Value is defined as the cost of generating electricity without a given technology minus the cost of generating it with the technology. In other words, it is the cost savings to the system from adopting the technology. Appendix B summarizes basic electricity generation and transmission considerations.

While California's state utility and energy agencies have not until very recently begun to model OSW in integrated resource planning portfolios (IRPs) (CPUC, 2020), empirical studies of the technology in the wake of the erection of OSW farms around the globe have provided evidence of this technology's potential for transforming California's power grid.

One key component of OSW's value proposition involves the more traditional benefit of integrating the technology into the state power grid. A recent estimate by the CEC/CPUC/CARB (2021) in a joint agency report estimates that the inclusion of OSW into the state's portfolio of clean electricity generation could contribute up to $1 billion in annual total resource cost savings. Another estimate places this contribution at up to a net present value of $2 billion between 2030 and 2040 for 7–9 GW of installed capacity (Energy and Environmental Economics, 2019). The majority of the savings stem from the displacement of higher-cost energy alternatives. Resource portfolio diversity can thus generally lower system-wide costs.

6. Co-benefits

6.1. Reliability Co-benefits

The first area of analysis in determining the efficacy of OSW in California concerns grid-system benefits. One significant reason for the difficulty in integrating renewable energy into electric grids is that the energy generation profiles of existing technologies do not always adjust for system reliability (Wang et al., 2019).[3] In order to match energy supply and demand during peak hours, California often deploys costly and carbon-intensive natural gas peaking plants. This mix of energy generation may be adequate in the short-term, but as the state's share of renewable power purchases increases, this grid incompatibility will not be sustainable and could lead to rolling blackouts, as witnessed recently (Smith et al., 2015). The hourly generation profile of OSW could potentially address the grid balancing problem, as Pacific winds generally blow 24 hours a day and peak around 6–9 PM, when energy demand is highest (Wang et al., 2019; Hull et al., 2019). By bridging the late-afternoon gap between diminishing solar radiation and rising electricity consumption, OSW could also reduce the need to import power from other Western states, and, moreover, allow California to develop additional renewable capacity without destabilizing the grid. Additionally, OSW is typically stronger and more consistent than land-based wind, and this reliability can provide more constant power to the grid, further reducing the need for backup gas generation (AECOM, 2017). Development of OSW close to coastal load centers (or connected to coastal load centers via subsea transmission) may also decrease the need for transmission system upgrades and can provide greater flexibility to independent system operators by helping to decentralize the system (AECOM, 2017).

6.2. Job creation

The suitability of OSW for California's power grid must also take into consideration economic ramifications in terms of impacts on regional economies as well as net energy costs. Recent studies have estimated that a California OSW industry could support about 185,000 job-years between now and 2045 with the buildout of 18 GW of offshore energy capacity (American Jobs Project, 2019). OSW is also projected to bring new investment via the creation of industrial clusters; a study focusing on the East Coast OSW rollout estimated that every $1 invested into a project will result in $1.83 in regional economic GDP (American Jobs Project, 2019). A 2016 NREL study on the OSW development scenarios of 10 GW and 16 GW in California by 2050 estimated job impacts of 135,000 to 327,000 job-years between 2020 and 2050 (Speer et al., 2016). Our estimates, to be presented in more detail in Section 7 below, indicate that a 10 GW installed OSW capacity in California by 2040 can stimulate a total of 97,000 to 195,000 job-years between 2020 and 2040 for the construction of the wind facilities and another 4,000 to 4,500

[3] "Reliability" is used here in the narrow sense of continuous supply of electricity in relation to renewable energy input. This differs from more general definitions of the term that relate to any cause of electricity system disruption as defined by the North American Electric Reliability Corporation (NERC, 2020).

annual operation jobs starting in the Year 2040. The job impacts are very comparable when we adjust for the differences in capacity in these studies.

Our estimates also project that construction and operation of the OSW facilities provide good opportunities of high-paying jobs. For example, the wage rate for construction-related labors (including foundation, erection, electrical workers) is about $50 per hour. The salary for O&M labor is around $40/hour for technicians and environmental scientists & specialists, and nearly $60/hour for managers and supervisors (American Jobs Project, 2019; Musial et al., 2020b).

6.3. Environmental benefits

Environmental benefits relate to the role OSW could play in preserving California's natural resources and achieving GHG reduction goals. Meeting the targets outlined in SB 100 will require tremendous build-outs of onshore wind and solar power plants; specifically, under the high electrification scenario in the recent Joint Agency Report, an average of 2.7 GW of solar and 0.9 GW of wind must be constructed each year to remain aligned with SB 100 objectives. Commensurately, approximately 36,500 acres and 22,100 acres of land will be needed for land-based wind and solar per year, respectively, for the next 25 years (Defenders of Wildlife and the Nature Conservancy, 2020). OSW requires sea-space area, but the footprint of a project in the ocean and its impacts to wildlife and habitats may be relatively low. California must therefore make sure that its clean energy goals do not compromise its natural resource and climate goals. Land-based wind and solar are both increasingly valuable generation sources; however, land-use constraints could threaCEten California's ability to achieve 100% clean energy without OSW. California has also suffered from drought for several years, and the OSW farms do not consume any of California's freshwater supply (Musial et al. 2016a).

Furthermore, as mentioned previously, the integration of OSW into the state grid can lead to substantial displacement of fossil-fuel electricity (CPUC, 2019; Collier et al., 2019). For example, if the development of 10 GW OSW would enable a displacement of 5 GW gas-peaker power plants, it would result in a reduction of 4.73 million metric tons of carbon dioxide equivalents in the year 2040. Given the latest estimate of the societal cost of carbon (GAO, 2020), this translates into a savings of $42.56 million to $340.45 million (depending on whether domestic vs. global climate change damages are considered).

Although California has seldom been hit by hurricanes, there has been an increasing threat of earthquakes. Companies have begun to design their turbine to better withstand the strikes from both of these threats. The well-designed OSW turbines are required to be able to continue stable electricity generation under high magnitude earthquake strikes, as well as strong winds, hitting the California coastline.

6.4. Equity and environmental justice

Port revitalization to accommodate shipment of OSW component parts is a major co-benefit of OSW development, especially when it is implemented in economically lagging areas, such as Humboldt County. It offers an opportunity to promote socioeconomic equity for small businesses, low-income residents and disadvantaged minorities (Brightline Defense, 2020). However, it is necessary to consider only the incremental gains from this development vis-à-vis its potential displacement of other renewable and non-renewable energy sources.

In addition to the promotion of socioeconomic equity, OSW can also aid in securing environmental justice for minority and low-income communities by displacing fossil fuel generators. The retirement of natural gas plants is especially important from an environmental justice standpoint, since many gas-fired peaking plants are located in areas with economically disadvantaged populations,[4] such as in the City of Los Angeles. Given California's coastal resource base, the potential to develop 10 GW of OSW by 2040 would go a long way in achieving environmental justice goals.

7. Details of job creation potential of OSW in California

We summarize our analysis of the impacts of OSW development in California on the state's economy. The impacts are evaluated in terms of major macroeconomic indicators of employment, gross domestic product (GDP), and personal income. We quantify not only the direct impacts of construction and operation of the OSW plants and associated transmission line improvements, but also various indirect impact indicators as the direct expenditures ripple throughout the economy. Our analysis is based on the use of input-output (I-O) modeling, the standard approach to estimating regional economic impacts of energy development utilized previously by the authors (see, e.g., Rose and Wei, 2012; Wei and Rose, 2016) and others (Speer et al., 2016; Bae and Dall'erba, 2016; American Jobs Project, 2019; Hackett and Anderson, 2020; Faturay et al., 2020).

7.1. Study areas and development scenarios

Our major source of data on the projected capital expenditures and O&M costs of commercial-scale offshore wind projects in California is a recent study conducted by NREL (Beiter et al., 2020c). This study analyzes the cost of large-scale OSW deployment along the central and northern coast on the Outer Continental Shelf in California. The water depth of the analysis domain ranges from 40 m to 1300 m. Floating offshore wind technology is well-suited to this water depth.[5] We analyze the economic impacts of a hypothetical deployment scenario of a cumulative 10 GW of offshore wind capacity by 2040 across five selected study sites in California consistent with the latest NREL study (see Table 1).

7.2. Basic construction impacts

Table 2 presents the results for the development of 3 GW and 7 GW OSW between 2020 and 2030 and between 2030 and 2040, respectively. In both cases, lower- and upper-bound locally produced content (RPC)[6] adapted from Speer et al. (2016) are used. The table presents the results for both wind farm construction and transmission system upgrades separately, and the total impacts combined.

The hypothetical deployment of 3 GW offshore wind between 2020 and 2030 in California is estimated to increase employment by 31,691 and 63,656 job-years for the lower and higher RPC scenarios, respectively. The estimated impacts on GDP and personal income are $4.0 billion and $3.7 billion for the lower RPC scenario, and $7.9 billion and $7.4 billion in the higher RPC scenario (all nearly doubled compared to the lower RPC scenario).

The deployment of the additional 7 GW offshore wind between 2030 and 2040 is estimated to increase employment by 65,279 and 131,615 job-years for the lower and higher RPC scenarios, respectively. The estimated impacts on GDP and personal income are $8.2 billion and $7.7 billion for the lower RPC scenario, and $16.2 billion and $15.3 billion in

[4] Seventy percent of current gas-fired peaker plants are in communities with environmental justice concerns (Brightline Defense, 2020).

[5] The energy production and associated costs presented in Beiter et al. (2020c) are adapted based on the assumption of a wind power plant size of 1000-MW at each possible site in the analysis domain.

[6] Regional Purchase Coefficient (RPC) represents the proportion of in-state demand of certain types of goods and services that is fulfilled by in-state production.

Table 1
Hypothetical offshore wind deployment scenarios in California between 2020 and 2040.

	Morro Bay	Diablo Canyon	Humboldt	Cape Mendocino	Del Norte	Total
Capacity Potential (MW)	2419	4324	1607	6216	6605	21,171
Hypothetical Deployment Scenario						
Between 2020 and 2030 (MW)	1000	1000	1000			3000
Between 2030 and 2040 (MW)	1000	2000		2000	2000	7000
Cumulative by 2040 (MW)	2000	3000	1000	2000	2000	10,000

Table 2
Economic impacts of capital expenditures for the deployment of 3 GW of OSW in 2020–2030 and 7 GW of OSW in 2030–2040 in California.

Impact Indicator	Category	3 GW OSW (2020–2030)		7 GW OSW (2030–2040)	
		Lower RPC	Higher RPC	Lower RPC	Higher RPC
Employment (job-years)	**Wind farms**	22,049	42,923	42,709	83,082
	Transmission upgrades	9642	20,733	22,570	48,533
	Total	31,691	63,656	65,279	131,615
GDP (million 2019$)	**Wind farms**	2818	5391	5466	10,449
	Transmission upgrades	1153	2477	2699	5799
	Total	3971	7869	8166	16,248
Personal Income (million 2019$)	**Wind farms**	2642	5062	5124	9810
	Transmission upgrades	1100	2364	2575	5534
	Total	3742	7426	7699	15,344

the higher RPC scenario (again all about doubled compared to the lower RPC scenario). The stimulus effects of wind farm construction are slightly more than two times of the stimulus effects of transmission upgrades.

7.3. *Operating impacts*

Table 3 presents the annual economic impacts associated with the operation and maintenance of the OSW plants. The results are presented for Year 2030 (the year in which we assume that the total cumulative offshore wind capacity reaches to 3 GW in California) and for Year 2040 (when the cumulative capacity reaches 10 GW). In 2040, the annual employment impacts are estimated to be 3979 jobs and 4513 jobs[7] in for the lower and higher RPC scenarios, respectively. The average annual GDP and personal income impacts are estimated to be $463 million and $429 million, respectively, for the lower RPC scenario, and $530 million and $492 million respectively, for the higher RPC scenario.

Sectors that are directly stimulated by the capital expenditures include Construction, Ship Building and Repairing (including offshore floating platforms manufacturing), Turbine Manufacturing, and Professional, Scientific & Technical Services. Sectors most directly stimulated by the O&M expenditures include Water Transportation and Professional, Scientific & Technical Services. Sectors that are stimulated by the indirect effect (supply-chain effect) and induced effect (spending effect of wages and salaries of the construction and O&M workers) include Retail, Food Services & Drinking Places, Health Services, Retail and Wholesale Trade, and Real Estate.

In general, the results are in line with recent estimates found in other studies. The construction of wind farms and associated transmission lines can stimulate 97,000 to 195,000 job-years of employment and about 4000 to 4500 annual operation and maintenance jobs in totality for all facilities built by 2040 throughout their operational life-cycles (see the summary of these studies in Appendix C).

Table 3
Economic impacts of operation and maintenance of OSW projects in California.

Impact Indicator	2030		2040	
	Lower RPC	Higher RPC	Lower RPC	Higher RPC
Employment (jobs)	1375	1560	3979	4513
GDP (million 2019$)	160	183	463	530
Personal Income (million 2019$)	148	170	429	492

7.4. *Prospects for developing a wind energy manufacturing cluster*

OSW has the potential to attract new investment and production both directly and indirectly via the creation of industrial clusters or agglomerations. Although there are no current instances, studies point to this promising opportunity (see, e.g., Navigant, 2013; Rigas, n.d.). There are, however, examples of clusters elsewhere for ocean wind and related technologies. The experiences of Denmark and Germany show that sustained government direction and support for port development can contribute to highly competitive regional industrial clusters (Collier et al., 2019). Moreover, investment into the U.S. OSW industry may be facilitated rather soon, as one of the largest turbine suppliers in the world, Siemens Gamesa, is considering a manufacturing facility in the states (Huxley-Reicher and Read, 2021).

We adapt our economic impact modeling to estimate the potential of industrial clusters specifically, and increased production of OSW components in California more generally to further stimulate California's economy. This involves modifying major parameters in the model based on estimates by NREL (Speer et al., 2016) of a potential increase of in-state production of OSW-related equipment, which leads to higher local (in-state) content shares of supplies of equipment and professional/technical services relating to the construction and operation of the wind farms. This results in estimates of about 90,000 more job-years

[7] We note that the concept of "job-years" is used for the employment impacts associated with the capital expenditures presented in Table VIIIB. This is because the employment impacts only occur in the year(s) of the construction of the new offshore wind facilities. One job-year refers to a worker working full time for that year. However, we use "jobs" in Table VIIIC for the employment impacts associated with the annual operation and maintenance activities of the wind farms. These jobs are of longer-term nature, which are expected to last for the entire life of the offshore wind generation facility.

than the scenario with assumptions of lower local content shares.

We also conducted a separate analysis to estimate the extent to which the in-state higher production capacity of wind turbine components could stimulate the state's economy by supplying the OSW facilities in California and exporting OSW components to other areas of the country for the buildout of OSW capacities between 2020 and 2040 in the U.S. In the lower-bound case, we assume the in-state supply of wind turbine tower and rotor nacelle assembly is increased to 50% and 25%, respectively; while in the upper-bound case, this is increased to 100% for wind turbine tower and 50% for rotor nacelle. The estimated employment impacts are between 9000 and 18,000 job-years, and the GSP impacts are between $1.5 billion to $3.0 billion. In the simulation of the increased export of wind turbine components to other regions in the U.S., we assume that 29 GW of OSW capacity will be installed in the rest of the country by 2040 (OWC, 2021; Zhang et al., 2020; AWEA, 2020). We further assume that the total domestic share of turbine components for OSW is between 40% and 60% (Zhang et al., 2020; AWEA, 2020), and the development of wind energy manufacturing clusters in California would enable California to obtain 25–50% domestic market share. The estimated employment impacts are 16,000–48,000job-years, and the increased GSP is between $2.3 billion and $7.0 billion in the lower-bound and upper-bound cases, respectively. Such outcomes would represent a sizable increase in the economic impacts presented in the previous section.[8]

8. Key challenges

There are a variety of challenges concerning OSW that need to be addressed before policy-makers and industry move forward to make Californian OSW energy a reality.

8.1. Need for new transmission infrastructure

In the case of a build-out on the North Coast, infrastructure currently in place in the Humboldt region is designed to serve only local load. New investments would need to be made, such as upgrades or new construction of cables or substations that serve as connecting points. For example, a utility-scale wind farm along the Humboldt coast would require either an undersea cable that connects to a major Northern California load center, or overland transmission lines, which would almost certainly get bogged down by permitting and inaccessible terrains (Severy and Jacobson, 2020). These overland routes may also encroach upon federally protected lands and could also potentially pose wildfire risks (Amul et al., 2020). Moreover, new transmission could cost in excess of $1 billion (Collier, 2020).

8.2. Seaport capacity

Few ports in California could serve as importation, manufacturing, or assembly hubs. The size of the OSW turbines will be significantly larger than those that are used for onshore wind power, and thus the final assembly cannot be accomplished at ports with tall seaward bridges. This requirement eliminates all ports in the San Francisco Bay Area and Delta, as well as Los Angeles, Long Beach, and San Diego. The ideal characteristics of suitable ports would ultimately require deep and sheltered harbors with high-quality port infrastructure and facilities, large areas of vacant land for manufacturing and assembly purposes, and no restrictions for ship access (Porter and Phillips, 2019).

Many studies have identified the Port of Humboldt Bay as a promising site for the final assembly of OSW turbines. The port has vast vacant industrial land at a deep-water harbor with limited access constraints, and the Humboldt Bay Harbor District (HBHD) has been active in the development of the port area into an offshore wind manufacturing hub (Hackett, 2020).[9]

Other reports, such as Hamilton et al. (2021), have studied the potential for a specialized OSW port along California's Central Coast. A specialized Central Coast port facility with several staging areas, possibly situated in San Luis Obispo, would be instrumental for final component assembly, as well as O&M and decommissioning-related activities.

8.3. Environmental and wildlife concerns

The North Coast Offshore Wind Feasibility Project has assessed two potential OSW scenarios along California's northern coast with multiple build-out scenarios. All scenarios would entail construction, operations, and decommissioning activities that could have adverse effects on both terrestrial and marine environments. H.T. Harvey & Associates (2020) found that effects from the build-out of both the onshore and offshore components necessary to support OSW integration will primarily be short-term and will mostly affect the immediate regions. Offshore wind-related operations and maintenance activities will present some long-term concerns, however, such as potential adverse interactions with wildlife and ship interactions and collisions with blades. Lastly, improvements to overland transmission infrastructure would also present long-term challenges for both terrestrial and marine habitats. Many of the potentially affected plant and animal species are subject to state and federal protections.

8.4. Military concerns

The U.S. Navy initially expressed significant concerns with OSW areas in the central coast of California following BOEM's call for interest and nominations in 2018. During the Trump administration, federal legislators from California sought to make progress in resolving these concerns, but did not reach a successful resolution. California state legislators have held talks with the Secretary of the Navy regarding the viability of OSW (Braithwaite, 2020). On May 25th 2021, the Biden-Harris Administration and the Governor of California announced plans to move forward with OSW leasing for 399 square miles in Morro Bay (the site of the major US naval base) and the original Humboldt Call Area. While there will likely be on-going discussions between Department of Defense, Department of Interior, and State of California on mitigation to protect DOD's long-term interests in the region, as well as to determine the space and timing for additional phases of OSW leasing, this announcement represents a major step forward in the establishment of an OSW industry in the state (DOI, 2021).

8.5. Fishing industry concerns

Impacts on marine wildlife could potentially adversely affect California's $183 million fishing industry. Industry groups have stated that not enough research has been done on how OSW could affect commercial fish harvests (Collier, 2020). The Diablo Canyon and Morro Bay call areas overlap with essential fish habitats and designated conservation areas. OSW development near these coastal regions proposes potential challenges for commercial fisheries, through both active fishing

[8] Strictly speaking this is not a direct comparison because the economic impacts presented in Section VIIB do not include the exports impact, though include the impacts of all components of OSW buildout, not only turbine components. However, the bottom-line statement still holds.

[9] However, the current challenges of this port include the lack of highway and rail transport access, grid interconnection, and the need for extensive upgrades to the supporting port facilities. Another potential concern is sediment deposits from the Eel River, making vessel transit to offshore sites only possible during part of the year (Amul et al., 2020). Port improvements may also prove to be extremely costly, with Collier (2020) estimating that renovations could cost in the neighborhood of $100 million for this location.

activities and the movement of marine vessels (Natural Resources Defense Council (NRDC) et al., 2019). At the same time, wind farms themselves may serve as marine protected areas for fish, or could create reef-effects which attract increased numbers or greater diversity of species (Dauterive, 2000; Hooper and Austen, 2013).

8.6. Cargo vessel availability

Specialized vessels with heavy lifting and specific stability characteristics are required to perform the decommissioning operations. However, the vessels also need to satisfy the requirement based on the site conditions. The number of turbines, the foundation type, the water depth, the distance to the operating ports and the seabed type need to be considered. Meanwhile, vessel operations are impacted by other uncertainties, such as the equipment used, the weather, and the market (Topham et al., 2019). However, the vessel availability challenges and Jones Act compliance for fixed-bottom OSW are expected to be much less of an issue for floating OSW.

8.7. Lack of wind power supply chain

Currently, California has minimal to no manufacturing of large-size turbine, rotor blades, nacelles, tower and other major components (Collier et al., 2019).[10] Therefore, the state may need to import major components from other states or countries. Many developers view shipping cost as a main issue compared to the manufacturing cost of the various components.[11] However, the development of an in-state supply-chain would be much preferable from the economic standpoint, as the establishment of new hubs of wind manufacturing industry would bring well-paid jobs and other benefits to the host region. California's decision on the scale of OSW development in the next two decades would affect the market demand of wind generation equipment in the state, and the potential for major turbine manufacturers to invest and establish production sites in California (Collier et al., 2019; Burke et al., 2021).

Developing a California supply-chain for essential turbine components will also help lead to commercial-scale and therefore cost-competitive wind farms. Clear long-term state goals of OSW development and aligned market acceleration targets will facilitate the strategic establishment of an in-state wind manufacturing supply-chain. Other state policies, such as adopting financing mechanisms, building channels of knowledge exchange, attracting capital investment opportunities, establishing training capacity to prepare a skilled OSW workforce, and encouraging development of specialized wind port infrastructure, will also drive the establishment of local wind industry and supply chains in the state (American Jobs Project, 2019; DOE, 2021).

8.8. Decommissioning of offshore wind project

The final challenge of OSW projects is the decommissioning phase. While the U.S. is still in the initial stage of OSW development, many wind farms in Europe will be entering the lifetime extension, repowering, or decommissioning decision-making process. The decommissioning plans should ideally be integrated in the design phase of an OSW project. According to European experience, major challenges of OSW project decommissioning include: 1) limited and unclear guidelines and lack of specific regulations, 2) planning of the decommissioning process, 3) availability and cost of vessels to conduct the decommissioning activities; 4) the potential impacts to marine environment (Topham et al., 2019).

8.9. Short-term and unpredictable tax credits

The short-term nature of relevant subsidies and congressional pattern of not committing to consistent OSW tax credits makes it challenging for OSW developers to plan projects. These credits include both a production tax credit (PTC) and an investment tax credit (ITC). The PTC was extended by congress at 60% of its per-kilowatt value for one year in late 2020, and the ITC was set at 30% of the cost of a project that begins construction prior to 2026. As a result of their short-term nature, development drops when the credits expire and then increases again once the credits are reinstated. These incentives, while important for project financing, can create much uncertainty for OSW developers (Huxley-Reicher and Read, 2021). However, it should also be mentioned that, at the very end of 2020, the Internal Revenue Service (IRS) issued Notice 2021–05, which effectively extended the continuity safe harbor credits for qualifying offshore energy projects to ten years, meaning that any OSW project that begins construction prior to 2026 may delay operation for ten calendar years and still be eligible for the 30% ITC (IRS, 2020).

9. Benefit and co-benefit summary

Overall, offshore wind presents a number of attractive system, economic, and environmental attributes for California's electric grid and may help to achieve the goals outlined in SB 100. Its value proposition is attractive, as it is increasingly competitive with gas-peaker plants and solar/storage. In terms of reliability co-benefits, OSW has a generation profile complementary with solar, is a consistent generation source with high capacity factors, and, with proper transmission resources, can inject power directly into heavily populated coastal load centers. In terms of environmental co-benefits, it could also be instrumental in the early retirement of costly and pollution-heavy natural gas plants. There is also the potential to avoid degradation of important land that would otherwise be harmed by the construction of solar and onshore wind resources. OSW promises substantial job creation co-benefits. Moreover, California could reap additional economic co-benefits from the development of a local OSW industry, boosting manufacturing and creating still additional jobs. Additionally, OSW has the potential to advance environmental justice through its reduction of ordinary air pollutants in urban areas and can bring economic opportunities to lagging areas of the state.

Table 4 presents a summary of these findings. The first numerical column presents the best estimates and the second column presents a range for these estimates, given the uncertainties. In places where we did not perform the calculations ourselves, we present summaries of the findings of others. Final column of the table provides some comments to clarify the presentation.

Below we summarize important implications of our analysis results for the implementation of the OSW technology in other coastal states in the U.S. and other countries:

- Our framework for identifying and analyzing co-benefits of OSW has general applicability to all other locations.
- California's OSW resources are of equal magnitude and other desirable features as in many locations already implementing this technology and those not yet doing so, especially in developing countries, thereby providing an indication of the likely competitiveness of this electricity technology more broadly.

[10] Around the world, major manufacturers of wind turbines are located in Europe (e.g., UK, Germany, Denmark, France) and East Asia (e.g., China, Japan, and South Korea). According to the 2018 market assessment report by NREL, major wind turbine manufacturing facilities in the U.S. are concentrated in Ohio, Texas, Illinois, Wisconsin, and Colorado (Energy.gov, 2020).

[11] For example, the Block Island OSW project located in Rhode Island largely relied on sourcing of key components from out-of-state and foreign suppliers. This project used turbines and blades imported from France, and the foundations were constructed by an oil rig manufacturing firm in Louisiana (Musial et al., 2020a).

Table 4
Summary of benefits and co-benefits of offshore wind energy.

Benefit or Co-Benefit	Best Estimate	Estimate Range	Comment
Cost Saving	$1 billion (CEC, 2021)	up to $2 billion NPV (2030–40) (E3, 2019)	does not include transmission cost
Reliability	Improvement (complement to other renewables)	n.a.	complementary daily timing
Jobs – Construction	146,120 job-years (2020–2040);	96,970 to 195,271 job-years (2020–2040);	includes both direct and indirect jobs
Jobs – Operation	4246 annual jobs in 2040	3979 to 4513 annual jobs in 2040	includes both direct and indirect jobs
Jobs – Industrial Cluster[a]	45,578 job-years	25,057–66,908 job-years	in-state and exports to rest of U.S.
Environmental – Basic	$191.5 million	$42.56 to $340.45 million[b]	societal cost of carbon impact savings only
Environmental – Other	moderate reduction for ordinary pollutants; moderate reduction for land preservation (general literature)	n.a.	does not include all environmental impacts
Environmental Justice	improved health by race/income; economic stimulus for lagging regions (general literature)	n.a.	does not include all environmental justice attributes

[a] This analysis is only conducted for potential higher in-state production capacities of wind turbine components.
[b] Calculation assumes the development of 10 GW OSW in California would displace 5 GW gas-peaking power plants. The social cost of carbon data is for Year 2040 emissions. This estimate is based on an average of $9/ton for domestic climate change damages and $72/ton for global climate change damages (GAO, 2020).

- Reduction in greenhouse gas emissions will be the case for nearly all other sites, given the likelihood that OSW will displace fossil fuels.
- The displacement of fossil-fuel electricity generation is likely to take place in urban areas, thereby reducing concentrated local air pollutants, generally helping to improve environmental justice for local, more socially and economically vulnerable residents that typically live near such sites in industrialized countries.
- The need for additional transmission capacity to serve OSW generation, given its geographic remoteness, is likely to be the case for a great many prime resource sites.
- Most of the challenges confronting OSW in California are present universally, including environmental concerns, seaport capacity, complexity of permitting processes, and decommissioning.
- California provides examples of how government can positively support OSW development.
- Our analysis indicates how employment impacts can be increased significantly by the presence of more local OSW support industries, no matter what country is implementing this technology.

10. Conclusion and policy implications

We have analyzed the major benefit and co-benefits of offshore wind development in California. Although there are likely to be some negative side-effects and some details in relation to considerations, such as transmission lines and various externalities, still need to be worked out, we conclude that OSW is an attractive electricity alternative for the state's electricity generation mix.

Some specific examples of the various benefits and co-benefits of OSW include:

- Resource cost savings of at least $1 billion in providing clean electricity.
- Improved reliability of electricity services due to its higher and more stable capacity factors and the timing of its peak electricity generation.
- Job gains of the development of 10 GW OSW estimated to be a total of 97,000 to 195,000 job-years through 2040 for the construction of the wind facilities and another 4000 to 4500 annual operation and maintenance jobs, which translates into an additional 120,000 to 180,000 job-years of employment.
- Potential reduction of 4.73 million metric tons of carbon dioxide equivalents in the year 2040 if 5 GW gas-peaking capacity can be replaced under the scenario of 10 GW OSW deployment, translating into the prevention of up to $340.45 million of global climate change damages.
- Minimization/reduction of environmental impacts associated with the construction of land-based energy infrastructures such as onshore wind and solar.
- Improvements in environmental justice through the reduction of ordinary air pollution in socioeconomically disadvantaged urban areas of the state and construction of OSW facilities in some of its lagging regions.

At the same time, there are multiple challenges that must be addressed in order for OSW to reach its full potential in California. The first is affordability; floating OSW LCOE is currently more than double that of both solar-PV and land-based wind, and the technology is not expected to become cost competitive with these renewables until at least 2030 (Hull et al., 2019). In the case of a build-out on the North Coast, the state would also need to invest heavily in new transmission infrastructure (Severy and Jacobson, 2020). All candidate ports in California are also expected to require upgrades to enable OSW, and concerns have also arisen from the military, fishing industry, and conservationists worried about effects on the ocean environment. Despite these hurdles, offshore wind has the potential to play a pivotal role in meeting the goals set by SB 100, as well as turning California into a global hub for OSW development.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors wish to thank the sponsors of this study: The Energy Foundation (Grant Number: G-2008-32224), American Clean Power Association (ACP), and Offshore Wind California (OWC). We also thank Molly Croll (ACP) and Adam Stern (OWC) for their helpful suggestions on the study and access to their contacts. We also wish to thank Walter Musial from the National Renewable Energy Laboratory (NREL) and Arne Jacobson from Schatz Energy Research Center at Humboldt State University for providing their research reports on offshore wind and for answering our questions. We appreciate administrative support from Conyers Davis, Francisca Martinez, and Allison Kay of the Schwarzenegger Institute. We also wish to thank Xueliang Liu and Konstantinos Papaefthymiou for their research assistance. However, the authors are solely responsible for any errors or omissions.

Appendix A. Operating experiences with OSW in other states and countries

Global fixed-bottom OSW LCOE has dropped 67.5% to $84/MWh since 2012 and is expected to achieve $58/MWh by 2025 due to larger utility-scale projects, bigger turbines, and reduced cost of capital, which makes it comparable to or even cheaper than new gas and nuclear power (Lee and Zhao, 2020). OSW also has a high capacity factor (yielding more energy per unit of installed capacity). For instance, the Hywind floating OSW farm demonstrated a capacity factor of 65%, which is two to three times that of solar, nearly twice that of land-based wind, and even greater than that of coal (American Jobs Project, 2019).

Floating OSW is expected to account for 6% of neNw installations internationally in 2030 (Lee and Zhao, 2020). As of the end of 2020, there were around fifteen floating offshore wind projects in demonstration and trial phases. 2020 was actually a surprisingly prosperous year for OSW, in spite of the COVID-19 pandemic; in fact, the level of OSW capacity with a signed offtake agreement more than tripled between March 2019 and March 2020 (Huxley-Reicher and Read, 2021). There are also many floating projects in pre-commercial phases, with 1100 MW under construction and planned to be built by 2025. The scale of floating offshore farms is expected to increase significantly over the next ten years, with other projects recently announced to approach 2 GW by around 2030 (Lee and Zhao, 2020). Moreover, the Global Wind Energy Council projects that more than 70 GW of OSW capacity will be installed globally between 2021 and 2025 (Lee and Zhao, 2021). The International Energy Agency also anticipates that an annual development of around 80 GW of OSW will be installed worldwide in 2030, slowing to 70 GW annually by 2050 (Bouckaert et al., 2021).

The majority of OSW projects have thus far required government financial support, as the initial high-costs would otherwise make the resource uncompetitive with other renewables. In the U.S. east coast, OSW development has been promoted through a mix of capacity targets, investment tax credits, and research support. New projects are in various stages of development across the eastern seaboard, with total capacity commitments in eight states at a minimum of 29 GW by 2035 (OWC, 2021). Other initiatives to support an OSW rollout have been announced by New York and New Jersey, which have committed to upgrading ports for the purposes of OSW development (Huxley-Reicher and Read, 2021).

Appendix B. Basic cost considerations

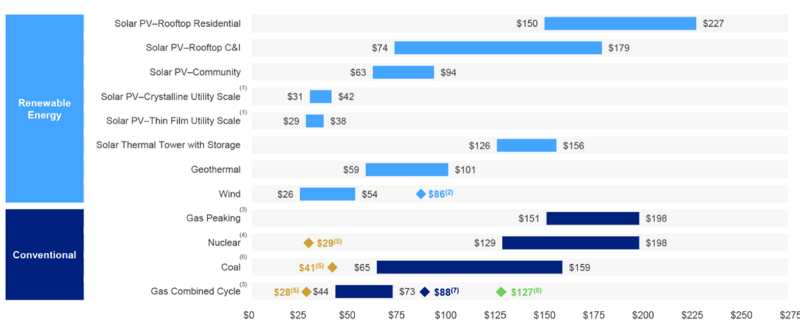
A. Electricity generation

The levelized cost of energy (LCOE) is the most widely used measure of the average cost of electricity generation over the entire lifetime of a facility. It provides a consistent basis to compare the cost of electricity generation using different energy sources and technologies. The LCOE includes both the capital cost expenditures (CapEx) and operational cost expenditures (OpEx). The former includes, for example, cost of the offshore wind turbine, platforms, electrical infrastructure, mooring and anchoring system, and installation costs. The OPEX cost can be divided into operation and maintenance cost, which consist primarily of labor cost and shipping cost (Maienza et al., 2020).

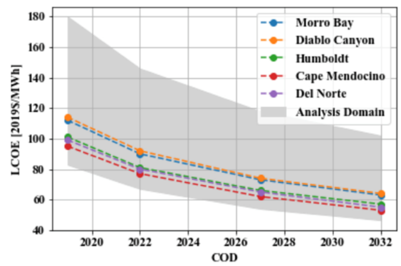
California offshore wind facilities would necessitate the use of floating turbines due to the state's deep coastal waters. Because of the nascent nature of this platform technology, the most recent NREL reports estimate that the current LCOE of floating OSW is about $113/MWh, and that the first offshore farms in California will arrive at an LCOE of about $92/MWh in the early-mid 2020 s. The LCOE is projected to decrease to $53-$64/MWh in 2032 (Beiter et al., 2020c). For comparison (see Appendix Fig. B1), solar-PV and onshore wind currently are at around $29–42/MWh and $26–54/MWh, respectively (Lazard, 2020). Natural gas combined-cycle generation has an LCOE range of about $44–73/MWh, and gas-peaking plants have an LCOE range of about $151–198/MWh. Floating wind farms are therefore at the moment only cost competitive with natural gas peaking plants, and still fall short of equalizing the energy costs of combined-cycle gas plants, as well as solar and onshore wind farms. However, it will become more economically viable in early 2030s

Despite the expectation of relatively high costs for floating OSW farms with CODs in the early-mid 2020s, by late this decade and early into the next, technological innovations in turbine size, as well as increased wind farm scale and industry standardization, could substantially reduce the cost differential between offshore wind and land-based renewables. This could help OSW play a large, complementary role in the state power mix (Collier et al., 2019).

Additionally, based on interviews with industry experts, floating offshore wind could actually become more economical than fixed-bottom offshore wind in certain locations, and could decrease in cost at a faster pace than fixed-bottom offshore wind, even at depths that



Appendix Fig. B1. Levelized Cost of Energy Comparison. Note: For wind generation, the estimate of $86/MWh represents implied midpoint of the LCOE of offshore wind, assuming a capital cost range of approximately $2,600-$3675/kW.
Source: Lazard (2020).



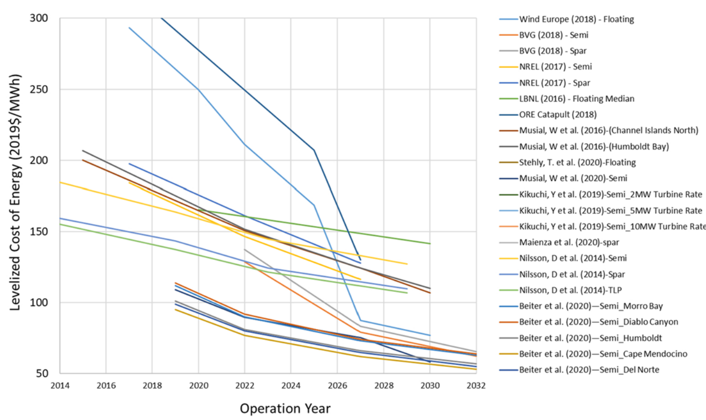
Appendix Fig. B2. Global LCOE Estimates for Floating Wind Farms.
Source: Beiter et al. (2020c).

would be feasible for both types of technologies. This potential cost advantage can be attributed with more portable components, scalable quayside manufacturing and assembly, and increasing ease of installation. These characteristics can allow floating platform components to scale using automated production in a way that would be more difficult for fixed-bottom components (Amul et al., 2020).

Accordingly, in the latest NREL estimation (Beiter et al., 2020c), the LCOE of floating OSW projects with a wind plant size of 1 GW at the five reference areas in California is projected to reduce from an average of $113/MWh in 2019 to $64/MWh in 2032, or a decline of 43% (see Appendix Fig. B2).

In Appendix Fig. B3, we depict the estimated LCOE of floating OSW projects over time based on the data gathered from the literature. All studies project steady declines of LCOE of floating OSW over the next decade. Another observation is that given the rapid development of the OSW technology (such as the significant increase in turbine size and plant size) in recent years, the estimated LCOE of commercial-scale OSW has decreased significantly in the studies. The major difference in the cost estimates across the studies that were conducted in different years is the estimates of capital expenditures. For example, the projected capital cost of OSW in 2032 dropped from about $4900/KW in Musial et al. (2016a) to about $3050/KW in Beiter et al. (2020c).

Moreover, although OSW is more expensive than solar on an LCOE basis, the economic value of offshore wind may rest in its potential to offset future costs of solar-PV generators with battery storage. As a variable renewable energy (VRE) source, offshore wind also has relatively low operating and fuel expenses in comparison to thermal generators. OSW generation enters the merit-order bid stack at a marginal cost near zero and can thus decrease the wholesale electricity price (Beiter et al., 2020b). Furthermore, OSW is expected to remain cost-competitive in comparison with potential out-of-state (OOS) wind resources and is projected to remain cost-competitive with solar even if operational and storage costs for solar generation facilities fall faster than expected (Collier et al., 2019; Hull et al., 2019). Ultimately, OSW can bring immense value to California's energy portfolio, and in spite of its present relatively high costs compared to utility scale solar PV, onshore wind, and NGCC, technological innovations and industry maturity will allow this source of renewable power to compete



Appendix Fig. B3. Comparison of Floating OSW Cost Trends Estimated in Various Studies.
Source: Developed by the authors based on LCOE data collected from the literature.

effectively with other types of generation technologies in the near future.

B. Transmission

The costs associated with building transmission infrastructure to support OSW deployment must also be analyzed in order to understand the extent of necessary co-expenditures. The greatest investment in transmission capacity would be required by an OSW build-out on California's northern coast, in and around the Humboldt region. This is because the infrastructure currently operating in this area of California is only designed to serve local loads, as opposed to moving electricity to other areas in the state. Connecting OSW to the grid would therefore necessitate upgrading or constructing entirely new cables and substations. These costs would ultimately fall on the wind farm developer; however, California ratepayers could end up footing the bill as well due to the pass-through of transmission access charges paid out by load-serving entities (Severy and Jacobson, 2020).

Electric generation and distribution are the largest components of electric rates. Utility-owned generation and purchased power sources, plus distribution, collectively account for approximately 80% of electric rates from California's three largest investor-owned utilities (IOUs): Southern California Edison, Pacific Gas & Electric, and San Diego Gas & Electric (Hurd et al., 2019).

Severy and Jacobson (2020) examined three OSW deployment scenarios on the North Coast to assess potential transmission routes and their respective costs. These scenarios include a Pilot Scale OSW farm (48 MW), a Small Commercial Scale OSW farm (144 MW), and a Large Commercial Scale OSW farm (1836 MW). Both overland and subsea transmission routes are considered for a large commercial scale OSW project connecting to major transmission lines in California or large load centers. The state's largest load-serving entity, Pacific Gas & Electric, notes that this size of a generator far outpaces the capability of regional power lines (Severy and Jacobson, 2020). The cost estimates for the Pilot Scale, Small Commercial Scale, and Large Commercial Scale OSW farms are $540 million, $970 million, and $1.7 to $3.0 billion, respectively. For the large 1836-MW commercial-scale projects, the unit transmission costs are estimated to be $938/kW to $1090/kW for the on-land transmission option and $1313/kW to $1630/kW for the subsea transmission option.

One important qualification of these estimates is that they assume transmission improvements are completed in a way that avoids OSW curtailment entirely. This could impact transmission upgrade requirements and likely lead to higher overall transmission costs. The most cost-effective transmission option may also be associated with an installed OSW capacity much larger than 1.8 GW, which would indeed be feasible given the available technical resource. Strictly speaking, larger scale projects would result in declining transmission cost upgrades per unit of installed capacity.

Outside of California, transmission studies have similarly been conducted for the expansion of OSW energy in the eastern United States. A recent grid study for New York state estimates that transmission costs to connect an 8.5 GW OSW farm could approach as high as $793/kW; a prior analysis for New York state also estimated that transmission costs for a 7.2 GW OSW farm could range from $917/kW to $986/kW (Pfeifenberger et al., 2020; Pfeifenberger et al., 2021).

Regarding current transmission availability, it should be noted that the first California offshore wind farm could be in waters near Diablo Canyon nuclear plant, whose reactors are slated to close in 2025. Wind farms in these locations could connect with the transmission lines surrounding these nuclear power plants to lower the cost. It would be especially easy and inexpensive if the projects are built in waters near Santa Barbara County and San Luis Obispo County. Wind farms in this area could easily connect with the 2 GW transmission line at the Diablo Canyon nuclear power plant or the 600 MW interconnection at Morro Bay Power Plant (Collier, 2017). While analysis of North Coast transmission requirements has been completed, little study has been accomplished concerning transmission needs and/or costs on California's central coast. However, CAISO has indicated that it would be manageable to connect somewhere around 3–4 GW of OSW capacity to the grid along the Central Coast (CAISO, 2019). CPUC staff have also commented that 5 GW of transmission capacity is available in California's Central Coast (CPUC, 2020). Further evaluations will need to be finalized in the future for central coast wind farms to be considered, which is significant given the large potential for the Morro Bay and Diablo Canyon call areas. This type of assessment is expected to be accomplished as part of the OSW sensitivity in the CAISO 2021–2022 Transmission Planning Process (TPP).

Appendix C. Comparison with other studies

Speer et al. (2016) estimated the economic impacts of the construction and operations of two hypothetical offshore wind development scenarios (10 GW vs. 16 GW installed capacity) between 2020 and 2050 in California. The total employment impacts of the buildout of 10 GW offshore wind in California are estimated to be about 130,800 job-years between 2020 and 2050. Our lower RPC scenario uses similar assumptions of local content shares as in the 10 GW development scenario in Speer et al. (2016). Our impact estimates are lower compared to the results in Speer et al. (2016) primarily because of the considerably lower estimates of the capital cost of OSW capacity between the 2016 and 2020 NREL studies (Musial et al., 2016a, Beiter et al., 2020c).[12]

Hackett and Anderson (2020) estimated the economic iImpacts of offshore wind projects in Humboldt Bay and Cape Mendocino area. The estimated job impacts range from 2000 for a 48 MW pilot project to 13, 000 for a 1836 MW commercial-scale project. The job estimates for the commercial-scale development are comparatively lower than the estimates in Wei et al. (2021) (even after the adjustment of the difference in total installed capacity). This difference is mainly a result of the relatively lower local (in-state) content shares assumed in Hackett and Anderson (2020).

The American Jobs Project (2019) estimated that the capital investment of 18 GW offshore wind capacities in California can create about 5500, 9000, and 13,000 jobs, respectively, in the last year of each of three phases of development over a 20-year period. This translates to about 185,000 job-years over the entire study period, which is close to our lower-bound estimate after adjustment for the difference in total buildout capacities.

Zhang et al. (2020) analyzed the potential economic impacts associated with the offshore wind investment activities as a result of lease auctions by BOEM between 2020 and 2022. In California, a total of 9 GW offshore wind capacity could be installed by 2040 in response to the anticipated auctions. It is estimated that an average of 38,000 jobs can be supported annually over a 5-year construction period. This translates to about 190,000 job-years, which comes close to our upper-bound estimate.

Hamilton et al. (2021) analyzed the regional economic impacts for a development of 3–7 GW OSW along the central coast of California. The Regional Economic Models, Inc. (REMI) Policy Insight Plus (PI+) model is used to estimate the economic impacts on San Luis Obispo County (assuming a specialized wind port is constructed in the County) and rest

[12] For example, the estimated per MW capital investment costs for OSW projects in the Central Coast area in Beiter et al. (2020c) are 33% lower in 2022 and 43% lower in 2032 compared to the cost estimates in Musial et al. (2016a) primarily because of the higher turbine rating and larger plant size assumed in the latter study. Note that lowered capital investment costs per MW of installed capacity of OSW, although increasing the cost competitiveness of the OSW technology compared to the other power generation technologies, are associated with lower economic impacts. This is because economic activities stimulated are primarily driven by the size of the total expenditures of projects.

of California. For the 7 GW OSW development scenario, the study estimated creation of 72,162 full-time equivalent (FTE) job-years. These include the jobs associated with the construction of the specialized wind port, assembly of OSW turbines at the port, and the maintenance and repair of the OSW turbines there. If the estimate in this study is scaled up to 10 GW, the job impacts would be closer to the lower-bound estimate in our study.

Finally, our estimated annual employment impacts in the operation phase of 10 GW offshore wind facilities are within the range of 2000 to 5000 jobs per year found in the other studies reviewed above.

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Questions for the Record
from Senator Chris Van Hollen
to Dr. Adam Rose
Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains
10-25-2023
Senate Budget Committee

Question #1:
Maryland's Port of Baltimore is the #1 importer and exporter of roll-on and roll-off cargo, like farm and construction machinery and automobiles. And, in 2022, the Port handled a record 43.3 million tons of international cargo, valued at $74.3 billion. Dr. Rose, can you explain the magnitude of how climate-related disruptions reducing efficiency at our ports could impact global markets?

Senator Van Hollen, thank you for the question.

Overall, the world economy is highly interdependent, and any major disruption to one sector or major facility, such as a seaport, in one location reverberates throughout it. The closing of the Port of Baltimore for a few days due to a hurricane, whose intensity has been increased by climate change, could cause delays and production cutbacks in the U.S. and other countries totaling in the tens of billions of dollars. Below are some examples of disruptions and their climate related causes.[1]

The Port of Baltimore, like ports everywhere, faces a wide range of climate related disruptions. This past September, the U.S. Coast Guard was forced to close the port for a 24-hour period due to tropical storm Ophelia.

https://www.news.uscg.mil/Press-Releases/Article/3535761/coast-guard-sets-port-condition-modified-zulu-for-port-of-baltimore/

While tropical storm modeling is not my area of expertise, I'll note that a growing body of evidence points to more storms, especially along the U.S. Eastern Seaboard.

https://www.nature.com/articles/s41598-023-42669-y

Such events disrupt normal trade activity and lead to cascading effects across the supply chain.

Another disruption, relevant to the Port of Baltimore, is the reduced capacity of the Panama Canal. Drought in the region has reduced the available water needed to operate the Canal, and ships are experiencing longer wait times.

[1] I wish to thank Captain Andrew Tucci, U.S. Coast Guard (retired) and Professor Fred Roberts, Rutgers University for these examples

https://www.nytimes.com/2023/11/01/business/economy/panama-canal-drought-shipping.html

Sea level rise is a threat to port infrastructure, and the experience that the New York City had with tropical storm Sandy in 2012 will likely occur again elsewhere. Salt water flooding of cargo areas, cranes, utilities, and connecting roads and railways can cause significant damage and will disrupt trade activity. The relatively flat, low-lying areas surrounding the Chesapeake Bay may make the region especially vulnerable to such events.

Sea level rise could have long-term effects on ports like Baltimore's where there are some low-lying areas. This might require moving certain operations, and is not limited to the terminals themselves. Ports are intimately connected to other components of the transportation system, which might mean moving of railroad tracks for example. Power supply, especially as ports are increasingly automated, is also potentially impacted, with the potential need to move power plants to higher ground. All of this takes long-term planning.

Increasing heat events are likely to require modifications in hours of port operations, with workers given more time off for hydration and possibly even shorter work days on days of intense heat. Heat could also affect the need to cool support systems such as large computer facilities and certainly increase the cost of heating and cooling at terminals and for cargo needing refrigeration.

The worldwide marine transportation system is interconnected in complex ways. Disruptions from climate change that are felt in one port will impact other ports, and so it is necessary, in planning for the future of the Port of Baltimore, to understand climate change in those ports around the world that are major sources of or destinations for commodities handled in Baltimore.

Questions for the Record
from Senator Ben Ray Lujan
for Ms. Kathy Fulton
Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains
October 25, 2023
Senate Budget Committee

Question: In New Mexico, the Rio Grande River is the lifeblood of our state's economy, and it is in crisis. The Rio Grande sustains the thousands of farms along the river corridor, as well as the high-tech semiconductor, aerospace, and space industries in New Mexico. In 2018, and again in 2021, the Elephant Butte Reservoir that stores much of the state's irrigation water was practically empty. In both years, the reservoir delivered only a fraction of the water needed by our farmers and ranchers. Continued warming, earlier snowpack melt, and stronger drought will produce more years like 2018 and 2021 in the decades ahead. Unfortunately, that is something we can be certain of. Ms. Fulton's testimony focused on the how rapidly evolving extreme weather events – like hurricanes – impact supply chains. What we are seeing in the Rio Grande River Basin and in other rivers across the West is a slowly evolving disaster where, each year, we should expect less water.

In terms of building resilient supply chains, how do we bring the same sense of urgency to addressing the disasters that will build over years as we do to hurricanes, wildfires, and other extreme events?

Answer: I am grateful to Senator Luján for raising the example of the Rio Grande River Basin. Concerns about water – for crops, for industry, and for human hydration – continue to rank high among risk concerns. The 2023 World Economic Forum Global Risks Report found that, "In the absence of appropriate intervention, water availability is now a concern in all regions."[1] Yet risk management policies and practice still tend to focus on rapid-onset, short-notice events, rather than relatively slow-onset climate-related crises or systemic vulnerabilities.

Despite multiple studies showing that mitigation investments save money post-disaster[2,3], neither governments nor businesses have fully embraced ways to prevent, mitigate, or diversify away from strategic risks. A recent survey by PricewaterhouseCoopers found that less than one-fifth of firms have "implemented initiatives to protect their workforce or physical assets from the impacts of climate risk."[4] Meanwhile, research from Accenture shows that businesses who have invested in resilience show an additional 3.6% revenue growth compared to their less resilient peers.[5]

Rapid onset disasters provide ample visual evidence of their destruction, like downed foliage, or damaged homes and businesses. Slow-onset, long-term stress related disasters, even when accompanied by visual cues like low water levels in reservoirs and or rising salinity in rivers[6], do not always get the attention of rapid onset disasters because they evolve over time. Thus, the challenge of creating urgency to address them.

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1 https://www.weforum.org/publications/global-risks-report-2023
2 https://www.fema.gov/sites/default/files/2020-07/fema_mitsaves-factsheet_2018.pdf
3 https://www.nibs.org/files/pdfs/NIBS_MMC_MitigationSaves_2019.pdf
4 https://www.pwc.com/gx/en/issues/esg/how-climate-adaptation-can-both-protect-and-grow-your-business.html
5 https://www.accenture.com/us-en/insights/industry-x/engineering-supply-production-resiliency
6 https://www.mvn.usace.army.mil/Missions/Engineering/Stage-and-Hydrologic-Data/SaltwaterWedge/SaltwaterWedgeNow/

There is no quick fix for the Rio Grande River Basin or other crucial capacity concentrations – it is a wicked problem requiring cross-sector collective action. But lack of a quick fix should not equate to a lack of urgency. An early 2020 National Academies of Science, Engineering, and Medicine consensus study[7] offers recommendations for an approach to support collective actions. The first and fourth recommendations are related to distribution planning and supply chain education. But the second and third recommendations hold promise for the supply chains served by the Rio Grande:

- Build system-level understanding of supply chain dynamics as a foundation for effective decision support.
- Support mechanisms for coordination, information sharing, and preparedness among supply chain stakeholders.

Understanding the supply chain dynamics – the supply "ecosystem" of the Rio Grande, and then building mechanisms for those supply chains to coordinate and prepare together, is a strong first start to collective solution identification. Again, it is not a quick fix, but it is something that can begin immediately.

Thank you again for this insightful inquiry. I welcome any follow-on questions.

[7] https://nap.nationalacademies.org/catalog/25490/strengthening-post-hurricane-supply-chain-resilience-observations-from-hurricanes-harvey

Questions for the Record
from Senator Charles E. Grassley
for Dr. David Barker
"Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains"
October 25, 2023
Senate Budget Committee

Question #1:

The testimony submitted by Dr. Rose expressed his findings of a $18.1 billion loss in U.S. GDP due to climate change. Is there any way to determine if his modeling is accurate? Moreover, do you have a topline estimate for the impact of climate change on U.S. GDP in the foreseeable future?

Answer:

Dr. Rose estimated that climate change would cause an $18.1 billion loss of GDP due only disruptions to shipping on the Mississippi River. Unfortunately, he provides no link to the research that produced this result, only a footnote referencing a forthcoming publication. An Internet search for the paper was unsuccessful. In order to evaluate the plausibility of Dr. Rose's estimate, it would be useful to know how easily the model he used allowed substitution between barge, rail and truck transportation, the discount rate used to convert future losses into a net present value of losses, and other assumptions that were built into the model.

It is clear from other research published by Dr. Rose and from his written testimony that he is not directly modelling climate change. Instead, he assumes that climate change will be responsible for drought, damage to Lock and Dam 27, and hurricanes affecting shipments through New Orleans. He simply says that "the most likely cause" of drought is climate change and that Lock and Dam 27 is "especially vulnerable to climate change" and that an interruption of shipments through New Orleans "could also be due to climate change, since this city is a typical bull's-eye for hurricanes." No evidence of the probabilities that climate change will have these effects is provided in Dr. Rose's testimony.

Given the information I have received, there is no way to determine if Dr. Rose's modeling is accurate.

The best estimate of the total effect of climate change on the economy is provided by the DICE model created by William Nordhaus. It predicts that if nothing at all is done to reduce greenhouse gas emissions, GDP in the year 2100 will be 2.6% lower than it would be with no climate change. Assuming a normal rate of economic growth, this would mean that GDP will be 4.9 times today's level instead of 5 times today's level. The effects in years before 2100 would be even less.

In my testimony I explained why there is no reason to believe that climate change will lower the rate of economic growth. There are many unknown factors that will affect GDP over the next 77 years by far more than the small effect of climate change, and many risks that are much greater, such as ballooning government debt, regulation that discourages technological innovation, and war.

Question for the Record from Ranking Member
From Senator Charles E. Grassley
for Mr. Robert McNally
Bottlenecks and Backlogs: How Climate Change Threatens Supply Chains
October 25, 2023
Senate Budget Committee

Question #1:
Senator Whitehouse inserted a Time Magazine op-ed titled, "A World Without Fossil Fuels Funding Our Enemies Would Be A Safer World for America", into the record. It reads, "a global transition to renewable energy would greatly assist in our nation's fight against the world's most corrupt and illicit regimes." Is this overwhelming "renewable transition" even feasible? What does history tell us about the impact of attempts to rapidly transition away from fossil fuels?

Answer:

There is no chance that the world will overwhelmingly switch to renewable energy in the near future, which is defined as the next few decades. This is because of the inherently slow and incremental nature of energy transitions and prevailing physical, engineering, and economic realities.

Hydrocarbon energy (oil, natural gas, and coal) accounts for nearly 80% of global energy use and has delivered humanity from millennia of squalor, darkness, immobility, and discomfort. Wind and solar combined account for 5%. Even broadening the definition of "renewable" to include biomass and hydroelectric power raises the global share to only 11%.[1] Hydrocarbon energy's past and future dominance relative to renewables arises from its abundance, energy density, ease of storage, and sunk capital investment in supply chains and end-use equipment.

As leading energy expert Vaclav Smil has noted, policy attempts to hasten energy transitions will not succeed. Smil wrote, "[h]istorical evidence shows that energy systems, the most complex and capital-intensive mass-scale infrastructure of modern societies, are inherently highly inertial, and that our determination can accelerate their change but cannot fundamentally alter the *gradual* nature of their evolution."[2] (Emphasis added.)

Moreover, as noted in my prepared testimony, my firm's research concluded that policies that restrict energy supply or increase energy costs often spark unrest. Most often, governments respond to this unrest by reversing the policy. Larger oil-consuming countries, especially those with oil consumption higher than 450 kb/d, are often unwilling to bear the political pain of sustained price increases that spark public resistance. Examples include France's brief attempt to impose a carbon tax on diesel fuel that triggered the "Yellow Vest" social protest and, more recently, Germany's dilution and delay to a planned ban on natural gas-fired home heaters.

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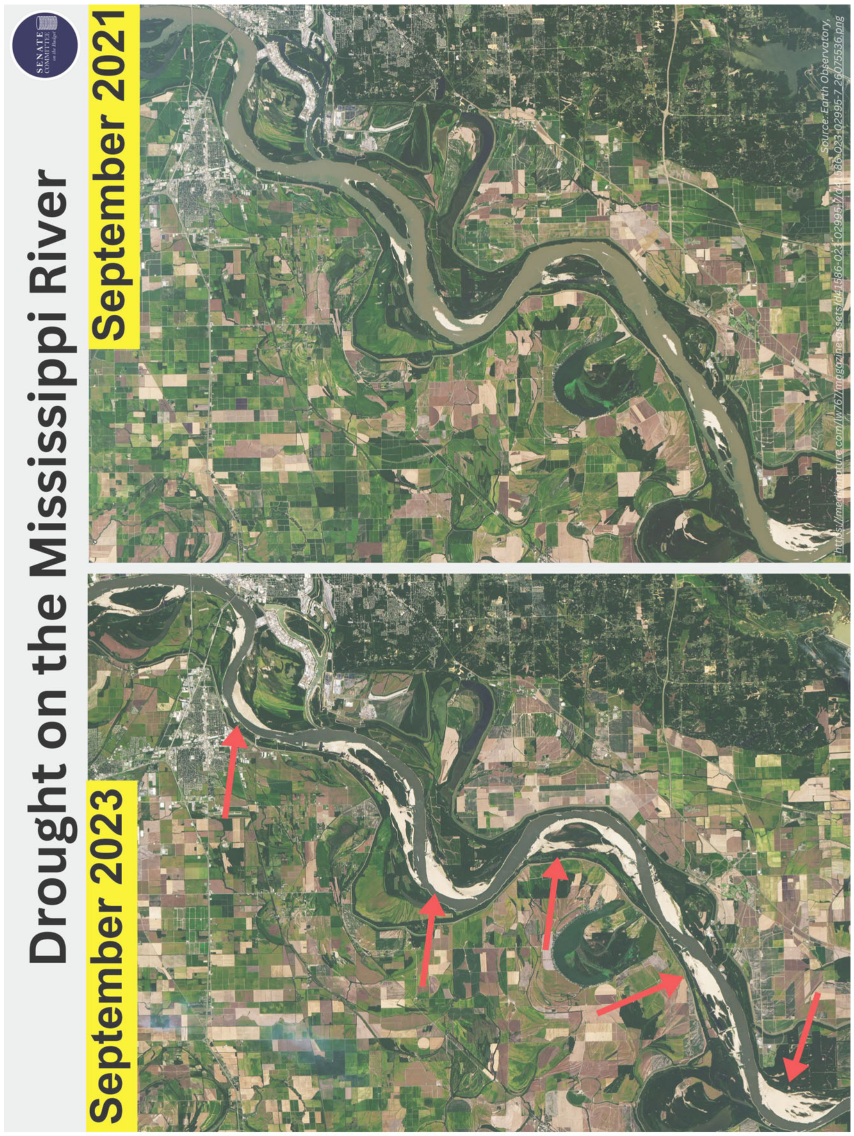
[1] International Energy Outlook, 2023 Energy Information Administration. Figure 6 data. https://www.eia.gov/outlooks/ieo/narrative/index.php
[2] Vaclav Smil. *Energy Myths and Realities*. (Washington, D.C.: The AEI Press, 2010), p. 59

The perceived supply losses brought on by Russia's invasion of Ukraine last year served as a stress test for 2022 fuel price spikes, revealing how governments responded to an abrupt, supply-driven price increase for oil and gas. The stress test showed governments rushed to reduce the burden those energy price increases placed on consumers. Western governments, predominantly European, initially allocated $750 billion to direct stimulus, tax cuts, subsidies, and corporate bailouts, hoping to lessen the bite of soaring energy costs on their citizens.

- Twenty-three governments subsidized or lowered taxes on gasoline, diesel, natural gas, and electricity, making this the most popular policy response to increased energy costs.
- Twenty-one governments issued direct stimulus to households to help with monthly bills and pump prices.
- Six governments rolled back or delayed existing climate policies like renewable fuel obligations, levies to fund renewables deployment, GHG targets and carbon taxes, and EV subsidies.

While hydrocarbon energy use entails negative externalities, including ambient pollution and greenhouse gas emissions, it is and will remain the lifeblood of modern civilization. Any suggestion that the world can soon transition, or revert, to running entirely on renewable energy is a pure fantasy. To accelerate energy transitions, officials should avoid costly mandates, bans, and other forms of winner-picking industrial policy and instead support basic scientific research that leads to new and innovative technologies, processes, and materials.


Drought on the Mississippi River
September 2021
September 2023
SENATE COMMITTEE
Source: Earth Observatory

For the Record

TIME

IDEAS • ECONOMY

A World Without Fossil Fuels Funding Our Enemies Would Be A Safer World for America

BY LINDSEY GRAHAM AND SHELDON WHITEHOUSE JUNE 17, 2021 10:09 AM EDT

IDEAS

Sheldon Whitehouse, a Democrat, represents Rhode Island in the U.S. Senate. Lindsey Graham, a Republican, represents South Carolina in the U.S. Senate.

We are a conservative Republican and a progressive Democrat who disagree on a great many things. We write today, however, to highlight an area of strong agreement: a global transition to renewable energy would greatly assist in our nation's fight against the world's most corrupt and illicit regimes. If you could wave a magic wand, and transition the world away from fossil fuels, Americans would instantly be safer.

Oil and gas development has often been associated with autocracy and corruption. Governments in countries such as Russia and Iran have used oil and gas to threaten neighbors and fund terrorism. Corruption, autocracy, and terrorism are a persistent threat to nations that stand on the rule of law, and America has long been the exemplar of the rule-of-law nation. A world in which oil and gas money has less power is a world that will likely have less corruption, autocracy, and terror. That world will be a safer world for America.

Let's be more specific. Iran is the most dangerous enemy we have in the Middle East. Iran is the largest state sponsor of global terrorism today, and a serial human rights abuser at home. It is the implacable enemy of our ally and friend, Israel. It is developing nuclear weapons, which would create a nightmare arms race in the already unstable Middle East. And Iran keeps itself afloat on tens of billions of dollars of export revenues from its oil and gas industry. It has vast oil and gas reserves, with one field estimated to have a trillion dollars in production capacity. Deprive Iran of that revenue, and it becomes a less dangerous nation. Without the potential for future fossil fuel revenue, Iran would have a strong incentive to engage in the world economy in ways that would force it to stand down from its worst behavior, and, hopefully, even join the community of nations. The Middle East becomes a safer place.

Look at Russia. Russia is the most dangerous enemy we have in Europe, and poses a threat to our interests around the world. Russia is the primary sponsor of autocracy, corruption, and discord in Europe. Russia's agents commit murders in London; Russia's army occupies Eastern Ukraine, Crimea, and parts of the Republic of Georgia. Vladimir Putin's petro-politics leverages Russian gas supplies to put constant hostile pressure on its Western neighbors. Russia was memorably described by our departed friend Senator John McCain as "a gas station run by a mafia … masquerading as a country." Take away the gas in the gas station, and the gangsters have nothing to run their gang. Without that source of money and power, Russia's ability to bully and corrupt its neighbors diminishes, its gangster oligarchs have less to steal, and its economy shrinks from the size of Italy's to the size of Switzerland's. All of Europe becomes a safer place.

Look at Saudi Arabia. Nominally our strategic partner, Saudi Arabia has a history of funding madrassas that spawned and nurtured anti-Western hatred and recruited terrorist fighters. The Saudi government was responsible for the disgusting murder of Jamal Khashoggi, a U.S. permanent resident who was dismembered at a Saudi consulate in Turkey. His remains have still not been recovered. Only recently have Saudis allowed women to get behind the wheel of a car in their country. Sunni extremism would dramatically diminish if its Saudi oil financing expired.

Our point today is not about climate change. That has its own set of national security concerns. This is about who our friends are and who our foes are; and what the stabilizing and destabilizing forces in our world are. This is about where our foes, and the forces they employ like terror and corruption, get their resources. All too often, it's from extractive industries like oil and gas. Some see this as a "resource curse" in which countries with wealth to extract fail to develop healthy models of governance. One need not agree on the reasons to observe the fact, and we cannot leave the damage unaddressed.

The fact is simple: a world without fossil fuel resources funding foreign adversaries would be a safer world for America.


World Climate Declaration
THERE IS NO CLIMATE EMERGENCY
1609 SIGNATORIES
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World Climate Declaration

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There is no climate emergency

Climate science should be less political, while climate policies should be more scientific. Scientists should openly address uncertainties and exaggerations in their predictions of global warming, while politicians should dispassionately count the real costs as well as the imagined benefits of their policy measures

Natural as well as anthropogenic factors cause warming

The geological archive reveals that Earth's climate has varied as long as the planet has existed, with natural cold and warm phases. The Little Ice Age ended as recently as 1850. Therefore, it is no surprise that we now are experiencing a period of warming.

Warming is far slower than predicted

The world has warmed significantly less than predicted by IPCC on the basis of modeled anthropogenic forcing. The gap between the real world and the modeled world tells us that we are far from understanding climate change.

Climate policy relies on inadequate models

Climate models have many shortcomings and are not remotely plausible as policy tools. They do not only exaggerate the effect of greenhouse gases, they also ignore the fact that enriching the atmosphere with CO_2 is beneficial.

CO_2 is plant food, the basis of all life on Earth

CO_2 is not a pollutant. It is essential to all life on Earth. More CO_2 is favorable for nature, greening our planet. Additional CO_2 in the air has promoted growth in global plant biomass. It is also profitable for agriculture, increasing the yields of crops worldwide.

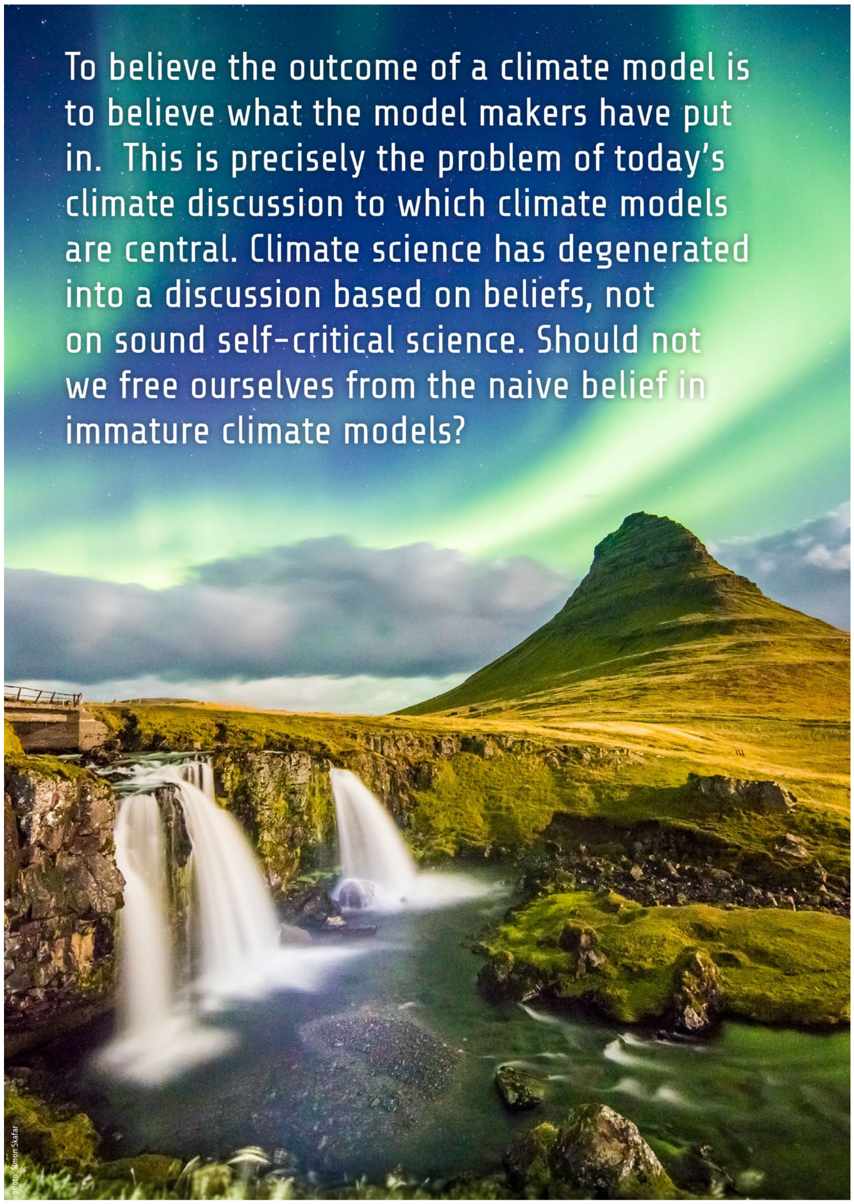
Global warming has not increased natural disasters

There is no statistical evidence that global warming is intensifying hurricanes, floods, droughts and suchlike natural disasters, or making them more frequent. However, there is ample evidence that CO_2-mitigation measures are as damaging as they are costly.

Climate policy must respect scientific and economic realities

There is no climate emergency. Therefore, there is no cause for panic and alarm. We strongly oppose the harmful and unrealistic net-zero CO_2 policy proposed for 2050. Go for adaptation instead of mitigation; adaptation works whatever the causes are.

OUR ADVICE TO THE EUROPEAN LEADERS IS THAT SCIENCE SHOULD STRIVE FOR A SIGNIFICANTLY BETTER UNDERSTANDING OF THE CLIMATE SYSTEM, WHILE POLITICS SHOULD FOCUS ON MINIMIZING POTENTIAL CLIMATE DAMAGE BY PRIORITIZING ADAPTATION STRATEGIES BASED ON PROVEN AND AFFORDABLE TECHNOLOGIES.


To believe the outcome of a climate model is to believe what the model makers have put in. This is precisely the problem of today's climate discussion to which climate models are central. Climate science has degenerated into a discussion based on beliefs, not on sound self-critical science. Should not we free ourselves from the naive belief in immature climate models?

The undersigned:

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5. David Archibald, Research Scientist
6. Rick Armstrong, retired metallurgist and strategic planner
7. Michael Asten, Retired Professor in Geophysics and Continuing Senior Research Fellow at the Monash University, Melbourne
8. József Balla, retired teacher and manager of a small business
9. Stuart Ballantyne PhD, Senior Ship Designer, Sea Transport Corp.
10. Jeremy Barlow, Energy and Mining professional, Director and CEO
11. Dr. Colin M. Barton, Geologist, Retired Civil Engineer with Experience in Project Control, Research and Professional Training, Honorary Fellow RMIT University Australia
12. Gordon Batt, Director GCB Investments Pty Ltd.
13. Maxwell Charles S. Beck, lifetime of experience in law, retired Magistrate and Coroner on the bench
14. Robert M. Bell, Retired Geologist, Victoria
15. Karen Benn, Double major PhD Biologist and Environmental Scientist, Government Policy, Educator and University Lecturer in Sciences, Biology, Environmental Sciences, Water Quality and Water Resource Management
16. Richard Blayden, Professional Engineer
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18. Howard Thomas Brady, Member Explorers Club of New York, Member of the Australian Academy of Forensic Sciences
19. Geoff Brown, Organizer of a Critical Climate Group
20. Andrew Browne, Exploration Geoscientist, Fellow AusIMM (CP), 50 Years Global Experience
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23. Douglas Buerger, Fellow Australasian Institute of Mining and Metallurgy, Member of Australian Institute of Comapany Directors
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30. Michael F. Clancy, Retired Civil Engineer, Brisbane
31. Martin Clark, Expert in Building Design, Planning and Landscaping, Townsville NQ
32. Richard Corbett, Member Royal Australian Chemical Institute, Member of The Clean Air Society of Australia and New Zealand

33. Dr. Michael Creech, lifetime active as Geologist; Dr. Creech informs the public by giving presentations on Climate Change
34. Matt Crisanti BSc, UniSA, Science Faculty Coordinator at St. Columba College in 2008
35. Majorie Curtis, Retired Geologist, Stratigrapher and Palaeoclimatic Studies, Canberra
36. Eric Daniel, Retired IT Consultant
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38. Dr. Geoff Deacon PhD, MSc, BSc (hons), geologist, palaeontologist, advocate for geological truth in Climate Science
39. David H. Denham, lifetime experience as Architect (B Arch), active in giving talks and writing opinion articles on climate change
40. Geoff Derrick, Geologist
41. Trish Dewhirst, Retired Geologist, Queensland
42. Bevan Dockery BSc (UWA), Grad.Dip.Computing (Curtin U), Exploration Geophysicist in minerals world-wide
43. Aert Driessen, Geologist, Fellow Australian Institute of Geoscientists
44. John A. Earthrowl, Retired Geologist, Brisbane
45. Mike Elliott, Dux of School in Mathematics, Co-Founder of Climate Realists of Five Dock
46. Jeremy K. Ellis, Retired Chairman of BHP, now Chairman of the Saltbush Club Australia
47. Dr. Stephen David English, PhD in Crop Physiology from University of New England, Retired Agricultural Scientist
48. Matthew J. Fagan, Founder and President of FastCAM Inc.
49. Paul S. Forbes, Financial Advice Specialist
50. Nick Franey MSc Mineral Exploration, Mineral Exploration Management Consultant
51. Dr. Rodney Fripp, Mining Geologist and Chemist by education, lifetime experience in the fields of Mining and Exploration Geology, Analytical Chemistry and Physics of the Earth
52. Michael Fry PhD, retired Professor, ex Head of School and Dean of IT
53. Christopher J.S. Game, Retired Neurophysiologist
54. Robin George, Geologist, Canterbury
55. David Gibson, Experimental Physicist
56. Andrew Gillies, Geologist
57. Gavin Gillman, Former Senior Principal Research Scientist with SCIRO Australia, Founding Director of the IITA Ecoregional Research Centre in Cameroon for the International Institute for Tropical Agriculture (IITA)
58. Paul R.C. Goard BSc Sydney University, Physics & Maths, + Two years geology, one year Chemistry, member of the Australian Meteorological & Oceanographic Society
59. Brendan Godwin, Weather Observations and General Meteorology, Radio (EMR and Radar) Technical Officer, Retired from Bureau of Meteorology
60. Hamish Grant, MR Spectroscopy & Imaging Consultant, Victoria
61. Dr. Kesten C. Green, Leading Researcher on forecasting Methods and Applications, University of South Australia, first author of "Validity of Climate Change forecasting for public policy decision making
62. Jeffrey R. Grimshaw MSc Information Technology specialising in computer modelling, prediction, optimisation and advanced AI, Author of Trigger Warming, Everything You Wanted To Know About Global Warming But Were Afraid To Ask
63. Guy Grocott MSc Engineering Geology, Retired Consulting Engineering Geologist/ Geotechnical Engineer
64. Lindsay Hackett BSc, Author of the paper "Global Warming Misunderstood" (https://www.scribd.com/document/383385011/) and the paper "The Impact of Greenhouse Gases on Earth's Spectral Radiance" (https://www.scribd.com/ document/529064626/), Founding Member of the Saltbush Club in Australia
65. Maureen Hanisch PhD, Biochemistry, Medical Research 1997, Australian National University, Retired
66. Erl Happ, Managing Director at Happs
67. John Happs, Geoscientist, Retired University Lecturer
68. Peter J.F. Harris, Retired Engineer (Electronic), now Climate Researcher
69. Paul Leonard Harrison, Geophysicist with an M.Sc in Geology and Geophysics, over 45 years experience in research and exploration for the geo-energy industry
70. Jarvis Hayman, Retired Surgeon, Recently retired Archaeologist and Visiting Fellow at the Australian National University
71. Mark Henschke, Retired Geologist in Mining, Oil and Gas

72. Stewart Hespe, Consulting Civil and Forensic Engineer, Critic of Government Policy on Climate Related Matters
73. Gerhard Hofmann, Geologist and Palaeontologist, Former Director of the Geological Survey of Queensland
74. Robert Ian Holmes PhD in Climate Science/Mitigation, University Lecturer (retired) and Climate Scientist
75. Selwyn Hopley, MSSSI, Retired Land and Engineering Surveyor
76. Antonia Howarth-Wass, Mathematician
77. Geraint Hughes, Climate Researcher, Mechanical Building Engineer, Climate Researcher
78. Douglas Hutchison BSc and MSc degrees in geology, consulting geologist in the mining industry, member of the Australian Institute of Geoscientists
79. David Hyde MEnvSt, Environmental Biology, Former Scientific Chairman of Australian Underwater Federation (NSW)
80. Paul Ingram, Qualified Geologist, Member of the Australian Institute of Mining and Metallurgy, studying Palaeoanthropology and Human Evolution
81. Mr. Anthony Jackson, Bachelor of Arts degree, Bachelor of Laws degree, retired
82. Ian Johnson, Bachelor of Engineering, consultant
83. Mike Jonas, IT consultant, retired, frequent contributor to Watts Up With That?
84. Prof. Aynsley Kellow, Professor emeritus of Government, College of Arts, Law and Education, University of Tasmania
85. Alison Kelsey PhD, Palaeoclimatogist and Archaeologist University of Queensland
86. Kevin Kemmis, Climate Researcher, Expert in Information Technology
87. Neil Killion, MA in Psychology, active in the climate debate, member of the Saltbush club
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94. Ian Levy, CEO Australian Bauxite Ltd.
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99. John Ross May BSc, Adip, Cres., Management of Forests and National Parks in Victoria
100. Gerard McGann, Technical Director Eon NRG
101. Rodney McKellar, Retired Geologist, Queensland
102. John McLean, Author of First Major Review of HadCRUT 4 Climate Temperature Data, Member of New Zealand Climate Science Coalition
103. Toby McLeay, General Medical Practitioner AM, MBBS, FRACGP, FACRRM
104. Ross McLeod, Retired Environmental Health Officer
105. Peter R. Meadows, Agricultural Scientist
106. Paul Messenger PhD, Earth Science
107. John Michelmore, Retired Industrial Chemist
108. Des Moore, Former Deputy Secretary of the Federal Treasury, Founder and Leader of the Institute for Private Enterprise
109. Alan Moran, Contributor and Editor of the Mark Steyn Compilation: "Climate Change, the Facts", Author of Climate Change: "Treaties and Policies in the Trump Era"
110. Hugh Morgan, Prominent Australian Mining Executive, Fellow of the Australian Academy of Technology, Science and Engineering (FTSE)
111. Peter Murphy PhD, Adjunct Professor, Social Sciences, La Trobe University (Melbourne) and the Cairns Institute, James Cook University
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114. Clifford David Ollier DSc, Geologist, Emeritus Professor of Geology and Honorary Research Fellow at the School of Earth and Geographical Sciences, University of Western Australia
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117. M. Louise Petrick MSc Applied Science, Materials and Welding Engineer
118. Alistair Pope PSc, CM, Sceptical Scientific Contrarian in the Climate Debate
119. Robert Pyper, Geologist and Director of Minnelex Pty Ltd.
120. Tom Quirk, Nuclear Physicist
121. Art Raiche PhD, Mathematical Geophysics, Retired CSIRO Chief Research Scientist
122. Campbell Rankine, Barrister and Solicitor
123. Peter Ridd, Oceanographer and Geophysicist
124. Tim Riley, Mining Geologist
125. John Cameron Robertson, Author of CO2 Feeds the World and The Climate Change Delusion
126. Philip Lance Robinson, Chemical Engineer, lifetime experience in the aluminium and steel industry
127. Nigel Rowlands, Retired from Mining and Exploration Industry
128. George (Rob) Ryan, Professional Geologist
129. Judy Ryan, Editor Principia Scientific Institution Australia
130. Robert Sambell PhD, Physics, Professional Geophysicist
131. Tony Schreck, Managing Director, 35 yrs experienced geologist, Member of the Australian Institute of Geoscientists, Member of the Australian Institute of Company Directors
132. Pasquale Seizis, Mechanical Engineer, climate critic
133. Jim Simpson, Retired from Managing Positions in different International Telecommunications Firms, nowadays Convenor of "The Climate Realists of Five Dock', Sydney Australia."
134. Case Smit, Physicist, Expert in Environmental Protection, Co-Founder of the Galileo Movement
135. Edward Smith, Charted Chemist, member of the Royal Australian Institute of Chemistry (RACI), lifetime of experience in the Pharmaceutical industry
136. Lee Smith, University Lecturer in Spatial Technology, Responsible for State Government Precise Monitoring of Sea Level and International Sea Boundaries
137. Peter Smith, Geologist (Retired), New South Wales
138. Darren Speirs, Independent Business Owner, Rangeland NRM Consultants
139. Geoffrey Stocker, Professor and Head of Department of Forestry, PNG University of Technology, Director of PNG Forest Research Institute
140. John Stone, Former Head of the Australian Treasury and Executive Director of both the IMF and the World Bank, Former Senator for Queensland in the Australian Parliament and Leader of the National Party in the Senate, Principal Founder of The H.R. Nicholls Society and the Principal Founder of The Samuel Griffith Society
141. Dr. Nancy Enid Stone, B.Sc (Hons), University of Western Australia. (1950), Ph.D Cantab. (1956), Retired Research Biochemist
142. Rodney R. Stuart, Retired Expert in Energy Industry, Tasmania
143. Roger Symons, Professional Engineer, Expert in Temperature Control of Industrial Buildings
144. James Taylor, Electrical Aerospace and Astrophysics Engineer, Computer Modelling Researcher
145. Rustyn Wesley Thomas, Retired Aircraft Engineer
146. Tony Thomas MA, BEc, journalist and author for more than 60 years
147. Baki M. Top, Senior Agricultural Scientist, Freelance Consultant Agricultural and Food Production & Agribusiness
148. John W. Turner, Science Educator, Noosa Heads
149. Ralph J. Tyler, Retired Senior Principal Research Chemist, CSIRO, expert in conversion of coal and natural gas to liquid fuel
150. Peter Tyrer, Project Controls Engineer in Mining Industry

151. Dr. Julian Vearncombe PhD, Geologist, Fellow Australian Institute of Geoscientists
152. Terrence Vincent, Security Engineer, Small Business Adviser AIST, ASIAL, SMBE
153. John Vucko, Bachelor of Electrical Engineering (Hons)
154. James Walter, Medical Doctor
155. John Warnock, Astro Economist
156. Chris Warren, Retired Engineer, Design and Construction of Dams and feasibility of Coal Mines
157. Alan C. Watts, Medical Practitioner specialized in Effects of Infrasound on Human Health
158. Colleen J. Watts, Retired Environmental Scientist with specialization in Aquatic Chemistry and Environmental Consequences of Renewable Energy
159. Glyn Weatherall, Energy Resources Advisor
160. Neil Wilkins, Retired Geologist
161. Richard Willoughby, retired electrical engineer with thirty years experience in the Australian mining and mineral processing industry
162. Lawrence A. Wilson, Professional Chemical Engineer, Melbourne
163. Michael Wilson PhD, DSc, Emeritus Professor, former Executive Dean UWS, Former Chief Research Scientists CSIRO, Low Emissions Transport Fuels Leader
164. P.C. Wilson, Former Journalist with the A.B.C. Queensland
165. Philip Wood, Qualified Lawyer in four Jurisdictions (Australia, New York, UK and Hong Kong), CEO of two ASX-listed Companies operating in the Mining and Minerals Processing Fields
166. Michael Wort, BSc Mining Geology, MSc Mineral Process Design, PhD Mineral Technology, Geologist interested in impact of high levels of atmospheric levels of CO2 as trigger for formation of limestone deposits

SCIENTISTS AND PROFESSIONALS FROM AUSTRIA

1. Dr. Gerhard Kirchner, Berg Ingenieur, Climate Realist
2. Dipl Ing, Dr rer techn Heribert Martinides, European Space Agency, retired
3. Rudolf Posch PhD, Retired Software Engineer of a Technical Multinational, Expert in Nonlinearities and Feedbacks
4. Dr. Eike Roth, retired physicist, author of several climate books, latest one in press: "Das große Klimarätsel: Woher kommt das viele CO2?"
5. Hans Dirk Struve, Dipl. Ing., Mechanical Engineer with large experience in business
6. Konrad Falko Wutscher, Doctor of Engineering Sciences, specialist in treatment of water and wastewater

SCIENTISTS AND PROFESSIONALS FROM BANGLADESH

1. Aftab Alam Khan PhD, Active Professor Geological Oceanography, BSMR Maritime University, Retired Professor of Geology and Geophysics of Dhaka University

SCIENTISTS AND PROFESSIONALS FROM BARBADOS

1. Fred Corbin, Director of CSW Engineering 2000, a company that is leading the Caribbean Region in Sustainable Economic Project Design, and co-founder of The FREEWINDS organization that is aiming at the enhancement of the economic opportunities of the 18 Caricom Territories

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1. *Henri A. Masson, Professor Emeritus Dynamic System Analysis and Data Mining, University of Antwerp, French speaking Belgium; WCD Ambassador*
2. *Ferdinand Meeus, Retired Dr. Sc (Chemistry, photophysics, photochemistry), IPCC Expert Reviewer AR6; WCD Ambassador*
3. Rudy Berkvens, Information Security and Quality Management Auditor in ICT and Aviation, Commercial Pilot, Flight Instructor
4. Eric Blondeel, Retired Civil Engineer
5. Emiel van Broekhoven †, Emeritus Professor of Economics, University of Antwerp
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22. Bart Ooghe, Geologist & Geophysicist, Independent Scientist
23. Luc Opdecamp, "The agronomist-philosopher" (independent researcher), Agronmist (Soil science)
24. Jaak Peeters, Psychologist and Writer
25. Eric Perpète, Microcomputed Tomography Scientist, FNRS Senior Research Associate in Chemical Physics
26. Dr. Hugo Poppe, Emeritus hoogleraar, Weer- en Klimaatkunde, KU-Leuven, 1966-2002
27. Alain R. Préat PhD in Geology, Emeritus Professor at Université Libre de Bruxelles
28. Phil Salmon, Computer Tomography Scientist, Kontich
29. Jozef Verhulst PhD, Chemistry, Author
30. Jean van Vliet, Retired Specialist in Space Weather
31. Dr. Marc Wathelet, PhD in Molecular Biology, Free University of Brussels
32. Appo van der Wiel, Senior Development Engineer

SCIENTISTS AND PROFESSIONALS FROM BOLIVIA

1. Ambassador Jose Brechner, retired Congressman and Ambassador for the Bolivian Government, Chair of the Foreign Affairs Committee, currently Syndicated Columnist and Senior Political Analyst

SCIENTISTS AND PROFESSIONALS FROM BRAZIL

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3. Jose Nestor Cardoso, Professor on first oceanography course in Latin America, Pioneer on Brazilian expedition to Antartic, First scientific diver for Brazil from CMAS
4. Mario de Carvalho Fontes Neto, Agronomist, Editor of 'The Great Global Warming Swindle'
5. José Bueno Conti, Geographer and Professor of Climatology, Full Professor of the Geography Department at the University of Sao Paulo (USP)
6. Dr. Johnson Delibero Angelo, Master and PhD in Material Science, Industrial Chemist, Emeritus Collaborating Professor of Postgraduate Studies in Mechanical Engineering at UFABC

7. Prof. Dr. Ricardo Augusto Felicio BSc Meteorology - USP, MSc Antarctic Meteorology and Satellites - INPE, PhD in Climatology - Physical Geography - USP
8. Richard Jakubazsko, Executive Editor of Agro DBO Magazine and Co-Author of the Book 'CO2, Warming and Climate Change: Are you kidding us?'
9. Dr. George Lentz Cesar Fruehauf, BSc Doctor of Sciences – USP, MSc Meteorology – SJSU, expert in environmental engineering
10. Agnaldo Martins, professor and researcher at the Department of Oceanography and Ecology at the Federal University of Espírito Santo
11. Luiz Carlos Badicero Molion, Emeritus Professor of the Federal University of Alagoas (UFAL), Formerly of the National Institute of Space research (INPE)
12. Prof. Marcos José de Oliveira, Environmental Engineer, Master in Climatology, Author of research articles about climate cycles and natural causes of climate change
13. Fernando Paiva PhD Animal Science, Full professor at the Federal University of Mato Grosso do Sul
14. José Carlos Parente de Oliviera, Physicist, Professor at the Federal Institute of Education, Science and Technology of Cearà (IFCE), Retired Associate Professor of the Federal University of Cearà (UFC)
15. Guilherme Polli Rodrigues, Geographer, Master in Climatology, Environmental Consultant
16. Adelino De Santi Júnior, BSc Biology and Ecology, MSc Applied Ecology, Biologist, works with environmental education, licensing, restoration, sustainability management and staff supervision
17. Geraldo Luis Saraiva Lino, Geologist, Author of 'How a Natural Phenomenon Was Converted into a False Global Emergency'
18. Marcello Silva Sader, Graduated in Veterinary Medicine and Computer Sciences
19. Daniela de Souza Onca, Professor of the Geography Department of the State University of Santa Catarina (UDESC)
20. Igor Vaz Maquieira, Biologist, Specialist in Environmental Management

SCIENTISTS AND PROFESSIONALS FROM BULGARIA

1. Ivan Daraktchiev MSc Applied Science (Electronics engineering, Chemistry, Physics), Independent Researcher
2. Fabrice Toussaint, lifetime of experience in the Geo-Energy Industry, expert in complex numerical modelling

SCIENTISTS AND PROFESSIONALS FROM CANADA

1. *Dr. Patrick Moore, Ecologist, Chair CO2 Coalition, Co-Founder Greenpeace; WCD Ambassador*
2. *Reynald Du Berger, Retired Professor of Geophysics, Université du Québec a Chicoutimi, French Canada; WCD Ambassador*
3. Steven Ambler PhD, Full Professor University of Quebec, Dept. of Economics
4. John Andersen BSc, Honours, University of Alberta
5. Dr. Grant Armstrong, Leadership development and coaching
6. Russ Babcock, retired biochemist, lifetime experience in the mining and smelting industry with emphasis on pollution abatement
7. Tim Ball †, Emeritus Professor Geography, University of Winnipeg and Advisor of the International Science Coalition
8. Ron Barmby M.Eng in Engineering with major in Geoscience, Author of 'Sunlight in Climate Change: A Heretic's Guide to Global Climate Hysteria
9. Timothy J. Barrett PhD, Geochemical Researcher, Ore Systems Consulting
10. Callum Beck PhD in Religious Studies, Sessional Professor in Religious and University Studies
11. Mario Blais, Science and Mathematics Teacher
12. Kevin Burke MSc in Marine Biology, high school teacher, author/co-author of 2 technical reports with the Departement of Fisheries and Oceans and 2 scientific articles published in the Journal of Shellfish Research
13. Robert Douglas Bebb, Professional Engineer (Mechanical), MBA
14. Rick Beingessner, BSc, BA and LLB University of Alberta, lifetime experience in the Geo-Energy Industry, recently involved in researching Climate Change Matters
15. Jean Du Berger, Ingénieur Retraité, Bell
16. Alain Bonnier PhD, Physique, INRS-Centre de Recherche en Énergie, Montréal

17. Andrew Bonvicini, Professional Geophysicist, President of Friends of Science Society
18. Jacques Brassard, Minister of Recreation (1984), Minister of Environment (1994), Minister of Transport and Intergovernmental Affairs of Canada (1996), Minister of Natural Resources (incl. Hydro-Québec) and House Leader
19. Chris Carr, BSc (Hons) Engineering Geology and Geotechnics, retired Geoscientist
20. Michel Chapdelaine MSc, Géologie, Montréal
21. Henry Clark, Thermal/Power Engineer
22. Ian Clark, Professor of Earth and Environmental Sciences, University of Ottawa
23. Edmond (Ted) Clarke MSc, Engineering, Member of Friends on Science Society
24. Paulo N. Correa, Biophysicist and Oncologist, Inventor, Author of numerous books and research papers, Director of Research at Aurora Biophysics Research Institute
25. Hortense Côté, Ingénieur Géologue, Goldminds
26. Susan Crockford, Zoologist and Polar Bear Expert, Former Adjunct Professor University of Victoria
27. Norman Curry, Technical College, Design Engineering-Mechanical Engineering, President of National Zephyr Research
28. Ronald Davison, Professional Chemical Engineer
29. Dr. E. David Day BSc, PhD, Chemistry
30. A.E. (Ted) Dixon PhD, Emeritus Professor of Physics, University of Waterloo
31. Eric Ducharme MSc, Géologie, Abitibi
32. Michel Dumais, Ingénieur Civil Retraité, Université d'Ottawa
33. Dr. George Duncan PhD, retired Environmental Consultant from A&A Environmental Consultants Inc.
34. Claude Duplessis BcSc, Géologie, Ingénieur Géologue, Goldminds
35. Craig A. Elliott MSc Mechanical Engineering, Design Consultant, President at CAElliott Inc
36. Ashton Embry, Research Geologist, Embry Holdings
37. David Fermor, Anaesthesiologist, B.A., M.D., FRCPC
38. Jeffrey Foss †, Professor of Philosophy of Science, University of Victoria
39. Joseph Fournier PhD, Expert in Physical Chemistry
40. Paul M. Gagnon, Professional Engineer
41. Thomas P. Gallagher, Earth Scientists, life-long career in the study of paleoclimate, geology and earth ocean systems, see https://www.youtube.com/watch?v=pj-Iu1i317E
42. J. Claude Gobeil BSc, Geology
43. Douglas Goodman, Life of time experience in the geo-energy industry
44. Kenneth B. Gregory, Professional Engineer, Director Friends of Science Society
45. Dr. Paul Hamblin, Retired Research Scientist Environment Canada, Advisor to the Georgian Bay Association
46. Mark T. Hohm, Professional Engineer registered with the Association of Professional Engineers and Geoscientists of Alberta (APEGA)
47. R.G. Holtby, profesional agrologist
48. Patrick Hunt, former member of the Royal Canadian Navy, former member of the Legislative Assembly of Nova Scotia, retired entrepreneur in the high-tech field (35 Years)
49. Rick Ironside, Director Fortress ESG, provides specialized expertise to help clients map out their journey to attempt to achieve the goal of net zero by 2050
50. Eric Jelinski M. Eng. P. Eng., Alumni and Contract Lecturer, University of Toronto, Department of Chemical Engineering and Applied Chemistry, CHE568 Lecturer, Nuclear Plant Engineering
51. Paul A. Johnston, Associate Professor, Paleontology, Paleoecology, Department of Earth and Environmental Sciences, Mount Royal University, Calgary, Alberta
52. Richard T. Jones, experimental physicist, researched in the field of fission energy
53. E. Craig Jowett, Geologist and Environmental Researcher PhD University of Toronto
54. Andre Julien, MSc Mechanical Engineering, Thermodynamics Expert, over 40 patents published
55. Klaus L.E. Kaiser, Retired Research Scientist, National Water Research Institute, Author of Numerous Press Articles
56. Bogdan Kasprzak, Professional Geoscientist, life time experience in data modelling, data analysing and data interpretation
57. Madhav Khandekar, Expert Reviewer IPCC 2007 AR4 Report
58. David Koop BSc, Analytical Chemist

59. Kees van Kooten, Professor of Economics and Canada Research Chair in Environmental Studies and Climate, University of Victoria
60. Emil Koteles PhD in solid state physics, Max Planck Institute for Solid State Research in Stuttgart, GTE Labs in Waltham (Massachusetts), National Research Council of Canada in Ottawa (Ontario), visiting professor at Zhejiang University in Hangzhou, retired
61. Jean Laberge, Professeur Retraité de Philosophie, CEGEP du Vieux Montréal
62. Sherri Lange, CEO North American Platform Against Wind Power, Great Lakes Wind Truth
63. M.J. Lavigne MSc, Professional Geologist
64. Douglas Leahey PhD, Meteorology, past President of Friends of Science
65. Professor Denis Leahy, PhD in Astrophysics, Full Professor in the Department of Physics and Astronomy, University of Calgary
66. Robert Ledoux PhD, Professeur Retraité en Géologie, Université Laval
67. Dick Leppky, Retired businessman and Independent Truth Seeker
68. Richard Lewanski BsC (Hons) in Geophysics from the university of Manitoba, lifetime experience as an exploration geophysicist, founder and CEO of several exploration and production companies in the oil industry, as well as several private companies
69. H. Douglas Lightfoot, Research Engineer in the Chemical Industry, Co-Founder of the Lightfoot Institute, papers on Alternative Energy and Atmospheric CO2
70. Gerald Machnee, Retired Meteorologist, Environment Canada
71. Allan M.R. MacRae, Retired Engineer
72. Paul MacRae, Independent Climate Researcher
73. J. David Mason, Applied Geologist, B.A.Sc, Applied Geology, M.Eng, Mining
74. Stuart McDonald, Retired Canadian Insurance Broker
75. Dwight McIntosh, degree in physics and geology at the University of Alberta, lifetime of experience in the geo-energy industry, advisor on GHG quantification and regulation
76. Norman Miller, Former P.Eng, now Retired
77. Ron Mills, Geologist/geochemist Emeritus NS Geological Survey
78. Randall S. Morley, veterinary epidemiologist, retired
79. Dr. Thomas F. Moslow PhD, P. Geol., President Moslow Geoscience Consulting Ltd., Adjunct Professor Department of Geoscience, University of Calgary
80. Roland Moutal, Teacher Physics and Chemistry at Vancouver Community College
81. Prof. Frank Mucciardi, retired Professor in the Department of Mining and Materials Engineering at McGill University in Montreal, my research was focused primarily on energy, heat transfer, fluid mechanics and modeling
82. Christian Olivier, former Postdoc @ UC Berkeley
83. Robert Orr, Historical Linguist
84. Scott Patterson, Professional Geologist
85. Andy Pattullo, Associate Professor of Medicine at the University of Calgary
86. Prof. David A. Penny PhD, Former Associate Professor, Dept. of Computer Science, University of Toronto, veteran Software Industry Executive
87. Jozinus Ploeg, retired Vice-President, Engineering and Technology, National Research Council, Field of expertise Energy transfer from atmosphere to surface of ocean, wave mechanics
88. Joe Postma, Research Analyst, Physics & Astronomy, University of Calgary
89. Brian R. Pratt, Professor of Geological Sciences, University of Saskatchewan
90. Michael Priaro, BSc Chem.Eng, P.Eng, Member of Association of Professional Engineers and Geoscientists of Alberta
91. Gerald Ratzer, Professor Emeritus, Computer Science McGill University, Montreal
92. John Angus Raw, aerospace engineer, specialised in aerodynamics, life time career in the international aerospace industry
93. Dr. Michael Raw PhD in Mechanical Engineering, specialization in computer modelling of fluid flow and heat transfer, current field of work in technology management
94. Robert James Reid, BSF degree, Registered Professional Forester, lifetime experience in the forestry industry
95. Norman Reilly, Professor Emeritus of Mathematics, Simon Fraser University, British Columbia
96. Gérald Riverin PhD, Géologie, Géologue Retraité
97. John Robson, Historian, Journalist, Documentary Filmmaker
98. Peter Salonius, Retired Research Scientist, Natural Resources

99. Marcelo C. Santos, Professor of Geodesy, University of New Brunswick
100. Paul R. Schmidt BSc, Professional Engineer Ontario, Research Scientist, Author/ Lecturer 'Review & Analysis of Climate Change', Member Friends of Science
101. Ian de W. Semple, Retired Exploration Geologist and Mining Investment Analyst of McGill University
102. Afshin Shahzamani, Retired professional (Medical Science Liaison) pharmaceutical industry
103. Élie Shama, Ingénieur Retraité en Électromécanique, Président d'Éconoden, Montréal
104. Wayne Shepheard MSc Geology, Retired oil and gas explorer
105. H.F. (Gus) Shurvell, Emeritus Professor of Chemistry, Queen's University
106. Brian Slack, Distinguished Professor Emeritus, Concordia University Montreal, Department of Geography, Planning and Environment
107. Rodolfo (Rudy) Spatzner, graduated from Environmental/Civil Engineering Technology, Humber College, Ontario, lifetime experience in wireless networks across North America
108. Michelle Stirling, Writer/Researcher with focus on 'consensus' social proofs, Top 10% downloaded author on SSRN, Communications Manager, Friends of Science Society
109. Mary Taitt PhD Zoology, MSc Ecology, retired
110. Graydon Tranquilla, BScEE, Electrical Power, Senior Electrical Engineer (retired), now an energy advisory consultant
111. Marc Vallée PhD, Geophysicien
112. Petr Vaníček Dr. Sc, Professor Emeritus of Geodesy, University of New Brunswick
113. Duncan Veasey, psychiatrist with a particular interest in mass hysteria, authoritarianism and social compliance
114. Prof. Dr. Ir. Frank C.J.M. van Veggel, Full Professor at the University of Victoria, M.Eng and PhD in Chemical Technology, University of Twente, The Netherlands, Since 2015 Fellow of the Royal Society of Canada
115. Jean-Joel Vonarburg PhD, Professeur Ingénieur, Université du Québec à Chicoutimi
116. Dr. Ronald Voss PhD Chemistry, lifetime career in the environment department of a research consortium
117. Robert Wager, BSc and MSc, Microbiological Sciences and Immunology, Biochemistry and Molecular Biology, Retired
118. Dr. Helen Warn PhD in Fluid Dynamics from McGill University
119. Dr. Thorpe W. Watson, material science, lifetime career in the mining industry with focus on intellectual property protection
120. Larry Weiers, energy engineer, retired, author of "Sustainability of the Modern Human Economy"
121. William van Wijngaarden, Professor of Physics, York University
122. Ken Wilson, Professional Engineer (retired)

SCIENTISTS AND PROFESSIONALS FROM CHILE

1. *Douglas Pollock, Civil Industrial Engineer, University of Chile; WCD Ambassador*
2. Rafael Muñoz Canessa, Part time Academic University of Talca, Economics and strategic management
3. Juan Luis Edwards Velasco, Civil engineer in hydraulics, Universidad Católica de Chile, Master in hydraulic engineering, Universidad de Santander, Spain
4. Carlos Varea, Energy Engineer

SCIENTISTS AND PROFESSIONALS FROM CHINA / HONG KONG

1. Dr. Robert Hanson, PhD, BA (Hons), MA, LL.M, PGCE, CPE, Barrister
2. Wyss Yim, Retired Professor, Department of Earth Sciences, The University of Hong Kong, Deputy Chairman Climate Change Science Implementation Team, UNESCO International year for Planet Earth 2007-2009, Expert Reviewer IPCC AR2
3. NG Young, Principal Geoscientist, Danxiashan Global Geopark of China

SCIENTISTS AND PROFESSIONALS FROM COSTA RICA

1. Eugenio G. Araya, Theoretical Physicist, Researcher, former scientist at University of Costa Rica

SCIENTISTS AND PROFESSIONALS FROM REPUBLIC OF CROATIA

1. *Dušan Bižić MSc, Meteorologist; WCD Ambassador*
2. Zorislav Gerber MSc, Meteorologist

SCIENTISTS AND PROFESSIONALS FROM CYPRUS

1. Darko Krstic, editor of https://philosophyofgoodnews.com/

SCIENTISTS AND PROFESSIONALS FROM CZECH REPUBLIC

1. Pavel Dudr, Ing, Independent publicist and climatologist / Pravy prostor, EP Shark/
2. Marek Eiderna, Agricultural Engineer and graduated in General Biology
3. Tomas Furst PhD, teacher of mathematics at Palacky University in Olomouc and a proponent of correct, i.e. Bayesian inference
4. Vaclav Hubiner, Retired Ambassador, Anthropologist, Climate Policy Commentator for www.forum24.cz
5. Pavel Kalenda PhD, CSc., Coal Expert
6. Václav Klaus, Former President of the Czech Republic, Professor of Economics, Founder of the Václav Klaus Institute
7. Lubos Motl PhD, former Harvard faculty, high energy theoretical physicist, co-author of the 2009 NIPCC report
8. Ivan Spicka, Professor of Internal Medicine at Charles University with speciality in Hemato-Oncology, Prague
9. Dalibor Štys, professor of Applied physics, Faculty of Fisheries and Protection of Waters, University of South Bohemia in České Budějovice
10. Gary M. Vasey PhD, Geology, Managing Partner and Analyst in Commodity Technology Advisory llc
11. Ing. Miroslav Žáček PhD, aplied geochemistry, been working on the climate for more than 10 years as a geochemist

SCIENTISTS AND PROFESSIONALS FROM DENMARK

1. *Jens Morten Hansen PhD, Geology, Professor at Copenhagen University, Former Vice Managing Director for the Geological Survey of Denmark and Greenland, Former Director General for the Danish National Research Agency and National Research Councils, Former President of the Nordic Research Council under Nordic Council; WCD Ambassador*
2. Bjarne Andresen, Professor of Physics, Niels Bohr Institute, University of Copenhagen
3. Dr. Hans Götzsche, Emeritus Associate Professor, Linguistics and Philosophy of Science, President Nordic Associaton of Linguists (NAL), Director, Center for Linguistics, Aalborg University
4. Frank Hansen, Emeritus Professor, Department of Mathematics, University of Copenhagen
5. Niels Harrit PhD, Emeritus Associate Professor of Chemistry, Dept. Chemistry, University of Copenhagen
6. Sören Kjärsgaard, Professional Chemical Engineer
7. Johannes Krüger, Emeritus Professor, Dr. Scient, Department of Geosciences and Natural Resource Management, University of Copenhagen
8. Knud Larsen PhD, Natural Sciences
9. Peter Locht, Senior Lecturer, Business Academy Aarhus (statistics)
10. Peter Kjær Poulsen, Metering Engineer
11. Steen Rasmussen Bsc in Electrical Engineering from Denmark Technical University, lifetime career at IBM Denmark Aps
12. Niels Schrøder, Geophysist/Geologist, Associate Professor Institute of Nature and Environment, Roskilde University
13. Pavel Svennerberg, Master of engineering, Technology of oil and gas processing

SCIENTISTS AND PROFESSIONALS FROM ESTONIA

1. Andres Saukas, Diploma Electrical Engineer, Estonian Society of Moritz Hermann Jacobi

SCIENTISTS AND PROFESSIONALS FROM ECUADOR

1. Fernando Villon MSc, Industrial Engineer, Lifetime Experience in the Geo-Energy Industry

SCIENTISTS AND PROFESSIONALS FROM FINLAND

1. Simo Mykkanen, Ba Econ, small business owner, retired
2. Dr. Antero Ollila, Emeritus Adj. Ass. Professor Aalto University, expert in atmospheric modeling
3. Simo Ruoho, President Ilmastofoorumi ry Finland, Signature of association https://ilmastofoorumi.fi including its scientists and professional members
4. Boris Winterhalter, Retired Marine Geology, Geological Survey of Finland

SCIENTISTS AND PROFESSIONALS FROM FRANCE

1. *Benoît Rittaud, Assistant Professor of Mathematics at University of Paris-Nord, President of the French Association des climato-réalistes; WCD Ambassador*
2. Jean-Charles Abbé, Former Research Director at CNRS, Labs Director (Strasbourg, Nantes) in Radiochemistry, Expert at NATO and IAEA
3. Pascal Acot, Centre National de la Recherche Scientific, Paris
4. Bertrand Alliot, Environmentalist
5. Frédéric Antoine, graduated from Sciences Politiques in France
6. Charles Aubourg, Full Professor at the University of Pau, Geophysicist
7. Hervé Azoulay, Engineer (CNAM), Specialist of Networks and Systemics, CEO and President of several Associations
8. Guy Barbey, Alumnus of Harvard Business School, Retired Investment Banker, Founder and President of 'Climate et Vérité'
9. Jean-Pierre Bardinet, Ingénieur ENSEM, Publicist on Climate Issues
10. Yorik Baunay, Geographer (Master 2) specialized in the natural risk and crisis management, CEO of Ubyrisk Consultants (firm specialized on natural hazard mitigation)
11. Bernard Beauzamy, University Professor (Ret.), Chairman and CEO, Société de Calcul Mathématique SA (Paris)
12. Serge Bellotto PhD, Geology
13. Guy Bensimon, Retired Associate Professor of Economics at Institute of Political Studies of Grenoble (SciencesPo Grenoble)
14. Jean-Claude Bernier, Emeritus Professor (University of Strasbourg), Former Director of the Institute of Chemistry of the CNRS
15. Pierre Beslu, Former Researcher and Head of Department in the French Nuclear Energy Commission (CEA)
16. Michel Bouillet PhD, Human Geography, Emeritus Professor, Former Associate Researcher at the MMSH (Aix-en-Provence)
17. Christian Buson PhD, Agronomy, Director of Research in a Company (impact studies in Environmental Issues, Sewage Treatment)
18. Jean-Louis Butré, Head of Laboratory at Grenoble Nuclear Research Center, Chief Executive Officer of the Pharmacie Centrale de France, President of Procatalyse, President of the Fédération Environnement Durable and the European Platform Against Windfarms, Knight of the National Order of Merit
19. Emmanuel Camhi MSc in Physics, life time experience in Complex Systems Modeling and Data Analysis in the Aerospace industry
20. Bernard Capai, Retired Chemistry Engineer, Specialist of Industrial Processes avoiding the use of Carcinogenic Solvents
21. Patrick de Casanove, Doctor of Medicine, Chairman of the Cercle Frédéric Bastiat
22. Philippe Catier, Medical Doctor
23. Vincent Chaplot PhD Soil Science, Senior Research Scientist
24. Bruno Chaumontet, Engineer ENSEA, specialized in Feedback Systems
25. Pascal Chondroyannis, Forest Engineer, Retired Director of the National Alpine Botanical Conservatory (2008-2013)
26. Jean Michel Colin PhD, Retired Chemist Engineer, Expert for the French Academic Evaluation Agency (AERES)
27. Philippe Colomban, CNRS Research Emeritus Professor, Former Head of Laboratory at Université Piere-et-Marie Curie, Expert in Hydrogen-based Energy Storage

28. Jacques Colombani, Former Research Director ORSTOM-IRD, numerous Studies in Hydrology and Climatology and Specialist in Fluid Mechanics, Member of the Board of ORSTOM for twenty years
29. Christian Coppe PhD, Organic & Analytical Chemistry
30. Philippe Costa, Energy Engineer at ENSEM Nancy, specialist in Industrial Process and Energy Saving
31. Vincent Courtillot, Geophysicist, Member of the French Academy of Sciences, Former Director of the Institute de Physique du Globe de Paris
32. Pierre Darriulat, Professor of Physics, Member of the French Academy of Sciences
33. Jean Davy, Engineer (ENSAM), Digital Modeling Software Developer
34. Dr. Stephen John Dearden, Retired Research Chemist, lifetime R&D experience in the general chemical, pharmaceutical and photographic industries
35. Pierre Delarboulas, CEO of a Robotics Company, Former R&D Director at Partnering Robotics, Silver Medal at the 2016 Lépine contest of the Ministry of Foreign Affairs and International Development
36. Jean-Pierre Desmoulins, Retired Professor of Thermal and Energy Engineering at the "Institut Universitaire de Technologie, Université-Grenobles-Alpes"
37. Gérard Douhet PhD, Nuclear Physics, Retired Engineer at CERN, Technical Manager on Digital Transmission and Video Encoding
38. Hubert Dulieu, Emeritus Professor Applied Ecology, Formerly Senior Researcher in the CNRS, President of the National Scientific Research Committee, Vegetal Biology Section (XXVII)
39. Doctor Denis Dupuy, Urologist, climate realist
40. Bruno Durieux, Economist, Former Minister of Health and of Foreign Trade, Ancient Administrator of the French National Institute of Statistics and Economic Studies (INSEE)
41. Ralph Ellis, Bsc in Aviation, ATPL
42. Max Falque, International Consultant in Environmental Policy
43. Serge Ferry PhD, Retired Teacher-Researcher (MCF), University of Lyon
44. Patrick Fischer, Associate Professor in Applied Mathematics, University of Bordeaux
45. Michel Frenkiel, Engineer (Arts et Métiers), Former Researcher at NCAR in Boulder
46. Francis le Gaillard PhD, Natural Sciences and Pharmaceutical Sciences, Emeritus Professor of Biochemistry at the Faculty of Pharmaceutical Sciences of Toulouse
47. François Gauchenot, Governance Specialist, Founder of Saint George Institute
48. Jean Gergelé, Engineer Graduate from the Ecole Centrale de Lyon, R&D Director, Freelance Consultant, mainly in the Li-ion battery development
49. Christian Gérondeau, Former Advisor of several French Prime Ministers, Formerly responsible for the Road Traffic Safety Policy for France and the European Union
50. Francois Gervais, Emeritus Professor of Physics and Material Sciences, University of Tours
51. Philippe Giraudin, Ecole Polytechnique Paris, Geographic Sciences
52. Bernard Grandchamp, Agronomic Engineer and Environment & Plant Defense Expert, Managing Director of Famoux Chateaux Viticoles in Bordeaux
53. Gilles Granereau, Former Meteorologist, currently Project Manager Environment and Tourism in a Public Institution, Worked on Coastal Risks, Marine Erosion, Sand Dune Fixation, Hydraulics, Forest Management, Botany
54. Maximilian Hasler, Associate Professor in Mathematics, University of French West Indies
55. Charles Hazan, Retired Chemist (ENSCP) and Chemical Engineer (UMIST) Former Technical Director Nosolor
56. Manfred Horst, MD, PhD, MBA, lifetime career in healthcare and pharmaceuticals
57. Yvon Jarny, Emeritus Professor in Thermal and Energy Sciences, Nantes University
58. Claude Jobin, Retired A&M Engineer specialized in Microwave Communication
59. Vladimir Klein, lifetime career in renewable energy projects, patent holder in aerobic composting of organic waste
60. Alexandre Krivitzky, Psychoanalyst, Member of the International Psychoanalytical Association
61. Roger Lainé, Retired Geological Engineer
62. Philippe de Larminat, Professor at École Centrale de Nantes, specialist of Business Process Modeling
63. Jacques Laurentie, Aeronautical Engineer, and CEO of a software publishing company
64. René Laversanne, Researcher at the CNRS, 16 patents

65. Christian Liegeois PhD Physics, patent holder in photonics
66. Jean-Marie Longin, Engineer (Saint-Cyr), Chief of the Pole Operations of Security Inventory Management
67. Guy Lucazeau, Emeritus Professor (Institut Polytechnique de Grenobel) in Material Sciences and Spectroscopy
68. Philippe Malburet, Emeritus Associated Professor of Mathematics, Founder of the Planetarium of Aix-en-Provence, Member of the Academy of Aix-en-Provence
69. Christian Marchal, Astronomer and Mathematician, Former Research Director at the French National Office for Aerospace Studies and Research
70. Dr. Yves G. Maria-Sube PhD in Geosciences Montpellier University, lifetime career in the geo-energy industry
71. Paolo Martinengo, Applied Physicist, Senior Staff Member in the Experimental Physics Department, Detector Technologies Group, CERN
72. Patrick Mellett, Architect and CEO
73. Marc le Menn PhD, Head of Metrology-Chemistry Oceanography Lab, Brest
74. Henri Mertz, Ingénieur Civil de l'école de la Métallurgie et des Mines de Nancy, Chef d'Entreprises
75. Serge Monier, former manager of various multinational companies, at present Co-founder and Treasurer of 'Climat et Vérité'
76. Jean-Laurent Monnier, Emeritus Research Director, CNRS-Université de Rennes, Research Worker at the CNRS from 1973 to 2013, speciality in Pleistocene Geology in Western Europe
77. Jacques-Marie Moranne, Retired Engineer (Ecole Centrale de Lille), Specialist in Air and Water Purification, Chemical and Nuclear Engineering
78. Serge Morin, Emeritus Professor Geography at Université Michel de Montaigne, Bordeaux, Honorary Mayer of Branne
79. Cédric Moro, Geographer on Natural Hazards Management, Co-Founder of Visov, a NGO in Civil Defense
80. Philippe Morvan, Engineer ENSTA and Génie Maritime, specialist in Software Development
81. Charles Naville, R&D Exploration Geophysicist, IFP Energies Nouvelles
82. Michel le Normand, Emeritus Professor of Botany and Plant Pathology and Chairman of Plant Production Department, National Superior School of Agronomy, Rennes
83. Ludovic Penin, former Senior Executive - Chief Information Officer (IT) and former Entrepreneur/Investor, Co-founder and Vice-president of 'Climat et Vérité', member of "Association des Climato-réalistes'
84. Dr Patrice Poyet, Graduated at Ecole des Mines de Paris as a geochemist and defended a D.Sc. (1986) at Nice University / INRIA, author of 'The Rational Climate e-Book'
85. Rémy Prud'homme, Emeritus Professor in Economics at University of Paris-Est, Former Deputy-Director, Environment Directorate, OECD
86. Jean Marie Ravier, Engineer of ECOLE CENTRALE DE PARIS, and diplomed SCIENCES POLITIQUES PARIS, recently retired MD of small industrial company
87. Pierre Richard, Engineer ESPCI Paris, Former Research Geochemist at Institut de Physique du Globe de Paris (IPGP)
88. Pierre Ripoche, Engineer INSA in Chemistry, Retired Project Manager in R&D, Expert in High Temperature Plasma for Optical Fiber Process
89. Isabelle Rivals, Associate Professor in Statistics at ESPCI Paris
90. Betrand Rouffiange, Doctor of Medicine, specialized in Radiology
91. Jean Rouquerol, Emeritus Research Director at CNRS Marseille, Expert in Gas Adsorption and Calorimetry
92. Georges de Sablet, Retired Associate Professor at University of Paris Descartes, Formerly in charge of Operating Systems and Networks at IUT Paris
93. François Simonet PhD, Biology, Former Director for Planning and Foresight in a State Agency for Water and Aquatic Ecosystems Management
94. Luc C. Tartar, mathematician, corresponding member of Académie des Sciences in Paris (since 1987), University Professor of Mathematics emeritus at CMU (Carnegie Mellon University, Pittsburgh, PA)
95. Marcel Terrier, Ex Engineers in Industry, Former Teacher at the Douai School of Mines
96. Michel Thizon, Chemical engineer, ACR (Association des Climato-Réalistes, France) member, former researcher at the Ecole Polytechnique, consultant, retired
97. David Uzal PhD philosophy of technics and PhD of practical philosophy

98. Etienne Vernaz, Former Director of Research of CEA (Commissariat à l'Énergie Atomique) in France, Professor at INSTN (Institut National des Sciences et Techniques Nucléaires)
99. Camille Veyres, Retired Engineer at École des Mines, specialist in Telecommunications and Broadband Networks
100. Brigitte van Vliet-Lanoë, Geoscientist, Emeritus Research Director (CNRS, Université de Bretagne Occidentale), Stratigraphy and Paleoenvironments, Quaternary and Holocene
101. Théa Vogt, Retired CNRS Searcher, Géomorphology, Quaternary Palaeoenvironments, Soil and Desertification Remote Sensing
102. Henry Voron, Retired Civil Chief Engineer, specialized in Water Management

SCIENTISTS AND PROFESSIONALS FROM GERMANY

1. *Fritz Vahrenholt, Professor (i.R.) am Institut für Technische und Makromolekulare Chemie der Universität Hamburg; WCD Ambassador*
2. Detlef Ahlborn PhD, Expert on German Energy Transition (Energiewende)
3. Hans-Jürgen Bandelt, Emeritus Professor of Mathematics, University of Hamburg
4. Dietrich Bannert, Professor Honoris Causa, University of Marburg
5. Graham George Baumber, former Agronomist & Irrigation Crop Specialist, Business Man & Investor
6. Lars Birlenbach, Dr. in Chemistry, University of Siegen
7. Michael Bockisch, Emeritus Professor Chemistry at the Technical University of Berlin
8. Klaus-Dieter Böhme, Dipl. Physicist, professional experience in X-ray spectroscopy
9. Thomas Brey, PhD in Natural Sciences (Dr. rer. nat), Marine Ecological Researcher
10. Stephan Bujnoch, Wirtschaftsingenieur (i.e. a combination of Economics and Engineering), Retired Manager with the Automotive Industry
11. Eike-Mattias Bultmann, Geoscientist
12. Eberhard Burkel, Prof. (i.R.) Dr.rer.nat , Physics of New Materials, University of Rostock
13. Dr. Arthur Chudy, Agricultural Chemist OT Warsaw
14. Günter Dedié, Physicist
15. Dr. Ing. Rolf Diederichs, Studie Eisenhüttenkunde in Clausthal-Zellerfeld, climate realist
16. Prof. Dr. Klaus D. Döhler, Professor of Pharma sciences, University of Hannover
17. Wolf Doleys, Retired teacher (high school, college) and writer (essay, poetry, novel)
18. Joerg Dornemann Msc in Geology, lifetime career in the Geo-Energy Industry
19. Jörg Eichner, Specialist in situational awareness in crises and risk management
20. Friedrich-Karl Ewert, Emeritus Professor Geology, University of Paderborn
21. Ludwig E. Feinendegen, Emeritus Professor Medicine
22. Dr. Dieter Freundlieb, Retired Senior Lecturer Griffith University, School of Humanities, Brisbane, Australia
23. Gerhard Gerlich, Emeritus Professor of Mathematical Physics, TU Braunschweig
24. Axel Robert Göhring, Doctor of Natural Sciences, EIKE e.V.
25. Dr. Klaus-Jürgen Goldmann, worldwide experienced petroleum geologist
26. Christian Habermann, Dr. in Economics, Investment Manager
27. Eberhard Happe, Eisenbahningenieur
28. Hermann Harde, Emeritus Professor of Experimental Physics and Materials Science, Helmut Schmidt-University, Hamburg
29. Prof. Dr. Bernd Hartke, Professor in Theoretical Chemistry, Expert Knowledge in Computer Modelling, University of Kiel
30. Manfred Hauptreif, Natural Scientist
31. Dennis J. Hendricks, Graduated Engineer of Environmental Technologies, Technischen Hochschule Ostwestfalen-Lippe, University of Applied Sciences and Arts
32. Dietmar Hildebrand PhD Biophysics and Nuclear Physics, patent holder in fuzzy logic based suveillance, IT expert and development manager
33. Dr. Andreas Hoppe, Systems biologist, Institute for Bee Research
34. Prof. Axel Janke PhD, professor of evolutionary genomics
35. André Karutz, Chemist, Dr. rer. nat. expert in environmental matters
36. Professor Dr. Gerhard Kehrer, Retired Physician, Internist and Physiologist
37. Dr. Udo Kienle, Agricultural Scientist at University of Hohenheim
38. Werner Kirstein, Emeritus Professor of Climatology, University of Leipzig

39. Bernhard Kleinhenz, Collage teacher of Biologie, Chemistry and Physics
40. Gunther Klessinger, Physicist, University at Regensburg Germany and Boulder Colorado
41. Stefan Kröpelin, Dr. in Geosciences, Free University of Berlin and University of Cologne (Retired), specialized in Climate Change of the Sahara
42. Dr. rer. nat Gunter Kümel, lifetime career in virus research in the natural siences
43. Max Kupillas, Dipl.-Ing. Masch.-Bau, retired Prod.Ltr.
44. Ulrich Kutschera, Professor of Plant Physiology & Evolutionary Biology at the University of Kassel and Visiting Scientist in Stanford USA
45. Wolfgang Laub, Physics (J.W.Goethe University, 1977-1986), Medicine (Physiology-Biomechanics, Max-Planck Institute, 1980-1986), patent holder in different areas
46. Michael Limburg, Vice-President EIKE (Europäisches Institute für Klima und Energie)
47. Martin Lindner PhD in Chemistry, Dipl. in Chemistry, President of the Bürger für Technik
48. Prof. Dr. Kai van de Loo, Dr. rer. oec. Honorarprofessor der THGA und Senior Consultant im Forschungszentrum Nachbergbau
49. Dr. Stephan Lorenzen PhD Theoretical Biology, Bioinformatician, worked with nonlinear modelling
50. Professor Dr. Knut Löschke, studied crystallography, chemistry, physics, mathematics and computer science. He is an honorary professor at the University of Technology, Economics and Culture in Leipzig. As part of his work at the university, he deals with the energy industry and climate change
51. Horst-Joachim Lüdecke, Professor of Operations Research (i.R.) HTW of Saarland, Saarbrücken
52. Wolfgang Merbach, Professor Dr. Agrar. Habil. at Institut für Agrar Ernährungswissenschaften
53. Lothar W. Meyer, Emeritus Professor of Material Engineering, Chemnitz University of Technology, Saxony Entrepreneur 'Nordmetall GmbH', Member of the Board of 'Vernunftkraft Niedersachsen'
54. Jens Möller, Graduate Economist, Climate Realist
55. Wolfgang Monninger PhD, lifetime career in Petroleum Geology (Exploration, Petrophysics)
56. Werner Mormann, Emeritus Professor of Macromolecular Chemistry, Universität Siegen
57. Dipl. Phys. Raimund Müller, education in physics and thermodynamics, climate realist
58. Holger Neulen, Retired Mechanical Engineer
59. Prof. Dr.rer.nat Dr.med Peter Nielsen, retired Biochemist and Physician from the Universital Hospital Hamburg-Eppendorf, medical faculty of the University of Hamburg
60. Rainer Olzem, Diplom-Geologe, Aachen
61. Hans Penner PhD, Dipl.-Chem. Dr. rer. nat., Linkenheim-Hochstetten
62. Dr. Dr. Wätzold Plaum, Physicist and YouTuber
63. Michael Principato MSc in Electrical Engineering, specialised in Control Engineering and Modeling
64. Dieter Ramcke, retired geophysicist
65. Siegfried Reiprich, Dipl.-Ing, Geoscientist and Oceanography
66. Andreas Salzman, Dr. rer. nat., Diplom Chemiker
67. Dr. Hendrik Schlesing, Environmental Expert and Consultant
68. Dr. Jens-Christoph Schneider PhD in Isotope Chemistry, life time career in palaeoclimate and atmospheric geochemistry
69. Dr. rer. nat. Michael Schnell, Retired chemist
70. Prof. Dr. Dr. Karl-Heinz Schulz, Germany, University Hospital Hamburg-Eppendorf, interdisciplinary research in Medicine, Psychology and exercise science (https://www.researchgate.net/profile/Karl-Heinz-Schulz-2)
71. Dipl. Psych. Ulrike Schwan, Professional Psychotherapist, Psychotherapist look at the IPCC Organization
72. W.H. Eugen Schwartz, Emeritus Professor of Theoretical Chemistry, Universitaet Siegen
73. Dr.-Ing. Christian Singewald, Dipl.-Geologist, PhD Mining Engineering
74. Attila Sonal, Dipl.-Ing. der Elektrotechnik, Retired am Technischen Universität Kaiserslautern, Stadtratsmitglied Kaiserslautern, Preisträger Ansaldo Ricerche Price
75. Dr. Fritz Sontheimer, Retired Physicist, PhD in Condensed Matter Physics

76. Dr. Wolfgang Strehlau, Phys. Chemist, Technology Fellow in Johnson Matthey Plc, UK
77. Lothar Strenge, strategy and concept developer, full time writing on a large SF project
78. Manuel Tacanho, founder and president of the Afrindependent Institute
79. Matthias Thiermann, Parliamentary adviser in the Bavarian Parliament
80. Dr. Holger Thuss, President EIKE Institute
81. Jost Trier PhD, Retired Experimental Physicist at the Federal Institute in Braunschweig, Dept. of Atomic Physics
82. Ralf D. Tscheuschner PhD in Physics
83. Helmut Waniczek Dr. Dipl. Ing., Scientist, working 40 years in chemical industry
84. Thomas Weimer, Process Engineer (Dr.-Ing.), worked on CO2 capture from atmosphere and during hydrogen generation
85. Carl-Otto Weiss, Emeritus Professor in Non-linear Physics, Advisor to the European Institute for Climate and Energy, Former President of the German Meteorological Institute, Braunschweig
86. Peter Willingmann, Dr. rer.nat

SCIENTISTS AND PROFESSIONALS FROM GREECE

1. *Stavros Alexandris, Associate Professor Agricultural University of Athens, Dept. of Natural Resources and Agricultural Engineering, Sector of Water Resources ; WCD Ambassador*
2. Costas Fasseas, Emeritus Professor of Plant Anatomy & Electron Microscopy, Department of Crop Science, Agricultural University of Athens
3. Anthony Foscolos, Emeritus Professor of Mineral Resources at the Technical University of Crete, Energy Consultant for the United Nations Development Program (UNDP)
4. r. Vassilios C. Kelessidis, former Professor at Khalifa University, Texas A&M at Qatar and Technical University of Crete Greece, Lifetime of Experience in Petroleum Engineering
5. Christos J. Kolovos PhD, Mining & Metallurgy Engineer, Former Director of Mine Planning & Contractor Works Dept., Public Power Corporation of Greece
6. Emmanouil Kopanakis, Mechanical Engineer, Teacher at the Environmental Education Center of Karpenisi
7. Demetris Koutsoyiannis, Professor of Hydrology and Analysis of Hydrosystems at the National Technical University of Athens
8. Aristotelis Liakatas, Emeritus Professor of the Agricultural University of Athens on Agrometeorology, Member of the Greek Agricultural Academy
9. Nikos Mamassis, Associate Professor of Engineering Hydrology and Hydrometeorology at the National Technical University of Athens
10. Charilaos Markopoulos MSc in Waste Management
11. Spyridon Nikiforos, Economist, MBA
12. Sonia Perez † PhD, Biology/Immunology, Scientific Coordinator Cancer Immunology and Immunotherapy Center Saint Savas Cancer Hospital, Athens
13. G.-Fivos Sargentis, Dr Engineer-Sculptor, Dept. of Water Resources; School of Civil Engineering, National Technical University of Athens

SCIENTISTS AND PROFESSIONALS FROM GUATEMALA

1. Christopher Lingle PhD Economics Universidad Francisco Marroquín

SCIENTISTS AND PROFESSIONALS FROM HUNGARY

1. *Laszlo Szarka, Geophysicist, O.M.; WCD Ambassador*
2. Dr. Dezso Csejtei, retired professor of philosophy at the University of Szeged
3. Dr. Endre Fuggerth, Chemist, lifelong experience in gas-chromatography
4. Istvàn Héjjas PhD, Retired R&D Electrical Engineering
5. József Király, Chemical Engineer and one of the Authors of the Hungarian site www. klimarealista.hu
6. Dr. József Majer, Senior Professor of Ecology and Environment Protection at University of Pecs
7. Gábor Simon MSc Chemical Engineering, University teacher General, Anorganic, Environmental and Analytic Chemistry

8. Dr. Gábor Szász, Professor Emeritus, College Professor Dennis Gabor College Department of Economics and Engineering

SCIENTISTS AND PROFESSIONALS FROM INDIA

1. Dr. M.M. Ali, MSc in Meteorology and Oceanography with a PhD in Meteorology, Center for Ocean-Atmospheric Prediction Studies, Florida State University, USA
2. Dornadula Chandrasekharam, retired professor from Indian Institute of Technology Bombay, currently working in Izmir Institute of Technology as TUBITAK Professor working on geothermal energy systems
3. Vijay Jayaraj, Research Associate at CO2 Coalition, Contributor to Cornwall Alliance
4. Prem raj Pushpakaran, PhD in BioTechnology, Professor
5. Sanjeev Sabhlok, Economist with focus on Climate and Energy Policy

SCIENTISTS AND PROFESSIONALS FROM INDONESIA

1. Purwono Wahyudi, Entrepreneur and informed climate realist

SCIENTISTS AND PROFESSIONALS FROM IRELAND

1. *Jim O'Brien, Founder of the Irish Climate Science Forum, Expert Reviewer of IPCC AR6; WCD Ambassador*
2. Tom Baldwin, Electrical Engineer, specialist in Power System Security
3. Dr Timothy Dunne, DPsych, MSc, BA, ASFBPS, AFPSI, Consultant Clinical Psychologist, full member of the Psychological Society of Ireland and of the British Psychological Society
4. Gerald Fitzgibbon, Physical Chemist specializing in Electrochemistry and Thermodynamics
5. David Horgan, MA (Cambridge), MBA (Harvard), Resource Company Director
6. Seamus Hughes, BAgricSc, Specialist in Genetics
7. Mark Gerard Keenan, Former Science Advisor, Department of Energy and Climate Change, U.K., Former Environmental Affairs Officer, United Nations Environment Division, Geneva, Switzerland
8. Ultan Murphy, BSc (Hons) Chemistry, Industry Science Professional
9. Owen O'Brien, Business Founder and Entrepreneur, MBA, DBA
10. Patrick L O'Brien, MSc, MPhil, Senior International Environmental Consultant
11. Donal O'Callaghan, electrical engineer, retired food industry research scientist
12. J. Phillip O'Kane, Emeritus Professor, School of Engineering, University College Cork
13. Peter O'Neill, Retired, School of Engineering, University College Dublin, Expert Reviewer of IPCC AR6
14. Fintan Ryan, Retired Senior Airline Captain, Fellow Royal Aeronautical Society
15. Christian Schaffalitzky, FIMMM, Founder Institute of Geologists of Ireland, EurGeol
16. Norman Stewart PhD, former astrophysicist and meteorologist
17. Brian N. Sweeney, Founding Chairman of Science Foundation Ireland
18. Pat Swords, BE, CEng, FIChemE, PPSE, CEnv, MIEA, Challenger of Over-Reach in Environmental Legislation
19. Sean Tangney, Business Entrepreneur, Former Technical Director, CRH plc
20. David Thompson, BAgricSc, MA, Animal Nutritionist
21. Edward Walsh, Former Chairman, Irish Council for Science, Technology and Innovation, Former Director Energy Research Group, Virginia Tech, USA

SCIENTISTS AND PROFESSIONALS FROM ISRAEL

1. Dr. Gaby Avital PhD in Aerospace, member of the Israeli forum for rational environmentalism
2. Uriel Cohen, MSc in Computer Science from Technion - Israel Institute of Technology
3. Prof. Yonatan Dubi PhD, Professor of Theoretical Physics and Chemistry at Ben-Gurion University, co-founder of the Israeli Forum For Rational Environmentalism
4. Yakov Itenberg, BSc of Meteorology and Climatology, MSc of Physics Education, 25 years reserve meteorological officer of Israeli Defense Forces Home Front Command
5. Micha Klein PhD, Emeritus Professor, The Department of Geography and Environmental Studies

6. Nir J. Shaviv PhD in Physics at the Israel Institute of Technology, Professor of Physics at the Racah Institute at the The Hebrew University of Jerusalem

SCIENTISTS AND PROFESSIONALS FROM ITALY

1. *Alberto Prestininzi, Professore di Rischi Geologici, Honorary Cherman NHAZCA Università of Rome Sapienza, già Scientific Editor in Chief della Rivista Internazionale IJEGE e Direttore del Centro di Ricerca, Previsione, Prevenzione e Controllo dei Rischi Geologici (CERI); WCD Ambassador*
2. Pietro Agostini, Ingegnere, Associazione Scienziati e Tecnologi per la Ricerca Italiana
3. Aldo Aluigi, Nuclear Engineer, Consultant in Power Plants, Cogeneration end District Heating
4. Piero Baldecchi, Lettore
5. Achille Balduzzi, Geologo, Agip-Eni
6. Antonio Ballarin, Fisico, "Chief Artificial Intelligence Officer" di una pubblica amministrazione
7. Cesare Barbieri, Professore Emerito di Astronomia, Università di Padova
8. Donato Barone, Ingegnere
9. Sergio Bartalucci, Fisico, Presidente Associazione Scienziati e Tecnologi per la Ricerca Italiana
10. Giuseppe Basini, Astrofisico, Deputato, già dirigente di Ricerca dell'INFN
11. Franco Battaglia, Professore di Chimica Fisica, Università di Modena, Movimento Galileo 2001
12. Marco Benini, Ingegnere Idraulico, Libero Professionista
13. Eliseo Bertolasi, Dottore di Ricerca in Antropologia Culturale
14. Giorgio Bertucelli, Ingegnere, già Dirigente Industriale, ALDAI
15. Alessandro Bettini, Professore Emerito (Fisica) Università di Padova
16. Antonio Bianchini, Professore di Astronomia, Università di Padova
17. Luciano Biasini, Professore Emerito, già Docente di Calcoli Numerici e Grafici, Direttore dell'Istituto Matematico e Preside della Facoltà di Scienze Matematiche, Fisiche e Naturali dell'Università di Ferrara
18. Paolo Blasi, Professore Emerito (Fisica) e già Rettore dell'Università di Firenze, già Presidente della Conferenza dei Rettori delle Università Italiane
19. Enrico Bongiovanni, Dottore Commercialista
20. Paolo Bonifazi, Ex Direttore dell'Istituto di Fisica dello Spazio Interplanetario (IFSI) dell'Istituto Nazionale Astrofisica (INAF)
21. Roberto Bonucchi, Insegnante in Pensione
22. Giampiero Borrielli, Ingegnere
23. Francesca Bozzano, Professore di Geologia Applicata, Università di Roma La Sapienza, Direttore del Centro di Ricerca Previsione, Prevenzione e Controllo Rischi Geologici (CERI)
24. Antonio Brambati, Professore di Sedimentologia, Università di Trieste, Responsabile Progetto Paleoclima-mare del PNRA, già Presidente Commissione Nazionale di Oceanografia
25. Gianfranco Brignoli, Geologo
26. Marcello Buccolini, Professore di Geomorfologia, Università di Chieti-Pescara
27. Paolo Budetta, Professore di Geologia Applicata, Università di Napoli
28. Antonio Maria Calabrò, Ingegnere, Ricercatore, Consulente
29. Monia Calista, Ricercatore di Geologia Applicata, Università di Chieti-Pescara
30. Massimo Canali, Associate Professor of Agricultural Economics and Policy, Department of Agriculture and Food Sciences, University of Bologna
31. Cristiano Carabella, Geologo, Borsista presso l'Università di Chieti
32. Giovanni Carboni, Professore di Fisica, Università di Roma Tor Vergata, Movimento Galileo 2001
33. Peppe Caridi
34. Franco Casali, Professore di Fisica, Università di Bologna e Accademia delle Scienze di Bologna
35. Dr. Agronomo Fausto Cavalli, Agronomist, specialisation in meteorology
36. Giuliano Ceradelli, Ingegnere e Climatologo, ALDAI
37. Augusta Vittoria Cerutti, Membro del Comitato Glaciologico Italiano
38. Franco Di Cesare, Dirigente, Agip-Eni

39. Alessandro Chiaudani PhD, Agronomo, Università di Chieti-Pescara
40. Luigi Chilin, Dirigente in Pensione
41. Claudio Ciani, Relazioni Internazionali, Scienza Politica, Università di Roma La Sapienza
42. Edoardo Cicali, Membro del C.I.R.N (Comitato Italiano Rilancio del Nucleare) e dell'associazione "Atomi per la pace", ex Dipendente di un Centro Medico Radiologico ed Attualmente Impiegato nel Settore dell'Informatica
43. Pino Cippitelli, Geologo Agip-Eni
44. Carlo Colomba
45. Enrico Colombo, Chimico, Dirigente Industriale
46. Vito Comencini, Onorevole, Membro della Camera dei Deputati Italiana dal 2018
47. Enrico Conti, Physicist, Istituto Nazionale di Fisica Nucleare (INFN)
48. Ferruccio Cornicello, Fotografo e Lettore di Studi sul Clima
49. Domenico Corradini, Professore di Geologia Storica, Università di Modena
50. Carlo Del Corso, Ingegnere Chimico
51. Uberto Crescenti, Professore Emerito di Geologia Applicata, Università di Chieti-Pescara, già Magnifico Rettore e Presidente della Società Geologica Italiana
52. Fulvio Crisciani, Professore di Fluidodinamica Geofisica, Università di Trieste e Istituto Scienze Marine, Cnr, Trieste
53. Salvatore Custodero
54. Francesco Dellacasa, Ingegnere, Amministratore di Società nel settore Energetico
55. Alessandro Demontis, Perito Chimico Industriale, Tecnico per la Gestione delle Acque e delle Risorse Ambientali, Pomezia
56. Serena Doria, Ricercatore di Probabilità e Statistica Matematica, Università di Chieti-Pescara
57. Roberto d'Arielli, Geologo, Borsista presso l'Università di Chieti
58. Carlo Esposito, Professore di Rischi Geologici, Università di Roma La Sapienza
59. Gianluca Esposito, Geologo
60. Prof. Stefano Falcinelli PhD, Professor of Chemistry and Materials Technology, Department of Civil and Environmental Engineering, University of Perugia
61. Antonio Mario Federico, Professore di Geotecnica, Politecnico di Bari
62. Aureliano Ferri, Vicepresidente Associazione Piceno Tecnologie
63. Maurizio Fiorelli, Sommelier Professionale, studioso dell'evoluzione nella Coltivazione delle Vigne
64. Mario Floris, Professore di Telerilevamento, Università di Padova
65. Gianni Fochi, Chimico, Ricercatore in Pensione della Scuola Normale Superiore, Giornalista Scientifico
66. Sergio Fontanot, Ingegnere
67. Luigi Fressoia, Architetto Urbanista, Perugia
68. Mario Gaeta, Professore di Vulcanologia, Università di Roma La Sapienza
69. Stefano Galli MSc in Chemical Engineering, retired researcher
70. Sabino Gallo, Ingegnere Nucleare e Scrittore Scientifico
71. Stefano Gallozzi, Degree in Physics (old italian rules), Researcher at the INAF, Italian Institute for Astrophysics, Astronomical Observatory of Rome and presidente of the Safegarding Astronomical Sky Foundation
72. Giuseppe Gambolati, Fellow della American Geophysical Union, Professore di Metodi Numerici, Università di Padova
73. Alessio Del Gatto, Liceo Scientifico, Collaboratore Attivita Solare.it
74. Rinaldo Genevois, Professore di Geologia Applicata, Università di Padova
75. Umberto Gentili, Fisico dell'ENEA, Climatologo per il Progetto Antartide, ora in pensione
76. Enrico Ghinato, Perito Fisico
77. Mario Giaccio, Professore di Tecnologia ed Economia delle Fonti di Energia, Università di Chieti-Pescara, già Preside della Facoltà di Economia
78. Daniela Giannessi, Primo Ricercatore, IPCF-CNR, Pisa
79. Roberto Grassi, Ingegnere, Amministratore G&G, Roma
80. Roberto Graziano, Ricercatore di Geologia Stratigrafica e Paleoclimatologia/ Paleoceanografia, Università di Napoli, già Geologo presso il Servizio Geologico d'Italia
81. Alberto Guidorzi, Agronomo
82. Roberto Habel, Professore di Fisica Medica, Università di Cagliari
83. Thomas Kukovec, Tropical Agronomist and Subtropical Field Biologist in the private sector, specialised in semi-arid agriculture, ecophysiology and phytogeography of

Sahelian and Saharan plants. Scientific adviser and consultant in research-projects and learned societies

84. Nicola Iacovone, Physicist
85. Alberto Lagi, Ingegnere, Presidente di Società Ripristino Impianti Complessi Danneggiati
86. Dr Francesco Lamberti PhD in Material Science of the University of Padova, working on next generation PV
87. Luciano Lepori, Ricercatore IPCF-CNR, Pisa
88. Carlo Lombardi, Professore di Impianti Nucleari, Politecnico di Milano
89. Walter Luini, Geometra
90. Roberto Madrigali, Meteorologo
91. Angelo Maggiora PhD, INFN Senior Researcher, more than 40 years experience in research at CERN, Saclay, Dubna and Frascati
92. Franco Maloberti, Emeritus Professor, expert on microelectronics and modelling
93. Ettore Malpezzi, Ingegnere
94. Vania Mancinelli, Geologo, Borsista presso l'Università di Chieti
95. Ludovica Manusardi, Fisico Nucleare e Giornalista Scientifico, UGIS
96. Luigi Marino, Geologo, Centro Ricerca Previsione, Prevenzione e Controllo Rischi Geologici (CERI), Università di Roma La Sapienza
97. Maurizio Marsigli, Graduated in Geological Sciences and science author on the Sun and Space Meteorology
98. Alessandro Martelli, Ingegnere, già Dirigente ENEA
99. Francesco Martelli, Professor Emeritus of University of Florence, Former President of European Turbomachinery Society
100. Paolo Martini, consultant petroleum geologist with 30+ years of experience
101. Salvatore Martino, Professore di Geologia Applicata all'Ingegneria al Territorio ed ai Rischi, Università di Roma "Sapienza"
102. Maria Massullo, Tecnologa, ENEA-Casaccia, Roma
103. Enrico Matteoli, Primo Ricercatore, IPCF-CNR, Pisa
104. Paul P.A. Mazza, Associate Professor of Quaternary Geology and Paleontology and of Archeozoology, University of Florence
105. Paolo Mazzanti, Professore di Interferometria Satellitare, Università di Roma La Sapienza
106. Adriano Mazzarella, Professore di Meteorologia e Climatologia, Università di Napoli
107. Marcello Mazzoleni, Docente e imprenditore nel settore della formazione, fondatore del sito web MeteoSincero
108. Carlo Merli, Professore di Tecnologie Ambientali, Università di Roma La Sapienza
109. Enrico Miccadei, Professore di Geografia Fisica e Geomorfologia, Università di Chieti-Pescara
110. Gabriella Mincione, Professore di Scienze e Tecniche di Medicina di Laboratorio, Università di Chieti-Pescara
111. Umberto Minopoli, Presidente dell'Associazione Italiana Nucleare
112. Alberto Mirandola, Professore di Energetica Applicata e Presidente Dottorato di Ricerca in Energetica, Università di Padova
113. Aurelio Misiti, Professore di Ingegneria sanitaria-Ambientale, Università di Roma La Sapienza, già Preside della Facoltà di Ingegneria, già Presidente del Consiglio Superiore ai Lavori Pubblici
114. Maurizio Montuoro, Medico
115. Maria Luisa Moriconi, CNR researcher at Institute of Atmospheric Physics (retired) and associate to INAF until 2020
116. Renzo Mosetti, Professore di Oceanografia, Università di Trieste, già Direttore del Dipartimento di Oceanografia, Istituto OGS, Trieste
117. Daniela Novembre, Ricercatore in Georisorse Minerarie e Applicazioni Mineralogichepetrografiche, Università di Chieti-Pescara
118. Francesco Oriolo, Professore di Impianti Nucleari, Università di Pisa
119. Paolo Emmanuele Orrù, Professore di Geografia Fisica e Geomorfologia, Università di Cagliari
120. Sergio Ortolani, Professore di Astronomia e Astrofisica, Università di Padova
121. Alessandro Pagano, Geologist
122. Giorgio Paglia, Geologo, Borsista presso l'Università di Chieti
123. Massimo Pallotta, Primo Tecnologo, Istituto Nazionale Fisica Nucleare

124. Antonio Panebianco, Ingegnere
125. Giuliano Panza, Professore di Sismologia, Università di Trieste, Accademico dei Lincei e dell'Accademia Nazionale delle Scienze, detta dei XL, vincitore nel 2018 del Premio Internazionale dell'American Geophysical Union
126. Prof. Andrea Pardini PhD, University of Florence
127. Antonio Pasculli, Ricercatore di Geologia Applicata, Università di Chieti-Pescara
128. Ernesto Pedrocchi, Professore Emerito di Energetica, Politecnico di Milano
129. Davide Peluzzi, Ambasciatore del Parco Nazionale del Gran Sasso e dei Monti della Laga nel Mondo nel 2017
130. Corrado Penna, Docente di Matematica
131. Enzo Pennetta, Professore di Scienze Naturali e Divulgatore Scientifico
132. Gianni Pettinari, Impiegato Amministrativo, Fondatore del gruppo Facebook: "Falsi allarmismi sul riscaldamento globale"
133. Alessandro Pezzoli, Ricercatore Universitario e Professore aggregato in Weather Risk Management, Politecnico di Torino e Università di Torino
134. Tommaso Piacentini, Professore di Geografia Fisica e Geomorfologia, Università di Chieti-Pescara
135. Stefano De Pieri, Ingegnere Energetico e Nucleare
136. Paolo M.J. Pilli, Pensionato
137. Massimo Pilolli PhD Physics, Physicist, Meteorologist, Teacher
138. Mirco Poletto, Geologo libero professionista, registered at 'Ordine dei geologi del Veneto'
139. Andrea Pomozzi, Presidente Associazione Piceno Tecnologie
140. Guido Possa, Ingegnere Nucleare, già Viceministro del Ministero dell'Istruzione, Università e Ricerca con delega alla Ricerca
141. Alfonso Pozio PhD, Senior Researcher, ENEA CR Casaccia, Rome
142. Giorgio Prinzi, Ingegnere, Direttore Responsabile della Rivista "21mo Secolo Scienza e tecnologia"
143. Franco Prodi, Professore di Fisica dell'Atmosfera, Università di Ferrara
144. Franco Puglia, Ingegnere, Presidente CCC, Milano
145. Francesca Quercia, Geologo, Dirigente di Ricerca, Ispra
146. Nunzia Radatti, Chimico, Sogin
147. Arnaldo Radovix, Geologo, Risk Manager in Derivati Finanziari
148. Maurizio Rainisio, Mathematician, Lifetime career in Clinical Development and Epidemiology
149. Mario Luigi Rainone, Professore di Geologia Applicata, Università di Chieti-Pescara
150. Mario Rampichini, Chimico, Dirigente Industriale in Pensione, Consulente
151. Arturo Raspini, Geologo, Ricercatore, Istituto di Geoscienze e Georisorse (IGG), Consiglio Nazionale delle Ricerche, Firenze
152. Renato Angelo Ricci, Professore Emerito di Fisica, Università di Padova, già Presidente della Società Italiana di Fisica e della Società Europea di Fisica, Movimento Galileo 2001
153. Marco Ricci, Fisico, Primo Ricercatore, Istituto Nazionale di Fisica Nucleare
154. Renzo Riva, Comitato Italiano Rilancio Nucleare (C.I.R.N.), Buja
155. PierMarco Romagnoli, Ingegnere, Milano
156. Vincenzo Romanello, Ingegnere Nucleare, Ricercatore presso il Centro di Ricerca Nucleare di Rez, Repubblica Ceca
157. Piergiorgio Rosso, Ingegnere Chimico
158. Stefano Rosso, Insegnante di Geografia, Storia e Italiano, Scuola Secondaria, Modena
159. Alberto Rota, Ingegnere, Ricercatore presso CISE ed ENEL, Esperto di Energie Rinnovabili
160. Ettore Ruberti, Ricercatore ENEA, Docente di Biologia Generale e Molecolare
161. Giancarlo Ruocco, Professore di Struttura della Materia, Università di Roma La Sapienza
162. Sergio Rusi, Professore di Idrogeologia, Università di Chieti-Pescara
163. Massimo Salleolini, Professore di Idrogeologia Applicata e Idrogeologia Ambientale, Università di Siena
164. Nicola Scafetta, Professore di Fisica dell'Atmosfera e Oceanografia, Università di Napoli
165. Emanuele Scalcione, Responsabile Servizio Agrometeorologico Regionale ALSIA, Basilicata

166. Nicola Sciarra, Professore di Geologia Applicata, Università di Chieti-Pescara
167. Francesco Sensi, Generale di Divisione Aerea (R)
168. Massimo Sepielli, Direttore di Ricerca, ENEA, Roma
169. Leonello Serva, Geologo, Accademia Europa delle Scienze e delle Arti, Classe V, Scienze Tecnologiche e Ambientali, già Direttore Servizio Geologico d'Italia
170. Roberto Simonetti, Geologo, R&D c/o Azienda S.I.I.
171. Elio Sindoni, Professore Emerito dell'Università di Milano Bicocca
172. Enzo Siviero, Professore di Ponti, Università di Venezia, Rettore dell'Università e-Campus
173. Rinaldo Sorgenti, Deputy Chairman of ASSOCARBONI
174. Ugo Spezia, Ingegnere, Responsabile Sicurezza Industriale, Sogin, Movimento Galileo 2001
175. Luigi Stedile, Geologo, Centro di Ricerca Previsione, Prevenzione e Controllo Rischi Geologici (CERI), Università di Roma La Sapienza
176. Emilio Stefani, Professore di Patologia Vegetale, Università di Modena
177. Flavio Tabanelli, Fisico
178. Maria Grazia Tenti, Geologo
179. Umberto Tirelli, Visiting Senior Scientist, Istituto Tumori d'Aviano, Movimento Galileo 2001
180. Giorgio Trenta, Fisico e Medico, Presidente Emerito dell'Associazione Italiana di Radioprotezione Medica, Movimento Galileo 2001
181. Roberto Vacca, Ingegnere e Scrittore Scientifico
182. Gianluca Valensise, Dirigente di Ricerca, Istituto Nazionale di Geofisica e Vulcanologia, Roma
183. Prof. Paolo Sebastiano Valvo PhD - Associate Professor of Solid and Structural Mechanics, University of Pisa
184. Corrado Venturini, Professore di Geologia Strutturale, Università di Bologna
185. Flavio Vetrano, Honorary Professor of General Physics, DiSPeA, University Carlo Bo , Urbino
186. Benedetto De Vivo, Professore di Geochimica in Pensione dall'Università di Napoli, ora Professore Straordinario presso Università Telematica Pegaso, Napoli
187. Andrea Zaccone, Geologo, Dirigente Protezione Civile Regione Lombardia
188. Luigi Zanotto, Docente in Pensione
189. Franco Zavatti, Ricercatore di Astronomia, Università di Bologna
190. Antonino Zichichi, Professore Emerito di Fisica, Università di Bologna, Fondatore e Presidente del Centro di Cultura Scientifica Ettore Majorana di Erice

SCIENTISTS AND PROFESSIONALS FROM JAPAN

1. Masayuki Hyodo, Professor of Earth Science, Kobe University
2. Yoshihiro Muronaka, Professional Engineer, PE Office President, Energy & Environment
3. Mototaka Nakamura, Atmospheric and Oceanic Scientist (ScD in Meteorology, MIT)
4. Dr. Hiroshi L. Tanaka, Professor in Atmospheric Science, Centre for Computational Sciences, University of Tsukuba

SCIENTISTS AND PROFESSIONALS FROM KUWAIT

1. Mohammad A. AlKhamis, DVM, MPVM, PhD, Assistant Professor of Epidemiology, Department of Epidemiology and Biostatistics, Faculty of Public Health, Health Sciences Center, Kuwait University

SCIENTISTS AND PROFESSIONALS FROM MALAYSIA

1. Chris Schoneveld, Earth Scientist and Retired Shell Exploration Geophysicist

SCIENTISTS AND PROFESSIONALS FROM MALTA

1. Joseph Attard, Retired Scientist, PhD chemical engineering MSc Electronics Communication

SCIENTISTS AND PROFESSIONALS FROM MEXICO

1. Rubén Coronal Méndez, Master degree in Applied Economics, Industrial Engineer
2. Luis Frausto, Chemical Engineer
3. Armando Páez PhD, Urbanism, Expert in Sustainability and Energy Transitions
4. Victor Manuel Velasco Herrera PhD, Space Engineer

SCIENTISTS AND PROFESSIONALS FROM NAMIBIA

1. Dr Simon Idris Beshir, Cardiologist, currently involved in Green Project in Kalahari Desert

SCIENTISTS AND PROFESSIONALS FROM THE NETHERLANDS

1. *Prof. Dr. Ir. Guus Berkhout, Emeritus Professor of Geophysics, Delft University of Technology, Member of the Royal Netherlands Academy of Arts and Sciences; WCD Ambassador*
2. *Dr. Cornelis le Pair, Physicist, Former CEO Physics & Technology Research Organisations; WCD Ambassador*
3. Jan H. Akkerman MSc, Structural Geology, worked 19 years with Billiton in Mining and Geology and the last 20 years with DGA van Akkerman Exploration BV
4. Maarten van Andel, Author of the 'Groene Illusie'
5. Jan Asselbergs, Mechanical Engineer who started his career with IHC. Since 1990 he is active in revitalizing medium sized companies
6. Dries Ausems MSc, Earth Sciences, Lifetime Experience as Geologist in the Geo-Energy Industry
7. René Bakers, Former Lawyer and Attorney Liability and Insurance
8. Dr. Thomas W. Bakker, Lifetime Experience in the Geo-energy Industry, Founder and former (or retired) CEO of Well Engineering Partners BV
9. Robert Becht, Lifetime R&D Experience in Water Management with emphasis on water management in East Africa
10. Frans van den Beemt, Nuclear Physicist, Former Program Director Technology Foundation STW
11. Drs. A (Toine) J. A. Beukering, Bgen (b.d.), Member of the Provincial Council of Zuid Holland, Member of the Senate (Eerste Kamer) of the Dutch Parliament (the States General)
12. Jim van Beusekom, Retired Captain B747-400 with KLM, 35 years observational knowledge of the Earth's atmosphere
13. Maarten Biesheuvel MSc and PhD Chemical Technology, University of Twente, Senior Scientist Chemical Engineering and Water Technology, Wetsus
14. Andre Bijkerk, Retired Officer Royal Dutch Air Force, now Climate Researcher
15. Dr. Frans Bijlaard, professor-emeritus steel constructions, TU Delft
16. Dr. Ruud Binnekamp Msc. Integral Design and Management, teacher and researcher in design and decision systems at TU Delft
17. Peter Bloemers, Emeritus Professor of Biochemistry, Radbout University, Nijmegen
18. Albert F.T. de Booij †, Founder Speakers Academy Int. BV, Founder en CEO World of Consciousness.com
19. Hans Bouman MSc, Chemistry, Professional in Production Technology and Asset Management
20. Dr. Ir. Arnold Bovy, retired, former Director Energy Transmission Company MEGALIMBURG
21. Ben Braam Msc in Physics, lifetime career in space instrumentation
22. Paul M.C. Braat, Emeritus Professor of Pulmonary Physics, University of Amsterdam
23. Solke Bruin, Emeritus Professor of Product-driven Process Technology, University of Eindhoven and Former Member Management Committee Unilever Research, Vlaardingen
24. Dr. Theo Claassen, Aquatic Ecologist
25. Paul Cliteur, Professor of Legal Sciences, Member of the Senate of The Netherlands
26. Albert J.H.G. Cloosterman, Retired Chemical Engineer, Publicist on Climate and Cosmological Matters
27. Charles Coleman, former executive Olivetti Group International
28. Marcel Crok, Climate Researcher and Science Journalist

29. Gerhard Diephuis MSc, Geosciences, specialized in Geophysics, Lifetime Experience in the Geo-Energy Industry, Guest Lecturer TU Delft
30. Henck van Dijck, Sculptor, designer and innovator
31. David E. Dirkse, Former Computer Engineer and Teacher Mathematics
32. Dr. Tjibbe Dokter MBA, Expert in Scenario Analysis and Risk Assessment, retired from AkzoNobel
33. Marco Draaisma, ICT Process Coördinator
34. Vincent van Driel, MSc Mechenical Engineering TU Delft, Design and Construction of gas/oil processsing plants, Retired
35. Dr. Jan W. Drukker, Emeritus Professor Industrial Design Delft University of Technology, University of Twente and (Visiting Professor) Tsinghua University (Beijing PRC). Elected Member Regional Parliament of the Dutch Province Drenthe
36. Arjan Duiker, Process Technologist at Tata Steel, specialist on Thermodynamics and Fluid Mechanics
37. Louw Feenstra, Emeritus Professor Erasmus University and Philosopher, Rotterdam
38. Arnold Fellendans, Physics at TU Delft, 40 years at Unilever (retired), www.omdeaarde.nl
39. Frans Galjee, Mechanical Engineer, Retired Researcher at ECN
40. Jan van Gils, Teacher in Physics
41. Henk Goemans MSc, Geosciences, specialized in Reservoir Engineering
42. Frans H Gortemaker, Former Vice president Unilever Global R&D
43. W. J. Evert van de Graaff, Consulting Geologist, 50+ years Global Experience
44. Ton J.T. Grimberg, Oil & Gas Professional, Finance Adviser
45. Katharina Grimm Msc Agroecology and Sustainable Food Systems, Project Leader energy transition at the municipality of Epe
46. Kees de Groot, Former Director Upstream Research Lab. Shell
47. Paul de Groot PhD, Geoscience, Manager dGB Earth Sciences
48. Lex A. van Gunsteren, Marine propulsion expert, former director of Corporate Planning and R&D of the Royal Boskalis Westminster Group, former professor of Technology at TU Delft and Erasmus University
49. Leo Halvers, Former Director Billiton Research Arnhem and Former Director Technology Foundation STW
50. Hans Hamaker, University Degree in Phonetic Sciences, expert in biomechanics of speech, supporter of plasma cosmology, former wireless communication officer
51. Maarten Hardon BSc, Civil Engineering, Lifetime Experience in Offshore Industry, Director Venty BV
52. Eduard Harinck, Former Logistics Expert, Nedlloyd Group/KPMG Consulting
53. Godard Hazeu MSc, Geoscciences, specialized in Geology, past Technical Director of the Dutch State Oil and Gas Company EBN
54. Edward Heerema Msc in Civil Engineering TU Delft, President of Allseas, worldwide active in offshore pipelaying and platform lifting
55. J.R Hetzler, Retired WUR Engineer Forestry Economics
56. Dr. Tom van der Hoeven, Energy Transport Modeling Expert
57. Dr. Martijn Hoevenaar, Independent Researcher, Physics, Education, Medicine
58. Jan F. Holtrop †, Emeritus Professor of Petroleum Engineering, Delft University of Technology
59. Hans Hombroek MSc, Geoscience, Lifetime Experience in the International Geo-Energy Industry
60. Tom Hoornstra, Air-conditioning Engineer
61. Jan Horstink, Earth Scientist, Exploration Projects Oil & Gas ME & FE
62. A. Huijser, Physicist and Former CTO Royal Philips Electronics
63. Jan de Jager, emeritus professor Geology (VU University Amsterdam, University of Utrecht)
64. Jan C. de Jong Msc Process Engineering TU Delft, expert in energy-and thermal process engineering, lifetime career in the oil and gas industry
65. Jan de Jong, former director Sampo Industrial Insurance NV. Benelux and Electrorisk Verzekeringsmaatschappij N.V.
66. Wouter J. Keller, Emeritus Professor of Statistical Methods, Former Member Board of Directors, Central Bureau of Statistics (CBS)
67. Jacques van Kerchove, Economist and Marketeer, Former CFO Rabobank, now Climate and Environment Researcher

68. Henri G. Kerkdijk-Otten, Msc History, University of Nijmegen (graduated in 1998), Founder and chairman of Restoring Africa's Wildlife Foundation, Founder and former chairman (until august 2017) of True Nature Foundation https://truenaturefoundation.org/
69. Rob de Kok, Principal Geophysicist, researching Influence of CO2 on Atmospheric Temperatures
70. Hans Kolmschate, Chemical Engineer, University of Twente
71. Henk de Koning MSc, former Principal Management Consultant Atos Consulting with specialisation Logistics, IT and Information Security
72. Rob W.J. Kouffeld †, Emeritus Professor of Energy Conversion, Delft University of Technology
73. Hans H.J. Labohm, Former Expert Reviewer IPCC
74. Arjan Lenoir, MSc Industrial Sciences
75. B.G. Linsen, Former Director Unilever Research Vlaardingen
76. Jaap M. van Luijk, Msc. Petroleum Engineering, lifetime experience in the international geo-energy industry
77. Pieter Lukkes, Emeritus Professor of Economic and Human Geography, University of Groningen
78. Hugo Matthijssen, Former Teacher Meteorology, now Publicist on Climate Matters
79. Leo D. Minnigh, retired scientist in structural geology, lecturer/speaker for non-professionals
80. Dr. Rob Mooij, PhD in Nuclear Physics at University of Utrecht, MS Computer Science at Drexel University, Philadelphia, Retired as Medical Physicist from University of Pennsylvania
81. Ir. J.M. Mulderink, Former General Director Akzo-Nobel
82. Rob Nijssen, Radar Engineer and Publicist on Climate Matters
83. Rutger van den Noort PhD, Advisor in Innovation Processes, CEO Newcalf
84. Dr. Chris Oldenhof PhD in Photochemistry, Retired from the Dutch chemical company DSM
85. Peter Oosterling, Former Scientist E & P Shell, now active as Climate Researcher
86. Daan Osinga, Geologist
87. Kees Pieters, Mathematician, Former Operational Research and ICT manager at Shell
88. Robert J van der Plas MSc Applied Physics, MSc Development Studies, Sustainable Energy Management and Development Specialist
89. Reynier Pronk, Former IT Manager, Accredited Project Management Consultant and Trainer
90. Paul Ras Msc Geophysics TU Delft, Geophysical Consultant, climate realist
91. Ir B. Peter Rauwerda Msc. in nuclear engineering, TU Delft
92. Louis M.P.T. van den Reek, PharmD, Member of 'De Groene Rekenkamer'
93. Jan C. Reinoud, retired CEO Dutch chain of Supermarkets
94. A.G. Reitsma, MSc in Social technology, planned change (University of Groningen 1978) Social Technician
95. Kees Remi, Electrical Engineer, lifetime experience in Energy Distribution and Industrial Automation
96. Joseph Reynen, Finite Element Modeling Expert, Retired from EU Joint Research Centre in Ispra, Emeritus Associate professor TU Delft
97. G.T. Robillard, Emeritus Professor of Biochemistry and Biophysics
98. Jaap Romijn Msc in Civil Engineering TU Delft, lifetime experience in water management projects
99. Kees Roos, Emeritus Professor of Optimization Technology, Delft University of Technology
100. Rutger van Santen, Emeritus Professor of Anorganic Chemistry and Catalysis, Former Rector Magnificus, Eindhoven University
101. Don Schäfer, Former Director Shell Exploration & Production and New Business, Shell
102. Juleon Schins PhD in Molecular Physics, specialist in near infrared spectroscopy
103. Dr. Rob Schoevaart, Biocatalist, Co-founder and Managing Director of ChiralVision, being specialised in making chemical processes greener
104. Frans Schrijver, Strategy Consultant and Climate Publicist
105. Bert Sigmond, Geologist, Founder of EuGeNe Company in Geothermal Energy
106. Hendrick Smit, Chemical Engineer, specialised in Environmental Instrumentation
107. Jos de Smit, Emeritus Professor of Stochastic Operations Research and Former Rector Magnificus of the University of Twente

108. Barend-Jan Smits, Geologist, Former Director of Wintershall Nederland, BASF Group
109. Jack van Soest BSc, Geography teacher (retired)
110. Dr. Engel van Spronsen PhD in Physics, Lifetime career in Shell as researcher, reservoir engineer, and technical manager. After Shell he also worked for Maersk Oil, IMPaC Engineering, and Eneco
111. Albert Stienstra †, Emeritus Professor of Computer Simulation and Micro-Electronics, Delft University of Technology
112. P.J. Strijkert, Former Member Board of Directors of DSM, Delft
113. Hans van Suijdam, Former Executive Vice President Research and Development DSM
114. Dick Swart, MSC; worldwide drilling expert, lifetime of experience in the geo-energy industry
115. Dr. Harry C. M. de Swart, Emeritus Professor of Logic and Language Analysis, University of Tilburg and Erasmus University Rotterdam, Author of the book 'Philosophical and Mathematical Logic'
116. Peter van Toorn, Former Research Geophysicist Shell
117. Fred Udo, Emeritus Professor of Nuclear Physics, Vrije Universiteit Brussels
118. Ir. Arnold Uijlenhoet, retired electrical engineer with degree from Technical University Delft and postgraduate studies at the University of Pittsburgh (U.S.A). Lifetime international experience in power generation, transmission, and distribution
119. Maarten Vasbinder MD, specialized in prion theories and practice
120. J.F. van de Vate, Former Director ECN, Petten, Former UN Delegate IPCC
121. Jan Verheij, Retired Scientist Applied Physics at TNO Delft, Emeritus Professor of Noise Control Engineering at Eindhoven University of Technology
122. Hans Verschuur MSc, Geosciences, specialized in Mining
123. H. Verveer, Civil Engineer, lifetime experience in maritime infrastructure and building services
124. Jannes. J. Verwer, Former Director ECN and Former Chairman Supervisory Board State Owned Radio Active Waste Storage Facilities
125. Dr Koen Vogel, Geologist and Geostatistician, lifetime experience in numerical modelling, proficient in evaluating and developing global energy projects
126. Henk van der Vorst, Emeritus Professor of Numerical Mathematics, University of Utrecht
127. Bart Vos, Msc Petroleum Engineering, Lifetime of Experience in the Geo-energy Industry
128. Rob de Vos, Geographer and Editor of "Klimaatgek"
129. Henk de Vries, lifetime experience in organised crime, expert in digital forensics
130. Jaap van der Vuurst de Vries, Emeritus Professor of Petroleum Engineering, Former Dean Faculty of Applied Earth Sciences, Delft University of Technology
131. Dr. Jules de Waart PhD in Physical Geography, Exploration Geologist in Africa, Past-member of the Dutch Parliament, author of the book on Climate Change and Energy Transition "Don't believe everything"
132. Dr. André Wakker, energy expert, lifetime experience in nuclear energy, speaker and writer on energy transition
133. Karel Wakker, Emeritus Professor of Astrodynamics & Geodynamics, Delft University of Technology
134. Robert N. Walter MSc E.E., Member Advisory Board 'De Groene Rekenkamer'
135. Cyril Wentzel, Multi-Physics Engineer and Chairman of Environmental Think Tank 'Groene Rekenkamer'
136. Frans A. van der Werf, Master of Law, Owner of an International Business for Management, Consultancy and Finance
137. Dolf van Wijk, Formerly AkzoNobel Environmental Research Laboratory and Former Executive Director Cefic-Euro Chlor, Brussels
138. Jaap Wijsman, Mechanical Engineer, active in the offshore industry
139. Jan Winkel MSc, Chemical Engineering, specialization in Natural Gas Projects, Lifetime Experience in the Geo-Energy Industry
140. Theo te Winkel, Geo Scientist and International Health Care Specialist
141. W.J. Witteman, Professor of Applied Physics and CO2 Lasers, University of Twente
142. Dr. Hans Wolkers PhD in Dierfysiologie en natuurbeheer en ruim 20 jaar onderzoekservaring, onder andere in arctische ecotoxicologie, nu actief als wetenschapsjournalist en universitair docent in 'Schrijven over Wetenschap'
143. Theo Wolters, Chairman Environment, Science & Policy Foundation, Co-founder 'Groene Rekenkamer' and 'Climategate.nl'

144. Govert Zijderveld, MSc Mining Engineering, Consultant for all Drilling, Mining and Naval Engineering activities
145. Dr. E.J. (Ed) Zuiderwijk, Retired Astrophysicist and Data Manager
146. Diederik Zwager MSc Petroleum Engineering, CEO Air Drilling Associates

SCIENTISTS AND PROFESSIONALS FROM NEW ZEALAND

1. *Barry Brill OBE, Previously Minister of Science and Techology; WCD Ambassador*
2. Deborah Alexander, Agricultural Scientist
3. Jock Allison, Retired Agricultural Scientist, Ministry of Agriculture
4. Paul A. Catchpole, Qualified Land Surveyor & Fellow of New Zealand Institute of Surveyors, Retired Ex Commissioner of the New Zealand Environment Court
5. Roger High Dewhurst, Retired, Geologist/Hydrogeologist
6. Terry Dunleavy † MBE, Co-Founder (2006) and Honorary Secretary New Zealand Climate Science Coalition
7. Geoffrey. G. Duffy, Professor Emeritus, University of Auckland
8. Doug Edmeades, Managing Director agKnowledge Ltd.
9. Professor Michael J Kelly, MA, PhD, SCD, MAE, Emeritus Prince Philip Professor of Technology at the University of Cambridge, Fellow of the Royal Society, Fellow of the Royal Academy of Engineering, Fellow of the Institute of Physics, Fellow of the Institution of Engineering and Technology, Senior Member of the Institute of Electronic and Electrical Engineering
10. Joe Fone, CAD Engineer, Enatel Ltd.
11. Gary Kerkin, Retired Chemical Engineer, Upper Hutt. Executive member New Zealand Climate Science Coalition
12. Brian Leyland, Power Systems Engineer and Experienced Renewable Energy Specialist
13. Gerrit J. van der Lingen, Geologist and Paleoclimatologist, New Zealand, Author of the Book "The Fable of Stable Climate"
14. Dr. John Maunder, Climate Scientist, President of the WMO Commission for Climatology 1989-1996
15. Dr Richard Reaney, Climate Researcher, Post Graduate Qualification in Antarctic Studies, University of Canterbury New Zealand
16. Darag S. Rennie MBChB, Lifetime explorer of truth
17. John Scarry ME (Civil), Structural Engineer, Member of the New Zealand Climate Science Coalition
18. John Sexton, Member of the New Zealand Climate Coalition
19. David Shelley, Emeritus Associate Professor Geology and latterly Dean of Postgraduate Studies, University of Canterbury, Christchurch
20. David Steward, Electronic Engineer, Supporter of truth seeking in climate change
21. Philip Strong, Science Research Leader & Member of the New Zealand Climate Coalition
22. Richard Treadgold, Executive Member NZ Climate Scienc Coalition, Convenor Climate Conversation Group
23. Ian Wright, Professional Geologist

SCIENTISTS AND PROFESSIONALS FROM NORWAY

1. *Ivar Giaever, Nobel Laureate Professor, Nobel Prize Winner in Physics, Emeritus Professor of the Rensselaer Polytechnic Institute, Chief Technology Officer of Applied Biophysics Inc., Fellow of the American Physical Society; Honorary WCD Ambassador*
2. *Jan-Erik Solheim, Professor Emeritus Astrophysics, University of Tromsø – The Arctic University of Norway; WCD Ambassador*
3. Gunnar Abrahamsen, Professor Emeritus Soil Science, University of Life Sciences
4. Knut Åm, retired geoscientist, holding positions at the Geological Survey of Norway, the Norwegian Petroleum Directorate, Statoil (R&D Manager), several positions with Phillips Petroleum Company both in Norway and the United States and adjunct Professor of Geophysics at the University of Bergen, Norway. Knut Åm is Honorary member of The Norwegian Academy of Technological Sciences
5. Egil Bergsager MSc of UCLA, and also University of Oslo, Petroleum Geologist, Director Norwegian Petroleum Directorate, President Rogaland Science Park. Board member of many advanced technology companies

6. Stein Sorlie Bergsmark, Phycisist, Former Head of Renewable Energy Studies Programmes, University of Agder
7. Einar R. Bordewich, multidiscipline Engineering
8. Dr. Hans Borge, Associate Professor in Mathematics, University of Stavanger
9. Reidar Borgstrøm, Professor Emeritus in Fishbiology and Nature Conservation, University of Life Sciences
10. Ole Henrik Ellestad, Physical Chemist. Former Research Director and Professor in Petrochemistry at the Centre for Industrial Research and University of Oslo. Former Managing Director of Norwegian Computer Centre. Former Division Director of Norwegian Research Council. Previous Chairman of the Board, Klimarealistene
11. Jon Gulbrandsen PhD, Biologist, Associate Professor NOFIMA and NOAA (USA)
12. Arve Gleissner Gustavsen, Msc in Cybernetics, Lifelong Experience in Design and Engineering
13. Rögnvaldur Hannesson, Professor Emeritus, Norwegian School of Economics
14. Geir Hasnes, Adjunct Associate Professor, Institute of applied Cybernetics, Norwegian University of Science and Technology
15. Martin Torvald Hovland, Geophysical and Geological Advisor, Former Lecturer at University of Tromsø
16. Ole Humlum, Professor Emeritus in Physical Geography, University of Oslo
17. Morten Jødal †, Biologist, Former Employee of the Norwegian Research Council and the Centre for the Development and Environment at the University of Oslo
18. Dr. Ing. Hans Konrad Johnsen, Dr. Ing.
19. Olav Martin Kvalheim, Emeritus Professor, Chemistry, Bergen University
20. Arnfinn Langeland, Professor Emeritus Biology, Norwegian University of Science and Technology
21. Mikael Lindgren, MS Applied Phyics and electronics, PhD Chemical Physics, Prof Applied Physics (Optics) and Biophysics (spectroscopy)
22. Willy Nerdal, Professor of Chemistry, University of Bergen
23. Johannes Oraug, Landscape Architect, Researcher for 11 years at the Norwegian Institute for Urban and Regional Research
24. Egil Pedersen, Dr. Eng. and Professor of Technology at UiT The Arctic University of Norway
25. Elen Roaldset, Emertitus Professor in Geology, University of Oslo, Former Director of Natural History Museum Oslo, Professor at Norwegian University of Science and Technology
26. Ulf Torgny Rock, Master of Chemical Engineering, Norsk Hydro
27. Håkon Gunnar Rueslåtten, Geological Researcher, Trondhheim
28. Tom V. Segalstad, Associate Professor Emeritus of Geochemistry, University of Oslo
29. Einar Sletten PhD, Professor in the Dept of Chemistry, University of Bergen
30. Jørgen Stenersen, Professor Emeritus Eco-Toxicology, University of Oslo

SCIENTISTS AND PROFESSIONALS FROM PARAGUAY

1. Albrecht Glatzle, Retired Director Research of INTTAS (Iniciativa para la Inverstigación y Transferencia de Tecnología Agraria Sostenible)

SCIENTISTS AND PROFESSIONALS FROM THE PHILIPPINES

1. Melanchthon Bernil, Professional Chemical Engineer

SCIENTISTS AND PROFESSIONALS FROM POLAND

1. Marek Boinski, Chairman of the National Section of Energy Workers' Union NSZZ
2. Zbigniew Gidzinski, Advisor to the Chairman of the Silesian Region of the Solidarity Union in charge of the climate policy as well as a former Secretary of the National Energy Security Team of the Chancellery of the President of Poland
3. Jaroslaw Grzesik, Chairman of the National Secretariat of Mine and Energy Workers' Union NSZZ
4. Dominik Kolorz, Chairman of the Slasko-Dabrowski Region of NSZZ

SCIENTISTS AND PROFESSIONALS FROM PORTUGAL

1. Demétrio Carlos Alves, Chemical Engineer, specialized in Processes and Systems, Postgraduate in Legal Issues of Urban Planning, University of Lisbon
2. Rui Cruz, Pharmaceutical Development Scientist, PhD In Chemical and Biological Engineering (Material Science Focus for Solar Energy Applications)
3. Pieter IJzerman, entrepreneur in modern energy solutions and electric mobility
4. J.M.S. Martins, retired agrarian researcher
5. Pamela Matlack-Klein, Member of Portuguese Sea Level Project, USA
6. Dr. Peter Stallinga, Professor Associado com Agregação, Universidade do Algarve, Portugal, Faculty of Sciences and Technology, Department of Electronic Engineering and Informatics
7. João Tilly, Mechanical Engineer and Maths teacher

SCIENTISTS AND PROFESSIONALS FROM ROMANIA

1. Marius Bratu, Senior Meteorologist, short and medium range weather forecast

SCIENTISTS AND PROFESSIONALS FROM RUSSIAN FEDERATION

1. Habibullo Abdussamatov, Head of the Space Research Sector of the Sun, Pulkova Observatory RAS and Head of the Lunar Observatory Project on Monitoring of the Climate
2. Prof. Vladimir N. Bashkin, DrSc (biol), Professor in Biogeochemistry and Risk Assessment in Moscow State University, Cornell University, Seoul National University, Bangkok King Mongkut Technological University; vice-chairperson of WG of UN Convention on Long-Range Transboundary Air Pollution and PR in the Institute of Physico-chemical and Biological Problems of Soil Sciences RAS, Pushchino, Russia
3. Pavel Bizyukov PhD in Metallurgical Engineering, faculty member at Moscow State Institute of Steel and Alloys
4. Gleb I. Evgenev, Professor of Environment, Moscow State Technical University (MADI)
5. Vladimir G. Kossobokov, Chief Scientist, Professor Expert, Russian Academy of Sciences Past Vice-Chair, IUGG "GeoRisk" Commission (IUGG Commission on Geophysical Risk and Sustainability) Core Member, ISSO (International Seismic Safety Organization)
6. Eugene Nagibin, MA in Economics, CIR, Territorial Development and Management Consultant
7. Henni Ouerdane, Assistant Professor, Manager of the Energy Systems PhD Programme, Skolkovo Institute of Science and Technology, Moscow Region
8. Dr. Michael Petelin, professor of the University of Nizhny Novgorod, head researcher of the Institute of Applied Physics, Nizhny Novgorod

SCIENTISTS AND PROFESSIONALS FROM SAUDI ARABIA

1. Christopher M. Fellows Phd, physical chemist

SCIENTISTS AND PROFESSIONALS FROM SERBIA

1. Ivan Stefanovic, Curator of collection, Faculty of Mining and Geology, University of Belgrade

SCIENTISTS AND PROFESSIONALS FROM SINGAPORE

1. Andrew Frazer, offshore drilling, earth sciences and renewables
2. Dr. Lars Schernikau, Energy Economist, Entrepreneur & Author

SCIENTISTS AND PROFESSIONALS FROM SLOVENIA

1. Borut Bohanec, Emeritus Professor of Biotechnology, active to explain major missinterpretations of scientific discoveries
2. Ján Lakota MD, PhD molecular biology
3. Rafael Mihalič, Professor of Electrical Engineering, University of Ljubljana

SCIENTISTS AND PROFESSIONALS FROM SOUTH AFRICA

1. Rosemary Falcon, Emeritus Professor Clean Coal Technology Research Group at the University of Witwatersrand, Director Fossil Fuel Foundation
2. Dennis Shaun Garisch BSc (Civil) Eng, Professional Engineer registered with Engineering Council of South Africa (ECSA), over 30 years of practice, inclusive of many storm water management designs
3. Dr Hans Hofmann-Reinecke, nuclear physicist, author of several books "Grün und Dumm", articles an videos on global warming and alternative energies for the general public
4. Rob Jeffrey, Economic Risk Consultant: Senior Economist and Managing Consultant, leading expert in energy and electricity
5. Kelvin Kemm PhD, Nuclear Physicist, CEO Nuclear Africa, Pretoria
6. Dr. John Ledger PhD, Visiting Associate Professor at the University of the Witwatersrand, Energy and Environmental Consultant, Consulting Editor, Freelance Writer, Editor and Lecturer
7. Prof. Richard Meissner, Associate Professor, Department of Political Sciences, University of South Africa
8. Don Mingay, Retired Professor of Nuclear Physics
9. Dr. Henrique J.S. de Barros Pinheiro, Geologist, Invited Associate Professor, Universidade Fernando Pessoa, Porto, Portugal
10. Professor Martin R. Sharpe, PhD from University of Exeter, retired Geologist, Geochemist, Analyst and Field Mapper at University of Pretoria, Founder of geological consulting and exploration companies in Southern Africa

SCIENTISTS AND PROFESSIONALS FROM SOUTH KOREA

1. *Dr. Seok Soon Park, Professor of Environmental Science and Engineering, Ewha Womans University, Seoul, Founder of the Climate Truth Forum; WCD Ambassador*
2. Zonghie Han, economist at Daegu University

SCIENTISTS AND PROFESSIONALS FROM SPAIN

1. *Blanca PargaLanda PhD, Modelling Expert, specialist in Environmental Law; WCD Ambassador*
2. Dr. Saúl Blanco, Associate Professor of Ecology at the University of León
3. Ferran Brunet, Professor on the European Economy, Unniversitat Autònoma de Barcelona
4. Maria Teresa Estevan Bolea, Ingeniero Laureado 2019 Royal Spanish Academy of Engineering. World Award 2018 In Engineering WFEO (World Federation of Engineering Organizations), National Prize in Industrial Engineering 2019.
5. José Carlos Gonzàlez Hidalgo, Professor of Physical Geography, teaching more than 20 years on Climatology and doing Research on the Topic, University of Zaragoza, Dep. Geografia
6. Antonio J. Huertas, Engineer with 35 years experience in Energy Politics and Operation, and Environmental Care
7. Isabel López García PhD on Chemical Engineering, Assistant Professor of Physical Chemistry and applied Thermodynamics , University of Córdoba
8. Alexander Keith Martin PhD Geology and Geophysics, Consultant geologist
9. Antonio Jesús Muñoz Cobo Doctor in Environmental Sciences from the University of Jaén member of the research group TEP-233 (Environmental Technologies) of the Department of Chemical, Environmental and Materials Engineering
10. Luis Pomar, Emeritus Professor of the University of the Balearic Islands, Spain, Sedimentologist specialized in the study of Carbonate Rocks which the Impact of CO_2 and Paleoclimate are essential to understand the origin of these rocks
11. Javier Vinós PhD, Scientist and independent climate researcher
12. Wynn Williamson, co-founder and managing partner of real estate developer BWRE

SCIENTISTS AND PROFESSIONALS FROM SWEDEN

1. *Ingemar Nordin, Emeritus Professor Philosophy of Science, Linköping University; WCD Ambassador*

2. Michael Andersson Bsc in biology, medical doctor, retired Chief Medical Officer at a battalion of the Swedish Airforce
3. Leif Åsbrink PhD, Technology at KTH in Molecular Physics, Stockholm
4. Sture Åström MSc, Technology, Professional in Climate Issues, Secretary of the Swedish Network Klimatsans
5. Erik Axelkrans MSc in physics and physical oceanography, University of Gothenburg
6. Rolf Bergman, Emeritus Professor of Physical Chemistry, Uppsala University
7. Dr. Lars Bern, Member of The Royal Swedish Academy of Sciences, Retired CEO in Incentive AB
8. Joakim Blomqvist, Sr. Design Manager for design and energy solutions within a larger construction company
9. Magnus Cederlöf, Software Specialist, Stockholm
10. Tore Dalväg Msc, Physics, Research Engineer in Hydrodynamics and Thermodynamics, Senior Advisor in Environmental Standards, Author of 'CO_2 a source of life or a threat'
11. Hans Eklund PhD, Technology, Acting Professor at the Department of Laser-and Electro-optics, Chalmers University of Technology, Gothenburg
12. Per-Olof Eriksson, Physicist, Former CEO of Sandvik Group
13. Dr. Anders Flodin PhD, Mechanical Engineering, NC, USA
14. David D. Gee, Professor Emeritus Orogen Dynamics, Uppsala University
15. Anders Grufman MSE, MA Economics, Industrial and Environmental Economics
16. Jan Hagberg PhD, Statistics, Stockholm
17. Björn Hammarskjöld MD, PhD in Biochemistry, Assistant Professor in Pediatrics
18. Lars Hässler PhD, Rock and Soil Mechanics, Bsc Chemistry and Biology, MSc Civil Engineering
19. Eilif Hensvold PhD, Mathematics, Associate Professor of Mathematics (Retired), Simulation of Large-scale Industrial Systems, Uppsala University, Luleå Technical University
20. Gunnar Holmgren PhD, Space Physics, Retired Head of Dept. of Engineering Sciences, Uppsala University
21. Mats Janson MSc, Electrical Engineering, KTH Royal Institute of Technology, Stockholm
22. Hans Jelbring, Climate Researcher
23. Göran Johansson, Specialist in Energy Systems
24. Claes Johnson, Emeritus Professor of Mathematics at Royal Institute of Technology, Stockholm
25. Gunnar Juliusson, Professor of Hematology, Lund University, Senior Consultant, Skåne, University Hospital, Lund
26. Sten Kaijser, Emeritus Professor of Mathematics, Uppsala University
27. Johnny Kronvall Mah, Emeritus Professor in Building Physics, Malmö University and Lund University
28. Lars E. Linder, Associate Professor of Medicine, Gothenburg
29. Rune Lundgren MSc, Helsinki University of Technology, Energy System Expert
30. Johan Montelius, Associate Professor of Computer Science at the Royal Institute of Technology, Stockholm
31. Jacob Nordangård PhD, Technology and Social Change at the University of Linköping, Researcher on Climate Change History
32. Gabriel Oxenstierna PhD, retired, currently author for Klimatupplysningen.se
33. Gösta Pettersson, Emeritus Professor in Biochemistry, University of Lund
34. Marian Radetzki, Emeritus Professor of Economics, Luleå University of Technology
35. Mats Rosengren, Mathematics, Space Flight Trajectory Specialist
36. Torsten Sandström, Professor Emeritus, Department of Law, University of Lund
37. Rabbe Sjöberg PhD, Geology, Member of Paleogeophysics & Geodynamics Institute
38. Peter Stilbs, Emeritus Professor of Physical Chemistry, Royal Institute of Technology (KTH), Stockholm
39. Prof. Jan-Olov Strömberg, Emeritus Professor of Mathematics at Royal Institute of Technology, Stockholm
40. Tege Tornvall, Member of Klimatrealisterna and of its election committee, active in network Klimatsans
41. Lars H. Thylen, Professor Emeritus in Photonics, Dept. of Theoretical Chemistry and Biology, Royal Institute of Technology, Stockholm, specializing in Low Power Nanophotonics Technology

42. Gösta Walin, Proffessor Emeritus in Oceanography at Univerity of Gothenburg
43. Elsa Widding, Consultant, Author on Climate Change, Stockholm
44. Lech Wosinski, Researcher Emeritus, Associate Professor, Royal Institute of Technology, Stockholm
45. Örjan Wrange PhD, Emeritus professor in Molecular Genetics

SCIENTISTS AND PROFESSIONALS FROM SWITZERLAND

1. Dr. Denis Bednyagin, researcher specialised in integrated (Energy-Economy-Environment) assessment modelling
2. Thomas Binder, Cardiologist and Internist
3. Majed Chergui, Emeritus Professor of Chemistry and Physics
4. Helmut Elben PhD in Physics, working as Strategy, Technology and IT Consultant
5. Dr. Michael Esfeld, full professor of philosophy of science, University of Lausanne
6. Ferruccio Ferroni, Dipl.Ing. ETH, Energy Consultant
7. Rene Funk, Software engineer, specialized in Analysing Satellite, Sea and land Temperature
8. Werner Furrer MSc, Mathematics and Physics, President of the Climate Realistic Group in Switzerland
9. Christian Jacot, Pharmacist
10. Markus D. Knecht, chemist, 15 years research on climate change
11. Joseph Ongena, Member of the Permanent Monitoring Panel for World Energy, World Federation of Scientists, Geneva
12. Dr. Jean-Claude Pont, Dr. Math., Emeritus Professor of The History of Philosophy of Sciences, University of Genève
13. Dr. Franz-Karl Reinhart, Emeritus Professor of Physics, Lausanne
14. Claude Roessiger, Entrepreneur and Author of several Books on Organizational Management and Public Policy, Organiser and Chairman of the Portsmouth Conference 2018 on Climate Policies
15. Heinz Schmid, Dipl. Ing. Agr ETH, more than 10 years involement in climate science and climate communication
16. Dr. Ralf Lorenz Schmitt PhD in Chemistry, Product Manager
17. Thomas Stadler MSc in Physics, ETH Zürich, Geophysics, Specialty in Geothermics
18. Prof. Dr. Eric P. Verrecchia, Full professor at the University of Lausanne, Chair of Biogeochemistry at the Institute of Earth Surface Dynamics; expert in the terrestrial carbon cycle of the tropical and temperate zones
19. Dr. Eric Vieira retired PhD (organic chemistry), 27 years at Roche Pharmaceuticals (Principal Scientist)

SCIENTISTS AND PROFESSIONALS FROM TURKEY

1. Prof. Kerem Cankocak, Professor in Particle Physics at Istanbul Technical University
2. Ufuk Coscun, columnist at Milat Newspaper

SCIENTISTS AND PROFESSIONALS FROM UKRAINE

1. Vsevolod Lozitsky, DrSci, Astronomical Observatory of Taras Shevchenko National University of Kyiv, expert in area of solar physics, solar activity and magnetic field, as well as solar-terrestrial connections
2. Irina Vasiljeva CSc, Research Fellow at the Main Astronomical Observatory of National Academy of Science of Ukraine, research interests include solar physics

SCIENTISTS AND PROFESSIONALS FROM UK

1. *Christopher The Viscount Monckton of Brenchley, Peer of the Realm and Author of several reviewed papers on Climate; WCD Ambassador*
2. Neils C. Arveschoug, Geophysicist, Private start-up Oil E&P Company
3. Nigel Banks PhD Geology, Petroleum Geologist
4. Andrew P. Barker, Biological Chemist
5. John Anthony Barney, Retired Scientist and Technologist
6. Nik Bartley, Mechanical Engineer

7. Nigel Beckwith, professional graduate Podiatrist, Post Grad. in Sports Science, Post Grad. in Science Education
8. Alan Richard Belk, retired Mechanical Engineer with a 40+ year international career in energy, industrial gas and chemical industries
9. Roshan Bhunnoo, Mathematics and Statistics, former Climate Data Analyst at the Meteorological Office
10. Paul Binns, Former Research Geoscientist and Climate Researcher
11. David Bodecott, Geologist/Geophysicist, Fellow of the Geological Society of London
12. Dr. Richard Booth, retired Special Merit mathematician in the UK Civil Service
13. D.Q. Bowen, Emeritus Professor of Earth and Ocean Sciences, Fellow International Union for Quaternary Research, Cardiff University
14. Dr Phillip A. W. Bratby, Physicist, Member of the Institute of Nuclear Engineers, retired energy consultant
15. Michael Brown, Expert in Large Scale Thermal Fluid Dynamic Models
16. Paul Burgess, BSc, MSc, C.eng retures, Retired water resources engineer
17. Derrick Byford BSc (Hons) holder of 10 patents, previously Deputy Director Research & Statistics Inner London Education Authority
18. Gerry Byron BSc in Physics, MBA which included modules on statistical anylysis
19. Peter Cale, Solicitor, co founder and fund raiser for wave energy research project as Director of Staithe Energy Products (1988 1995)
20. George Carey, BSc Hons. Physics and Geology, Lifetime Physics teacher and amateur astronomer
21. Brian R. Catt, Physicist, Electrical Engineer, Retired, publishing papers on Energy and Climate Change
22. Arthur Champion, retired European Environmental Coordinator and CofE Diocesan Environmental Adviser
23. John Church, Earth Science Professional, Retired from Energy Sector
24. David Coe, MA(Oxon) in physics, Retired after a lifetime in industry working on gaseous absorption spectroscopy, Lead author of the paper "The Impact of CO2, H2O and Other Greenhouse Gases on Equilibrium Earth Temperatures"
25. John C.W. Cope, Professor of Geology, National Museum Wales, Cardiff
26. Richard Courtney, Retired Material Scientist, Expert Peer Reviewer of the IPCC
27. Chas Cowie, GDE Mining Engineering, Wits University, Retired IT Professional worked primarily in Mining and Logistics Industries
28. Dr. David Critchley, Senior Clinical Pharmacologist, mathematical modelling of complex systems
29. Michael Cross, Chemical Engineer
30. Peter Cunningham, Expert in Mathematical Modelling of Complex Physical Phenoma
31. Isabel Davies, Geophysicist and Entrepreneur
32. Dr Philip George Davies, Principal Lecturer in the Department of Computing and Informatics at Bournemouth University
33. Robert Davies BSc Airline pilot
34. Dr. Keith P. Dawson, Environmental and Agricultural Researcher
35. Jeremy Dawson, retired Chartered Engineer with a career in the oil and gas industries
36. John Dewey, Emeritus Professor of Geology at the University College Oxford, Distinguished Emeritus Professor University of California, Member of the US National Academy of Sciences, Fellow of the Royal Society
37. Howard Dewhirst FGS, Geologist, Initiator Open Letter to the Geological Society of London
38. James Dillon BSc Physics, DPhil Nuclear Physics, Former research physicist
39. Gregor Dixon FGS, Geologist, Former Member Geological Society of London
40. Peter Dorey BSc Physics, Senior Project Manager, (and unpaid educator & Climate Scientist)
41. Timothy (Tim) C. Duckworth, Retired Mechanical Engineer in the Oil & Gas industry, Senior Auditor in Management/Facility/HSE
42. Dr. Michael Earle, international earth scientist, energy professional, author
43. Dr. John S. Easterby, Retired Senior Lecturer in Biochemistry University of Liverpool, Research area: Protein chemistry, Enzymology, Metabolic Modelling
44. Roderick Paul Eaton, MBA FIET MCMI, Retired Consultant Energy Industry Analyst/ Management Consultant
45. Debra Eddy, Entrepreneur and Guest Lecturer in Business Management

46. Dr Andrew Edmonds, data scientist with a strong background in AI, past CTO of a publicly traded US tech company, currently CEO of a private US company, ThinkBase LLC
47. Peter Etherington-Smith, Geologist/Oceanographer, Coral Reef Researcher, MSc Petroleum Engineering (Imperial), life-time international experience in developing countries, retired from BG
48. Kevin Foo MSc, DIC, Dip. Met, AusIMM, IOM3, SME, Ch.Eng., President Tianshan Jade (UK) Ltd
49. Sean Galbally, Project Manager Water and Wastewater Systems
50. Kalghatgi Gauram PhD Aeronautical Engineering, Consultant Professor, 50 Years' experience in R&D in combustion, fuels and energy
51. Gil Gilchrist, Geophysicist
52. Alan Gill, Retired Engineer in South Wales
53. Peter Gill, Physicist, Ex Chair Institute of Physics Energy Group, Ex London Branch Chair & Fellow of EI
54. Paul R. Goddard, retired Professor of Radiology, University of the West of England
55. John D. Goss-Custard PhD Ecology, University of Aberdeen, Visiting Professor in the Department of Life and Environmental Sciences, Bournemouth University
56. Alastair Gray, retired geologist, 50 years in oil exploration, production and asset evaluation
57. Delphine Gray-Fisk, Former airline pilot, and parliamentary candidate for both the UK Independence Party and Brexit Party
58. Mick Greenway, specialized in Research and Development of Flight Control Systems for Modern Civil and Military Aircraft, Retired Head of Research and Development within a Multi-Million-Dollar Company
59. David P. Gregg, retired Unilever Research group leader and scientist, former visiting professor in control engineering, book author on studies of historical climate time series based on modern spectral analysis techniques
60. Brian Gregory, MA. in Natural Sciences, MSc. in Business Studies, Lifetime Career in the UK Chemical Industry, currently Policy Director of the Alliance of British Drivers
61. Jimmy Haigh, Independent Geological Consultant
62. Stephen Hardcastle, Retired Electronics Engineer, 10 years experience in the design of NDIR gas detectors, for gases including CFC's CO2, CH4 and N2O
63. Tim Harper, Geomechanics Consultant and Researcher, previous Recipient of the Royal Academy of Engineering MacRobert Award for Engineering Innovation
64. John Harrison, Former Chartered Physicist and Chartered Engineer
65. Ken Harrison, Retired Chartered Physicist
66. Peter Harvey, Project Manager – Renewable offshore wind industry
67. Raymond Hayes, BA (Lond) M.Litt (Oxon) FRGS Solicitor Hong Kong and England and Wales
68. Robert Heath, Retired Geophysicist, Honorary member of the Indian Society of Petroleum Geologists
69. Alex Henney, Formerly London Electricity Board, Consultant on Electricity Matters
70. Roger Higgs, DPhil (Oxon), Independent Geological Consultant, Geoclastica Ltd.
71. Tatiane Melchior Stefanello Hodson, Oceanographer, author, undertaking a Master's degree in International Public Policy at Queen Mary University of London
72. Dr Sinclair Holland, MBChB(Edin) Medical Doctor
73. Paul Homewood, Climate & Energy Policy Analyst
74. Keith H. James PhD, Consultant Geologist
75. Anthony Janio PhD in Physics, Independent Elected Councillor in Brighton and Hove
76. David A.L. Jenkins, Geologist, Director Hurricane Energy plc
77. Dr. Chris Jesshope, Emeritus Professor University of Amsterdam, Director Techne Consulting Ltd.
78. David Jessop C.Eng., M.I.C.E., lifetime career in the water industry
79. Robert Jones, BSc and PhD Mining Engineering, Director at Warwick Energy
80. Stephen Latimer Jones BA Chemistry, IT professional
81. Zana Juppenlatz, Consultant in environment, environmental law and sustainability, including renewable energy projects
82. John L.D. Kerr B.A. (Hons) in Environmental Science & Technology; B.Sc. (Hons) in Chemistry, active as Environmental Consultant
83. David A. Kirkwood MSc MIET, Professional engineer working in IT, Deputy Chairman of Reform UK Scotland

84. Geoffrey W. Lane, retired Marine Engineer and Technical Author
85. Roger Longstaff, Experimental Space Physicist and Company Director
86. Anthony Lowe BSc Hons Polymer Chemistry and Physics, Consultant Polymer Solutions
87. Peter Justin Lunt MSc Geology London, adjunct lecturer in geology (stratigraphy) at Universiti Teknologi Petronas and Shandong University of Science and Technology (SDUST) Qiangdao
88. Tom Mackay BSc, Geologist, Fellow of the Geological Society (FGS) of London
89. Chris MacKenzie MSc, Director and Geological & Environmental Consultant at Peak Minerals Ltd.
90. Stephen Martin, retired exploration geophysicist
91. CJ Matchatte-Downes, Geologist and Geochemist, particularly involved in studies about past Climates including Glaciation
92. William James McAuley MSc from Imperial College and an M.B.A. from Lehigh University, retired Chemical Engineer with a 40+ year international career in energy, industrial gas and chemical industries
93. Dr. Niall McCrae PhD in Mental Health
94. Krov Menuhin, Expert on ocean life, underwater filmmaker, professional diver, pilot and writer, explored the Earth's extremities, experiencing the oceans and the atmosphere first-hand
95. Geoffrey Middleton, Chartered Architect, Socal Science
96. Terence Mordaunt, Accomplished businessman, Self taught climate scientist mentored by Professor David Bellamy
97. Dr. William Morgan, Retired Clinician
98. Dr Ian Mortimore BSc, Phd, MB, BS, FRCP, retired Consultant Respiratory Physician in the NHS with research affiliations to Edinburgh and Newcastle Universities
99. Philip Mulholland, Geoscientist, Life time experience in the Geo-Energy Industry, co-author of the DAET climate model
100. Stuart Munro, Exploration Geologist and Geophysicist
101. Edward Nealon, Geologist Member of the Australian Institute of Mining & Metallurgy
102. Alex Nichols, BSc Geography, MSc Environmental Assessment, 27 years in sustainability consultancy, programmes and projects
103. Blair Nimmo, Electronic Engineer, working in Computer Networking and Optical Surface Metrology and Fibre Optics
104. Gerard O'Donovan, Entrepreneur, Business Owner, career in building international and multinational organisations
105. Michael John Oates, Geologist, Lifetime Experience in the Geo-Energy Industry, Fellow of the Geological Society of London
106. Peter Owen FGS, Fellow of the Geological Society of London
107. Jonathan R. Partington, Emeritus Professor of Mathematics, University of Leeds
108. Dennis Paterson, Geologist, Retired
109. Dr. James Petch, Physical Geographer, formerly Reader in Environmental Science at MMU and Head of Distributed Learning at the University of Manchester
110. Peter Phillips BSc Hons Mechanical Engineering, lifetime experience in the geo-energy industry
111. Graeme Phipps, geologist and geophysicist, Jersey Channel Islands
112. Dr. James Pindell, Geologist, specialised in plate tectonics and palaeographic evolution, Director of Tectonic Analysis Ltd (UK), Adjunct Professor at Rice University (USA)
113. Gerry A. Quinn, Research Scientist, Ulster University, lifetime career in microbiology, biochemistry and environmentalism
114. Clive Randle, Geologist, Fellow of the Geological Society of London
115. Michael J. Rath, Professional Forrester
116. Jonathan Charles Read, Honours degree in Physics from the University of Durham, member of the Institute of Physics (MInstP), Fellow of the Chartered Association of Certified Accountants (FCCA)
117. Dr. Colin Richard Reeves, Emeritus Professor of Operational Research, Expert in Mathematical Modelling
118. Ceri Reid, PhD Electrical and Electronic Engineering, Sonar Specialist
119. Steven Andrew Richards MSc, Retired Chartered Engineer, Retired Lecturer from Portsmouth University and Southampton Solent University
120. Michael F. Ridd, Geologist, Fellow of the Geological Society of London

121. Anthony Robb PhD, Retired Chemist
122. Salmaan Saleem, Family Medicine Doctor
123. Richard Saumarez, Biomedical Engineer from Imperial College
124. Robert M. Schneider MSCE, retired Civil Engineer
125. Michael Seymour, Geologist, Fellow of the Geological Society of London
126. Mike Sluman, Retired teacher with an honours Degree in Environmental Biology
127. Dr. Ian Smith, MSc Maritime Archaeology, PhD Chemistry
128. Mike Stigwood, Environmental Researcher
129. Stephen Taylor PhD, Infra-Red Physicist and Tidal Hydrographer, MD Geomatix Ltd., Member of Inst. of Physics, Member of Inst. of Electrical and Electronic Engineers, Associate Fellow of Royal Institute of Navigation, Member of the Hydrographic Society
130. Leslie Thomson, Retired Vice President Operations, BP Exploration, Aberdeen
131. Derek Tipp, BSc honours degree in chemistry, former research chemist and retired science teacher, currently councillor on New Forest District Council
132. David Todd, retired Associate Member of the Institute of Bankers, Post Graduate Certificate in Business and Management
133. Edwin Thwaites, Retired Principal Lecturer in Organisational Analysis and Crisis Management, University of Central Lancashire, Predton
134. Matthew D. Waggener, Financial professional, strategic consultant on business investments
135. Dr. Glenn K. Wakley, Emeritus Associate Professor Biological Science, Fellow of the Royal Society of Biology and member of The Anatomical Society
136. Professor David Wastell, Emeritus Professor of Information Systems at the University of Nottingham
137. Philip Linden Wilkes, Life time Experience in Marine Biology
138. Jay Willis, Marine Scientist, Associate of the OxNav Group of Oxford University
139. Paul White, BSc Physics, Durham University, Retired, Former Higher Scientific Officer Marine Climatology
140. Matt Wood, BSc in Metallurgy & Materials Science, Retired Airline Pilot, Patent holder
141. Valentina Zharkova, Professor of Mathematics and Astrophysics, Northumbria University, Newcastle upon Tyne
142. Ivor Zoeftig, International communications coach specialised in chaodynamics and NLP LP

SCIENTISTS AND PROFESSIONALS FROM USA

1. *Dr. John F. Clauser, Nobel Laureate Physicist; WCD Ambassador*
2. *Richard Lindzen, Emeritus Professor Atmospheres, Oceans and Climate, MIT; WCD Ambassador*
3. Edward Abbott MD, Retired obstetrician, BSc in math and chemistry
4. Dr. Syun-Ichi Akasofu, Professor of Geophysics, Founding Director of the International Arctic Research Center of the University of Alaska Fairbanks from 1998 until 2007. Previously, prof. Akasofu had been director of the University's Geophysical Institute
5. Ralph B. Alexander, Emeritus Professor of Physics, Science Writer
6. Michael Antonetti P.G., Professional geologist for 35+ years in Pennsylvania with Ms in glacial geomorphology
7. Anthony J. Armini, Retired Founder and CEO Implant Sciences Corp.
8. Dr. Malgorzata Askanas, Senior R&D Associate at the Aurora Biophysics Research Institute
9. Hans-Peter Bähr, Emeritus Professor of Pharmacology, Canada and Former Dean of Basic Medical Sciences, American University of Barbados, Barbados
10. Jeffrey Baldwin, petrophysicist and rock physicist specialist
11. Lynne Balzer, certification in Biology, Chemistry and Physics, founder of Faraday Science Institute, retired high school teacher (chemistry, physics and biology), adjunct college science professor
12. Donna Barr, lifetime career as investigative journalist worldwide
13. Bryan Barrilleaux, MD, Physician of Internal Medicine
14. Joe Bastardi, chief meteorologist Weatherbell.com, Author of Amazon weather/climate best sellers: The Climate Chronicles: Inconvenient Revelations you Won't Hear from Al Gore and others; 2cnd Book: The Weaponization of Weather in the Phony Climate War

15. Captain Walter Bates, flew virtually all of United Airline's aircraft all over the world, including everything from the old DC-6 up through the largest Boeings such as the B-777 and the B 747-400; from his lifetime of experience he knows that the so-called man-made Mid-Troposhere Hot Zone just does not exist
16. Charles G. Battig, Climate Adviser, Heartland Institute
17. Eric Baum PhD in Theoretical Physics, Princeton University
18. Scott Beattie, Juris Doctor Degree (Law), studied history of science for 25 years and climate science for ten years
19. Dr. Ernest Calvin Beisner, Expert on the Ethics and Economics of Climate and Energy Policy, Founder and Spokesman of The Cornwall Alliance for the Stewardship of Creation
20. Larry Bell, Endowed Professor of Space Architecture, University of Houston
21. Frank X. Bellini, Geologist and Environmental Scientist, lifetime experience in the nuclear power industry
22. Dr. Shmuel Ben-Shmuel PhD in Aerospace & Mechanical Engineering, retired aerospace engineer, worked on the Space Shuttle, doing Computational Fluid Dynamics simulations
23. David J. Benard, Chemical Physicist & Co-inventor of the Oxygen-iodine Chemical Laser
24. Haym Benaroya, Distinguished Professor of Mechanical and Aerospace Engineering, Rutgers University
25. Edward X. Berry PhD, Atmospheric Physicist, American Meteorological Society, Author, Climate Physics LLC
26. Ronald Berti, lifetime career in the semiconductor industry
27. Brent J. Bielema, studied Economics at Northern Illinois University, professional nutritional counseler
28. Dr. David L. Black, Clinical and Forensic Toxicologist (Microbiology, Immunology, Pathology, Pharmacology), Vanderbilt University Nashville, currently adjunct and member of Department of Medicine Board of Visitors
29. Jared L. Black, Numerical Analysis Consultant, ScD
30. Thomas Lindsay Blanton PhD in Tectonophysics, Texas A&M University, Over 40 years experience as an advisor and consultant in geomechanics specializing in compaction, subsidence, and lithospheric stress determination
31. Elliott D. Bloom, Emeritus Professor of Particle Physics and Astrophysics, KIPAC-SLAG, Stanford University
32. David Boleneus, Professional Geologist
33. Daniel Botkin, Emeritus Professor of Biology, Climate Researcher, Author of the Book: Twenty-five Myths That Are Destroying the Environment
34. Robert L. Bradley jr., CEO and Founder of the Institute for Energy Research
35. Dr. William Briggs, Alumnus Cornell University, Writer and Philosopher
36. Daniel Brimhall, MS Extractive Metallurgy, University of Utah, retired Vice President Operations, American Chemet, East Helena, MT, now active as consultant
37. Clare Livingston (Bud) Bromley III, BS Natural Sciences, scientific instruments executive
38. Joel M.G. Brown, retired petroleum engineer
39. Dr.Larry Frank Brown PhD in Range Plant Ecology (Ecophysiology) from Colorado State University (1974), President of L.F. Brown & Assoc. Inc.
40. Gerald Brunetto, Retired after lifetime career in engineering & building nuclear & fossil fuel fired steam power plants
41. James W. Buell PhD, Aquatic Biologist, Consultant
42. Robert Bugiada, Senior Process Engineer at R.C. Costello & Assoc. Inc
43. Dr. H. Sterling Burnett PhD, Applied Philosophy with a specialization in Environmental Ethics, past Senior Fellow of the National Center for Policy Analysis, now Senior Fellow Heartland Institute
44. David Burton, System and Computer Scientist, Expert Reviewer of AR5 and AR6, Member of the CO2 Coalition, and Creator of the SeaLevel.info website
45. Mark Shane Butler, MA in mathematics, lifetime career in data science
46. Roger Caiazza, Pollution Meteorologist, life time experience in the electric generating business, retired Director of the Environmental Energy Alliance of New York, currently managing the blog Pragmatic Environmentalist of New York
47. Ron Cakebread, mechanical engineer with 35 years in the industrial automation business; experience in modeling, simulation, and analysis of very complex systems
48. Sharon R. Camp PhD, Retired Analytical Chemist and Environmental Scientist

49. Nick Capaldi PhD, Author Books on Logic, the Scientific Method and the Philosophy of Science
50. John M. Cape, P.E. former military officer and economics instructor at West Point, Licensed Professional Engineer, Energy Consultant - Upstream Oil and Gas, now writing Net Zero themed novels
51. John Carr, Electronic Engineer, specialised in antenna and satellite installations
52. Marion G. Ceruti PhD Chemistry, Retired Research Scientist, Space and Naval Warfare Systems Center Pacific
53. Dr. Francis Cheng, Professor of Chemistry with specialties in carbon materials, batteries and energy conversion, University of Idaho
54. Mitchell R. Childress, Archaeologist and Cultural Resource Environmental Compliance Specialist, Commonwealth Heritage Group
55. Prof. Krishnan Chittur, emeritus-professor in chemical engineering and biotech, Univ of ALabama Huntsville, cofounder of medical diagnostics startup (genecapture)
56. Terigi Ciccone, Engineer, author of "A Hitchhiker's Journey Through Climate Change," and a proud former Sierra Club member
57. Dr. Claudio Cioffi-Revilla, PhD, DSc Pol, University Professor Emeritus at George Mason University, Jefferson Science Fellow of National Academy of Sciences, Fellow of AAAS American Association for the Advancement of Science, Member of AMS American Mathematical Society
58. Roy Clark, Climate Researcher, Retired Engineer, California
59. Bob Cohen, Certified Consulting Meteorologist (CCM), MS in (physical) oceanography from Texas A&M University and a BS in meteorology from Penn State University, I have been working with weather data and applications of this data for over 40 years
60. Dr. Richard Collingham PhD in Engineering, Professor for 16 years teaching Graduate Level Heat Transfer and Fluid flow courses
61. Sabin W. Colton PhD, Biochemist and Marine Biologist
62. Gary Cooke MSc Geophysical Sciences, Laboratory analyst and manager, studied sea level curves since the 1980s
63. Martin Cornell, Retired Senior Scientist, Dow Chemical Company
64. David T. Cramer, MS, Instructor of Sociology and Psychology, Pratt Community College
65. Daniel Clyde Cummings, M.D. University of Utah School of Medicine, B.A. mathematics, political advocate against all treaties and most legislative proposals to limit use of fossil fuels
66. John Curtin Msc in Economics, lifetime experience in strategic planning and forecasting
67. Joseph S. D'aleo, Professor of Meteorology and Climatology at Lyndon Stage College, Founder of Icecap.us, First Director of meteorology of the Weather Channel
68. Raphael D'Alonzo, Analytical Chemist, Retired Associate Director, the Proctor & Gamble Company
69. George Davey, Physicist, University of Iowa
70. Donn Dears, GE Company Engineer, and Senior Executive, Retired, Author of 'Net-zero Carbon, The Climate Policy Destroying America'
71. Ken DeGraaf, MSc Engineering Mechanics, Structural Dynamics, Colorado House of Representatives, USAF pilot, Instructor: USAFA AP Calc; weather for pilots, Environmental Manager, Michigan ANG
72. James DeMeo PhD, Retired Expert in Earth and Atmospheric Science, Oregon
73. David Deming, Professor of Arts & Sciences, University of Oklahoma
74. William Robert Detzner, retired special education teacher, fighter agains the continuing reduction of personal freedom
75. David Dilley MSc, Meteorologist-Climatologist-Paleoclimatologist, CEO Global Weather Oscillations Inc.
76. Robert G. Dillon, retired physician and astronomist
77. Robert G. Dodge, Attorney
78. Terry Donze, BS-Geological Engineering, Lifetime Career in Geophysical Consulting
79. Michael Down, Petroleum Engineer, lifetime experience in the geo-energy industry
80. Jack D. Downing, Geologist and Geophysicist
81. Gordon A. Dressler MSc, 36-year professional career as a rocket and spacecraft propulsion engineer, awarded six patents in the field of rocket propulsion
82. Paul Driessen, Senior Policy Advisor, Committee for a Constructive Tomorrow (CFACT) and Congress of Racial Equality (CORE)
83. John Droz jr., Physicist, Founder of AWED Alliance

84. Dr. William DuBroff PhD Metallurgy, Former Director of Research Inland Steel, Former Asst. Professor Clemson University
85. John Dueker, MBA University of Houston, BSEE University of Notre Dame, 45 years of experience in environmental permit compliance
86. Murray Duffin, BScEE, MBA, former Corporate Vice President for Total Quality and Environmental Management, Retired
87. John Dale Dunn MD, JD, Lecturer Carl R. Darnall Army Medical Center, Fort Hood, Texas
88. Prof. James E. Enstrom PhD, MPH, FFACE, Retired UCLA Research Professor in Epidemiology, President of the Scientific Integrity Institute, Los Angeles
89. Richard G. Eramian, BA in MPthematics and physics
90. Willis Eschenbach, Generalist and Author of many (peer-reviewed) critical Climate Articles with numerous Citations
91. Vincent Esposito, Adjunct Professor University of Pittsburg, PA, Doctor of Science in Nuclear Engineering (Un. FoVigînia), Retired Manager fromWestinghouse Electric Company
92. Douglas Fairobent, Retired Physicist trained in Condensed Matter Theory, PhD (Physics), University of Michigan, 1978
93. Peter Farrell, Fellow of the US National Academy of Engineering
94. Ralph English Fisler, Professional Aerospace Engineer
95. Edward Patrick Flaherty, American lawyer based in Geneva, litigating against the UN, WMO, WIPO and other IOs on behalf of staff members, whistleblowers and injured third parties
96. Rex Fleming, Research Scientist, Author of Book on Carbon Dioxide Fallacy, Retired President Global Aerospace
97. Jim Folcik, Geosciences Manager Extraction Oil & Gas
98. James Forensky B.S.E.E., M.D. with background in Physics, Engineering and Medicine
99. Dr. Geoffrey Q. Fox, Retired neuroscientist, PhD in Anatomy and Physiology from the University of California, Berkeley in 1973, post doctorate fellowship in the Department of Neuroscience at Albert Einstein College of Medicine, Wissenschaft Assistant in the Department of Neurochemistry at the Max Planck Institut fűr biophysikalische Chemie in Göttingen Germany, 1975
100. Dr. Neil Frank, Lifetime of Experience in Research and Forecasting in Tropical Meteorology, Former Director National Hurricane Center
101. Patrick Frank PhD, SLAC National Accelerator Laboratory, Stanford University
102. Robert S. (Steve) Friberg, Trend Resources LLC, Resources Exploration Geologist with +55 years of experience in the geological sciences field
103. Gordon J. Fulks, Astrophysicist, Board of Directors CO2 Coalition, Co-founder Global Warming Realists
104. S. Fuller Hunt, Biology Teacher at Preparatory High School of Mathematics, Science, Technology and Careers, Calabash, North Carolina
105. Lynn Warren Funk, accelerator physicist, climate realist
106. Terry Gannon, Physicist, Retired Semiconductor Executive
107. Dr. Philip Garrou PhD Chemistry 1974 Indiama Univ. Retired Director of Technology at Dow Chemical's electronics division. Serves DARPA and the DoD as a microelectronics subject matter expert (SME)
108. Louis Genevie PhD, Epidemiologist, www.LitStrat.com
109. Nicholas De Gennaro PhD, PE, Coastal Engineer, Southport North Carolina
110. Prof. Lee C. Gerhard PhD in Geology, Retired Getty Professor of Geological Engineering from the Colorado School of Mines and Retired Director and State Geologist of the Kansas Geological Survey
111. Ulrich H. Gerlach, Professor of Mathematics, Ohio State University
112. Ivar Giaever, Nobel Laureate Professor, Nobel Prize Winner in Physics, Emeritus Professor of the Rensselaer Polytechnic Institute, Chief Technology Officer of Applied Biophysics Inc., Fellow of the American Physical Society; Honorary WCD Ambassador
113. Thomas A. Gilliam PhD, Professor of Accounting, Retired
114. Alan Glabe PhD Organic Chemistry, University of California, Retired
115. Dr. William Glassco, PhD in Medicinal Chemistry, former researcher, currently Instructor
116. Curtis Fred Goddard, Retired Geologist
117. Dr. Indur M. Goklany, Science policy advisor in the United States Department of the Interior, Helped develop the work plan for the IPCC's First, Second and Fourth Assessment Reports, and served as expert reviewer for several IPCC reports,

Leaderof the U.S. delegation to, and Executive Secretary of the IPCC Resource Use and Management Subgroup (1988-90)

118. Dr. J.D. Gold, lifetime experience in Clinical Psychology; worked in the frontlines of the war against the madness of terrifying people
119. Leo Goldstein, MSc in Mathematics, lifetime experience in computer software, computer networks and cyber security. He is also a successful author and start-up founder
120. Derek Gordon, CEO HTS Engineering
121. Timothy W. Gordon, Retired USAF/USN Veteran, Independent Researcher
122. Steve Goreham, Executive Director, Climate Science Coalition of America
123. Laurence I. Gould, Professor of Physics, University of Hartford, Past Chair, New England Section of the American Physical Society
124. Jim Granato, Dean of the Hobby School of Public Affairs, University of Houston, lifetime career in research methodology
125. Charles F. Gritzner PhD, Professor Emeritus of Geography, author of the book "Changing Climates" (2010)
126. Mike Gruntman, Professor of Astronautics, Space Physics and Space Technology, Space and Rocket History University of Southern California
127. Thomas Gyorog, P.E., Project Manager and Designer of transportation infrastructure projects
128. Kenneth Haapala, President of the Science and Environmental Policy Project (SEPP), compiler of The Week That Was newsletter, and contributor to the NPCC reports. He is an energy and economics modeler and past president of the oldest science society of Washington
129. Stephen Hallin, Retired from Atmospheric Science (BA 81 MS 91)
130. Dale B. Halling, BSEE, MS Physics, JD, Retire Patent Attorney
131. Lyle W. Hancock, Professional Mathematician
132. Kip Hansen, Independent Science Research Journalist
133. Dr. William Happer, Professor Emeritus in the Department of Physics at Princeton University
134. Brett T. Harding, Materials Scientist in Sustainable Technology, over 20 granted patents in nanoceramics, OLED, photocatalyst, optical devices, and related materials
135. Steven Harford PhD chemistry and lifetime career in renewable energy and aerospace research
136. Richard Harris PhD atmospheric physics and chemistry as applied to radiation transport modeling, laser propagation, high power microwave propagation
137. Korbi Hart, Marketing Director Inland Crude Purchasing
138. Peter J. Hatgelakas, Masters in Petroleum Engineering, petroleum geologist, geophysicist, and petroleum engineer at Hatgelakas Consulting
139. Bryan Haycock PhD, Adjunct Faculty at a University in the state of Utah
140. Howard C. Hayden, Emeritus Professor of Physics, University of Connecticut
141. David Heald, Retired Electrical Engineer
142. Donald R. Healy, BS Degree in Forest Management from Oregon State University, Participated in Anthony Watts' first Surface Station Project
143. Dennis E. Hedke, Lifetime Career in Earth Sciences, Consulting Geophysicist; in 2018 Hedke was co-presenter of the testimony on Sea Level Rise before the Committee on Environmental protection of the New York City Council
144. **Tony Heller, Geologist, electrical engineer, climate communicator at realclimatescience.com 1500th signee**
145. Edward G. Helmig, Environmental Engineering Professional in the field of Industrial Water Treatment and Environmental Protection
146. Oliver Hemmers, Retired Executive Director of the Harry Reid Center at the University of Nevada, Las Vegas
147. James D. Henry, Consulting Geologist, BS Geology, U Texas Austin, 1970, founder of Old Aulacogen, L.P. in 1991
148. Glenn C. Hillam, Big Data Architect/Scientist
149. Gary L. Hoe P.E., Retired Colonel USAF, Technical Director of several Nuclear Weapon Effects Tests at the Nevada Test Site, Member Scientists for Accurate Radiation Information (SARI)
150. Jim Hollingworth, Social Scientist, Book: 'Climate Change: A Convenient Truth'
151. Dr. Gary M. Hoover, Geophysicist, Lifetime Experience in the Geo-Energy Industry, Retired Member Board of Directors Geo-Service Company

152. Christopher Paul Horger, lifetime experience in optical network design
153. Walter Horsting, leads national and international teams in high-profile projects, including Clean Energy, Entertainment Venues, Governmental Headquarters, Performance Centers, Resorts, Stadia, and Theme Parks. He is advocate of 4th generation Molten Salt Reactors
154. Captain Thomas C. Houghton USNR (Rtd), Qualfied Nuclear Engineering Officer; Sr. Director, Reactor Programs, Nuclear Energy Institute
155. J. Stephen Huebner PhD, Retired Research Geologist, U.S. Geological Survey
156. Edward Huff PhD, Retired NASA Senior Scientist
157. Kanzan Inoue, MS & PhD in Physics, President & Physicist of Exponential Future LLC
158. Jim Janota, Developing and improving petroleum based Chemicals, Plastics and applications
159. Laurence N. Johnson, Lt Col, USAF (Ret), MS in meteorology, MSE in aerospace engineering
160. Dr. Thomas J. Karr, PhD physicist, Retired Principal Director in the U. S. Office of the Undersecretary of Defense for Research & Engineering
161. James Kelly PhD Physics, data science executive
162. Kathryn E. Kelly, President Delta Toxicology
163. Kerry Kelly, Geology degree. Energy and Environment Professional
164. Michael L. Kelly, US Navy, BS, Tool Design Engineer (retired)
165. Hugh Kendrick PhD, Retired Director Plans and Analysis, Office of Nuclear Reactor Research, US Dept. of Energy, Fellow American Physical Society
166. Kevin T. Kilty, Adjunct Prof. Mechanical Engineering at University of Wyoming
167. Fred Kinsley, Retired Geologist (MSc)
168. Kevin Kirchman, Editor of the Climate Science Journal, more than a decade in renewable energy engineering
169. Floyd Lee Knapp BSc, Portland State University, 300 level Geography and Climatology
170. Stephen C. Knowles, Marine Scientist and Geologist, Beacon, New York
171. Kenneth D. Kok, retired Nuclear Engineer, ASME Fellow, Past Chair of the ASME Nuclear Engineering Division and the ASME Energy Committee
172. Alex Kozinski, Retired Judge on the US Court of Appeals
173. Wayne P. Kraus, Member American Institute of Chemical Engineers (AIChE)
174. Kirk Laird, retired. Oceanographer and Meteorologist (US Navy), Geologist with US Bureau of Land Management
175. Prof. Donald Langmuir PhD in Geological Sciences from Harvard University, Emeritus Professor of Chemistry and Geochemistry at the Colorado School of Mines, served on and chaired multiple committees related to water quality, and nuclear waste disposal; held also a US Presidential appointment to the US Nuclear WasteTechnical Review Board
176. David R. Legates PhD, Retired Professor of Climatology in the Department of Geography and Spatial Sciences at the University of Delaware, Cornwall Alliance for the Stewardship of Creation
177. Jay Lehr † PhD, Senior Policy Analyst for the International Climate Science Coalition, Former Science Director of the Heartland Institute
178. David P. Lentini, Chemist and Patent Attorney, New Hampshire
179. Dr. David H. Lester, PhD in Chemical Engineering, Advisor to allaboutenergy.net
180. James M. Leverentz, Instructor UCI, Manager, California
181. Ulf Lindqwister, PhD theoretical particle physics, Princeton University, Business executive with 30+ years of industry experience
182. Howard R. Lowe, Prof. Eng., Geologist
183. Dean Lusby, IT professional, business owner, Pennsylvania
184. Jeffrey Mahn, Retired Nuclear Engineer Sandia National Laboratories (New Mexico), Member Scientists for Accurate Radiation Information (SARI), Member Nuclear Society (ANS)
185. Matt Malkan PhD, Distinguished Professor of Physics and Astronomy, UCLA
186. Wally Manheimer, Retired from the US Naval Research Lab and life fellow of APS and IEEE
187. Prof. Paul Manner MD FRCSC, Joint Replacement/Hip and Knee Arthritis, Department of Orthopaedics and Sports Medicine, University of Washington
188. James A. Marsh, Emeritus Professor of Immunology, Cornell University, Dept. of Microbiology and Immunology

189. David Martinovich, General Science Teacher, grades K-12, United States, China, and Belize
190. John Mauer PhD in Atomic and Molecular Physics, 20 years experience as a physicist, currently business owner in statistical analysis and software
191. Kirk Maxey, BS Organic Chemistry, MD, President and Founder of Cayman Chemical Inc
192. Andy May, Writer and Retired Petrophysicist
193. Gene McCall, Consultant to the Defense Science Board, Former Consultant to the Department of Energy on Issues related to Inertial Fusion, Former Member and Chairman of the USAF SAB, Former Member of the Senior Review Group to the Defense Airborne, Airborne Reconnaissance Office (DARO) and Former Chairman of the Technology Assistance panel fir DARO
194. William McCann PhD Seismology, lifetime career in Earthquake Hazard modeling and analysis
195. Dr. Neil J. McCarthy, Financial Consultant at N J Mc Carthy & Assoc, PhD in Organic Chemistry Cornell University
196. Craig McCluskey PhD, Physics
197. Richard McFarland, Retired NASA Physicist
198. Sean McGrew, Analytical Chemist, lifetime career in Chromatography/Mass Spectrometry, applications to semi-volatile organic compounds in the environment
199. Edward P. McMahon PhD in Systems Science, has been involved with atmospheric physics at General Research
200. Mark Meier PhD, Professor of Physics, University of Houston
201. Samuel Melfi, Emeritus Professor of Physics, UMBC, Retired NASA Scientist
202. Kenneth Melvin MD, Retired Professor of Medicine, Portland, Oregon
203. Dr. Daniel M. Merfeld, systems engineer (BSME U Wisconsin-Madison; MSE Princeton; PhD MIT), neuroscientist/neuroengineer by vocation, former Professor at the Harvard Medical School, Professor at the Ohio State University
204. Dr. Peter B. Merkle, Associate Professor in the School of Engineering at Benedictine College, educator in the area of environmental science and engineering, previously served in the U.S. government in an advisory role with respect to modeling and simulation of catastrophic events
205. Patrick J. Michaels †, Competitive Enterprise Institute, Washington DC
206. Michelle Michot Foss PhD, fellow in energy, minerals and materials at Rice University's Baker Institute
207. Steven Milloy, MHS, JD, LLM, Publisher
208. Ference M. Miskolczi, Retired NASA/AS&M Senior Scientist, Foreign Associate Member of the Hungarian Academy of Sciences
209. Michael J. Mitchell, Mechanical Engineer
210. Guy K. Mitchell Jr., graduate mechanical engineer and physicist with extensive research in the field of anthropogenic global warming
211. Brian Moody, Former GET Specialist for SMS Equipment in Ft McMurray
212. James Moore, Commercial Fisherman, President Alaska Trawlers Association, Executive Committee Northern Southeast Regional Aquaculture Association, Board member Amstrong Keta Inc.
213. James R. Morris, Geophysical Exploration Oil & Natural Gas
214. Thomas L. Moser, Retired NASA Senior Executive - Program Manager of the Space Station and Space Shuttle, Chief Engineer at NASA Johnson Space Center, Fellow of the AIAA, Founder of the "Right Climate Stuff", a group of former NASA Engineers & Scientists
215. David R. Motes, Chemical Engineer, lifelong experience in the geo-energy industry
216. James F. Mundy, Retired Meteorologist
217. Daniel W. Nebert, Professor Emeritus, Department of Environmental Medicine and Center for Environmental Genetics, University of Cincinnati
218. Prof. Eric L. Nelson PhD, Assistant Clinical Professor, Department of Public Health Sciences, University of California
219. Danny L. Newton, Retired from Federal Aviation Administration (FAA), Experience in Working with NOAA with respect to Experimental Weather Data Collection
220. Richard Nicholson, MD University Of South Alabama 1988, Family Medicine
221. Ned Nikolov PhD, Physical Scientist at the USFS Rocky Mountain Research Station in Fort Collins CO, Managing a Fire-Weather Intelligence Project
222. Paul Noel, Research Scientist (retired)

223. Thomas O'Connor, Member American Association of Petroleum Geologists, Washington
224. Kenton Oma, Retired PE Chemical Engineer, Environmental Engineering, Environmental Consultant, R&D at DOE Nuclear Facility
225. Jane M. Orient, President of Doctors for Disaster Preparedness
226. Tench C. Page, MSc & BSc in Geology including study of causes and effects of earth's climatic history
227. Charlie Pappis, retired Semiconductor Industry Executive
228. Trueman D. Parish, Retired Director of Engineering Research Eastman Chemical Company
229. Arvid Pasto PhD, Ceramics, Retired from the Oak Ridge National Laboratory, TN
230. Chad M. Paton PhD, Associate Professor at University of Georgia
231. Bill Pekny, MS Physics, Retired atmospheric physicist and soldier scientist, specializing in battlefield atmospherics. Former U.S. Navy Meteorologist and Hurricane Hunter during "Project Stormfury-1969." Author of the book: A Tale of Two Climates—One Real, One Imaginary
232. Charles W. Pennington, Senior Vice President of Engineering NAC International (Retired), Secretary, XLNT Foundation, Board of Directors
233. Jeffrey S. Philbin, Retired Nuclear Engineer Sandia National Laboratories (New Mexico), Independent Consultant in Nuclear Facility Design and Safety Analysis, Nuclear Criticality Safety and Weapon Response
234. Dr. Robert B. Phillips, retired from radio astrophysics, specialised in calibration and validation of orbital IR and visible sensors (GOESS, STSS-1 and -2)
235. James Richard Poirier, BS degree in Meteorology, Lifetime Career in Atmospheric Science
236. James M. Policelli, Registered Professional Engineer
237. Herman A. Pope, Retired Aerospace Engineer NASA-JSC
238. Willem Post, Independent Researcher regarding Energy and Environment
239. Darrell Potter, Retired Geologist/Environmental Hydrogeologist
240. Dr. William H. Pound PhD Major in Industrial Engineering with Minor in Materials Science, lifetime experience in the manufacturing industry with focus on technical, engineering, environmental, and quality assurance
241. Dr. Victor Privalsky PhD, ScD in physics and mathematics, UT Oceanographer and specialised in random processes, retired from Space Dynamics Laboratory, Logan
242. Kenneth L. Purdy, Management Consultant, Retired Naval Officer in Operational Intelligence
243. Brian D. Ray PhD in science education from Oregon State University, Salem
244. Dr. George Rebane, Scientist with degrees from UCLA in Physics (BS) and Engineering (MSE and PhD), lectured at UCLA and California State University as an Adjunct Professor
245. Edward A. Reid, lifetime experience in the US energy industry in technical research and development, market development, marketing and consulting
246. Fred A Reitman, career as petrochemical toxicologist, retired
247. Forrest J. Remick, Commissioner (Retired), US Nuclear Regulatory Commission
248. David K. Rogers, PE, CEG MS, Geological Engineering, Member of the Boards of Consultants for the Federal Energy Regulatory Commission
249. Dr. Jennifer Runquist PhD from Northwestern Unv, Evanston IL related to photosynthesis
250. Marius Russo, IT expert
251. James H. Rust, Emeritus Professor of Nuclear Engineering, Georgia Institute of Technology
252. Charles L. Sanders, Retired Radiobiologist, Author of Radiobiology and Radiation Hormesis: New Evidence and Its Implications for Medicine and Society (Springer)
253. Rick Sanders M.A., Scientists for Accuracy in Radiation Information (SARI), Associate Editor, 21st Century Science and Technology Magazine
254. Kent Satterlee, Executive Director at Gulf Offshore Research Institute (GORI)
255. Dana H. Saylor Sr., a lifelong agriculturalist, retired, article "Living a lifetime of climate change"
256. Jesse Schilling, Certified Management Accountant
257. Mike Schimmelpfennig, Degreed Mining Engineer with more than 40 years of experience

258. Brian Schmidt, Co-Founder and Chief Visionary Officer of Primary Ocean Aquaculture division and Primary Bio Agriculture - Agriculture division
259. Harold Grant Scoggins, retired IT professional
260. Edwin T. Sewall, Retired BS Electrical Engineering, Southern Methodist University 1960 Dallas Texas
261. Mark W. Sellers, PhD Systems Science, Modeling and Analysis of Complex Systems
262. John A. Shanahan, Civil Engineer with career in Nuclear Power, Public Education about Fossil Fuels (including question of man-made Global Warming) and Nuclear Power through website: allaboutenergy.net
263. Roscoe M. Shaw, meteorologist and portfolio manager
264. Dr. Thomas P. Sheahen, PhD in Physics at MIT, Chairman, Science & Environmental Policy Project, involved in energy-related research for 45 years
265. Dr. Roger Sheley, Ecologist, USDA-Agricultural Research Service; Editor-in-Chief of the international journal-Rangeland Ecology and Management
266. John D. Sheppard MD, MMSc, FACS, Professor of Ophthalmology, Microbiology & Immunology, Eastern Virginia Medical School
267. John Shewchuk, Meteorologist (CCM) and Atmospheric Researcher
268. Stephen W. Shipman, Institutional Investor
269. Ryan Shrout, Environmental Attorney with a Masters of Law in Environmental Law practicing in the air emissions field
270. Dr. Matthew Eric Shultz, University of Delaware, Dept. of Physics & Astronomy, specialised in Stellar Astrophysics, Annie Jump Cannon Fellow
271. **David Siegel, author, entrepreneur, critical thinker, communicator (1000th signee)**
272. Elliot Smith, airline pilot, climate realist, 30+ years of studying AGW data
273. Robert J. Smith, Bachelor of Physics, Aircraft test and evaluation engineer
274. Robert P. Smith PhD, P.E., Environmental Scientist and Professional Engineer'
275. Professor William H. Smith, Professor of Earth & Planetary Sciences; Astronomer and Planetary & Atmospheric Scientist; most recently involved in the Analysis of the Earth's Climate and Renewable Energy Systems
276. Willie Soon, Independent Scientist
277. Prof. George Sowers PhD, Space Resources, Colorado School of Mines
278. Prof. Rick Bernard Spielman, Senior Scientist & Professor of Physics, University of Rochester, Laboratory for Laser Energetics
279. Robert M. St. Louis MSc in geology, owner of Mine Water Consulting LLC
280. Kirk Douglas Stahnke, MS Educ. Prof of Design Tech (Retired), Independent Climate Researcher
281. Walter Starck PhD, Marine Science, Pioneer in Coral Reef Studies, Policy Advisor to The Heartland Institute
282. Jess L. Stark, Founder and CEO of Stark Industries, Houston, Texas
283. Jim Steele, Emeritus Director Sierra Nevada Field Campus, San Francisco State University
284. Phil Stegemoeller, Professional Forester, Partnership with the Quinault Indian Nation, a BS in forest management at the University of Minnesota, 1979
285. Ronald Stein, Professional Engineer
286. Kenneth S. Stevens PhD, Professor, University of Utah, Electrical and Computer Engineering Dept
287. Brent K. Stewart PhD, Professor Emeritus, Radiology, University of Washington School of Medicine
288. Gerald M. Sulzer, MS Chemical Engineer, Retired Director of Technology, Albemarle Corporation
289. Soames Summerhays, Marine Biologist, Film Maker
290. Dr. Daniel P. Taggart PhD in Experimental Plasma Physics, life time career in Controlled Thermonuclear Research and Radiation Protection at Los Alamos National Laboratory
291. Tomer D. Tamarkin, Physicist, Founder and President/CEO of Energycite Inc., President and Chairman of ClimateCite Inc.
292. Paul Taylor, Energy Economist, Recipient Rossitor Raymond Award, Golden Colorado
293. Bradley Thomas, M.A. Air Pollution Meteorology
294. David E. Thompson, Professor Emeritus Mechanical Engineering and Computer Science, Dean Emeritus College of Engineering, University of Idaho
295. Francis Thompson, Space Vehicle Engineer, Masters in General Relativity

296. Roane Thorpe, BSME California Polytechnic, MBA University of California, lifetime career in global energy projects
297. Gordon Tomb, Energy and climate writer, communications consultant, primary editor of Inconvenient Facts and Senior Advisor for the CO2 Coalition
298. Cecil Joe Tomlinson, Retired Boeing Senior Principle Engineer
299. Frank Trask, BS Degree in Mechanical Engineering, University of Maine
300. Kip Trout, Lecturer in Physics, The Pennsylvania State University – York Campus
301. Karl Michael Frederick Truitt, BSEE, IEEE, US Veteran, 6 US Patents, Climate Data Researcher, Host of the The Climate Change Hoax Podcast
302. Richard Trzupek, Chemist and Air Quality Expert
303. Mark Twaalfhoven, Executive CEO Technology Companies
304. Arthur Viterito PhD, Physical Geography, Policy Adviser to the Heartland Institute
305. Dariusz Vogelsinger, Psychologist
306. Whitson G. Waldo, Scientist and Engineer with MS Chemical Engineering from Clemson Univ, lifetime career in the semiconductor industry, owner of 13 awarded patents
307. William B. Walters, Guggenheim Fellow, Professor of Atmospheric, Nuclear and Environmental Chemistry, University of Maryland
308. James Wanliss, Professor of Physics, Presbyterian College
309. Steven E. Weismantel, Retired Engineer and Climate Researcher
310. Isaac William Wells, Lawyer in International Law and Foreign Affaires
311. Dr. Steven C. Wendelken, EPA, OGWDW/TSC, climate realist
312. Gary S. Westerman PhD, physical geography with specializations in climate science and remote sensing
313. Stephen H Westing PhD, Director Medical Affairs, Regeneron Pharmaceuticals, Inc.
314. Jim Whiting, MD from McGill U, Montreal, Fellow of the American College of Radiology
315. Chuck F. Wiese, Professional Meteorologist
316. Dr Matthew Wielicki PhD in Geochemistry from UCLA, Assistant Professor of Geological Sciences at the University of Alabama
317. David Wojick, Cognitive Scientist
318. Dr. Calvin M. Wolff, Adjunct Professor University of Houston at Clear Lake, Expertise in Energy Management
319. Gregory R. Wrightstone, Expert Reviewer IPCC, Geologist, Author, Member CO_2 Coalition
320. Dan Youra, publisher Youra media, creator and editor of Carbon Tax News
321. Bob Zybach, Program Manager, Oregon Websites and Watersheds Project Inc.

SCIENTISTS AND PROFESSIONALS FROM VIETNAM

1. Dr. Thi Thuy Van Dinh, PhD in environmental law, University of Limoges, former official of the UN Secretariat, former Environment and Health Lead at Intellectual Ventures Global Good Fund, Bellevue, Washington, USA

Colofon

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The World Climate Declaration was initiated in 2019 by emeritus professor Guus Berkhout, founder of the Dutch Climate Intelligence Foundation (CLINTEL). The list of signatories is a living document that is regularly updated with new additions. The most up-to-date version can be found on www.clintel.org.

Graphic design: www.zinontwerpers.nl
Lay-out: Little Shop of Graphics (www.lsog.nl)


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