Testimony of Secretary Ernest Moniz, CEO, Energy Futures Initiative before the Senate Committee on Banking, Housing and Urban Affairs April 22, 2021

Chairman Brown, Ranking Member Toomey, and Members of the Committee, I am pleased to have the opportunity to discuss with you today the risks associated with climate change and some possible options for addressing those risks.

Climate Change Poses Risks to U.S. Financial Systems. Late last year, the U.S. Commodity Futures Trading Commission (CFTC) released a groundbreaking report, *Managing Climate Risk in the U.S. Financial System.* A central message of this report:

"… U.S. financial regulators must recognize that climate change poses serious emerging risks to the U.S. financial system, and they should move urgently and decisively to measure, understand, and address these risks. Achieving this goal calls for strengthening regulators' capabilities, expertise, and data and tools to better monitor, analyze, and quantify climate risks. It calls for working closely with the private sector to ensure that financial institutions and market participants do the same. And it calls for policy and regulatory choices that are flexible, open-ended, and adaptable to new information about climate change and its risks, based on close and iterative dialogue with the private sector."

The CFTC report identified categories of assets that are most likely to be put at risk by climate change and examples of those categories of financial products, including real property; infrastructure; companies whose assets are directly affected by climate risk; insurance companies; and government revenues (Table 1). A summary of some of the report's conclusions includes:

- the lack of standards and definitions for climate data and financial products is hindering the management of climate risk by market players and regulators. Methodologies, definitions, data on climate risks and financial products labeled "green" or "sustainable should be standardized and transparent.
- corporate disclosures of climate-related financial risks are critical for understanding and assessing the impacts of climate change on the range of financial market participants, processes, and products.
- A carbon price, appropriately developed and supported, is essential for adequately assessing climate risks and informing financial and investment decision-making.
- Cascading and inter-acting risks could amplify climate impacts on financial systems. At the same time, the re-pricing of assets based on climate risk should be orderly, informed, and systematic.

Table 1. Categories of Assets Exposed to Climate Change Impacts

Categories	Examples
Financial assets directly tied to real property	• Commercial mortgage-backed securities (CMBS) • Commercial real estate (CRE) bank loans • Government-sponsored enterprise (GSE) Credit Risk Transfer securities • Real Estate Investment Trusts (REITs) • Residential mortgage-backed securities (RMBS) • Residential mortgages
Financial assets tied to infrastructure	• Debt and equities of power and water utilities and communications companies • Debt and equities of public and private transportation infrastructure
Financial assets tied to companies with businesses models or operations likely to be impacted by physical or transition risk	Equities and debt of firms in the following sectors: • Agriculture • Airlines and the broader transportation sector • Automobiles • Cement, steel, chemicals, plastics • Energy, including coal, oil, and gas production • Hospitality • Metals and mining • Power generation • Service and infrastructure providers to oil and gas • Tourism
Financial assets tied to insurance coverage providers	• Insurance and reinsurance company debt and equities • Insurance linked securities (ILS)
Financial assets tied to streams of government revenue	• Municipal bonds • Sovereign bonds

Today we are dealing with two global challenges simultaneously -- a pandemic and climate change – that can reinforce each other as they pose risks to financial institutions, commodities, credit, financial aid, exports, insurance, supply chains and more – all issues of concern to this committee. Reasons for the interdependence are that COVID has already stressed balance sheets, required large government expenditures and threatened the financial health of many families and businesses alike.

The Range of Climate Risks is Growing. I will start by offering some perspective on today's risks from climate change. These risks are growing and manifest in increasingly serious ways. More specifically, I will discuss:

- the global risks of and responses to climate change;
- U.S. climate risks and the changing risk profile;
- risks to critical energy infrastructures;
- risks to economic growth and jobs;
- technology risks; and
- supply chain risks, both for existing US energy supplies; as well as risks to the supply chains for our allies.

Quantifying these risks is difficult but efforts to elucidate these risks are essential for the stability of the nation's financial, security, social, and health systems going forward.

The Texas "Big Chill" of 2021. The Texas events of last February provide an example of how climate risks and finances intersect, an example of the kinds of risks and concerns outlined in the CFTC report. In Texas, the recent extreme cold snap left much of the state without power and heat. In Dallas, February temperatures were -2°F, while the average low for this time of year was around 40°. Because two-thirds of Texans rely on electric heating, this led to a surge in electricity demand throughout the state of about 20 GWs, or one-third of the winter peak; this far exceeded ERCOT's worst case planning scenario.

It is clear that Texas was unprepared for the polar vortex of February 2021 even though ten years earlier, the state experienced another major cold snap, albeit not as severe as the most recent one. The 2011 event led to a FERC/NERC report with a set of recommendations, such as winterization of assets; unfortunately, there was no systematic response to these recommendations by Texas regulators and policymakers.

Another key recommendation: understanding the interdependencies of the electricity and natural gas infrastructures. Actions were not taken on this issue either, with disastrous consequences. The natural gas producers had electrified important parts of their production system, while the electricity system had become extremely dependent on gas supply. The approach to shedding electricity load did not adequately incorporate the need for natural gas supply to run generation, and the need for electricity to produce natural gas. The separated regulatory responsibilities of the Texas PUC and the Railroad Commission created a structural impediment to this kind of coordination – the crisis underscored the need for new cross-cutting structures to reflect these interdependencies and an empowered decision-making process to ensure reliable and resilient electricity in the face of increasingly extreme weather events.

In this regard, it is clear that the PUC, state officials and ERCOT did not adjust to the changing risk profile generated by increased global warming and extreme weather – but they are not alone. *Institutions, policymakers, system operators, and investors across the country need to acknowledge that yesterday's weather is not a good predictor of future weather extremes.* It must also be emphasized that the extreme weather risks are not only about cold, and they are considerable: heat and cold, floods and droughts, sea level rise and tropical storm damage, wildfires, and more. All need appropriately updated regional risk profiles for damage to critical infrastructures.

The Texas electricity market structure also needs reexamination. I stress that the choice of a deregulated system is not itself the issue, but rather the failure to erect sufficient guardrails in defining the energy-only market rules. I am reminded of the old joke about "How many Chicago economists does it take to change a light bulb?" Answer: "Zero – if the market wants it, the market will take care of it." Clearly, the "market" needs improved rules of the road to reduce physical and financial risk to the citizenry.

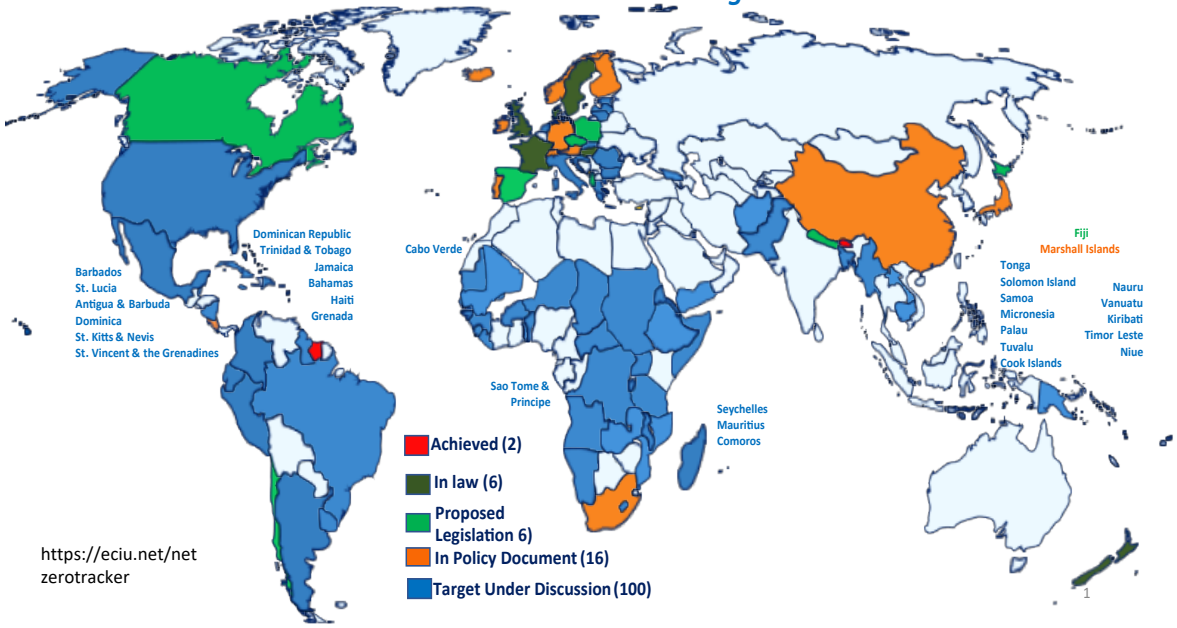
This brings us to the financial consequences. In addition to the enormous human suffering from the catastrophic weather event in Texas, there were huge financial consequences. Electricity rates were held at $9000/MWh for a sustained period, and natural gas prices exceeded $100/MMBtu, a price that had significant ripple effects on natural gas prices far from Texas. Within the state, there are now a significant number of stressed balance sheets for utilities, families, businesses, and even for military installations. The Navy reported, for example, that its electricity bill for Texas installations for February 2021 totaled $13.9 million, an order of magnitude greater than the February 2020 cost of $616,000.[i] The largest and oldest electric power cooperative in Texas filed for bankruptcy, and the last chapter has not yet been written on the financial fallout of the February events. Ultimately, some combination of rate payers, tax payers and shareholders will pay the price. This episode provides a stark example of the warnings in the CFTC's report. The open question is whether legislation in response to the big chill in Texas will materially improve resilience in the face of extreme weather events with highly uncertain risk profiles in the future.

Global Responses to the Increasing Risks From Climate Change. While the planet has seen major climate variation over its history, the pace of change today is well beyond that attributable to natural phenomena and is driven by human activity, especially from energy. The UN's 2019 Climate Action Summit brief noted that the last four years were the four hottest on record, and winter temperatures in the Arctic have risen by 3°C since 1990. The U.S. Fourth National Climate Assessment released in 2018 noted that, "Without significant reductions, annual average global temperatures could increase by 5°C or more by the end of this century compared to preindustrial temperatures."[ii] The growing intensity and frequency of floods, hurricanes, and droughts across the country and the world have underscored both the ferocity and costs of a changing climate.

This has not gone unnoticed by the nations of the world. In 2015, 197 countries adopted the Paris Accord at COP21. According to the Special Report by the Intergovernmental Panel on Climate Change (IPCC) published only three years after Paris, "limiting global warming to 1.5°C is projected to reduce risks to marine biodiversity, fisheries, and ecosystems, and their functions and services to humans" while a 2°C rise would bring with it greater increases in frequency and intensity of heavy precipitation in several regions along with an increase in intensity or frequency of droughts in others. [iii]

According to the UNFCC, since COP21, 191 countries have submitted their first Nationally Determined Contribution (NDC) and eight have submitted their second.[iv] Importantly, since Paris, the number of countries

Figure 1. Countries That Have Either Achieved , Have Laws, Policies, Proposals Under Discussion for *Net Zero Emissions Targets* as of 2020



130 countrieshave either implemented or are considering implementing net zero targets .

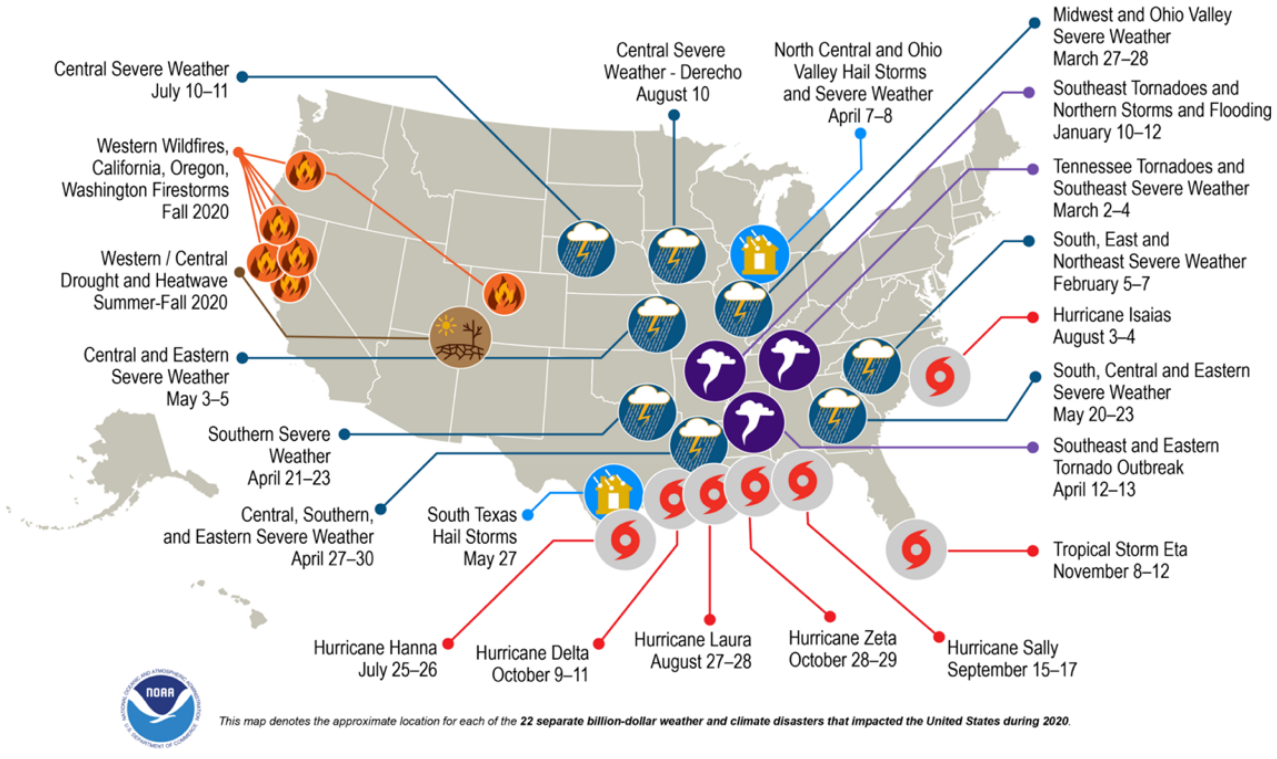
that have implemented or are considering net zero emissions targets, now stands at 130, up from around 17 just two years ago (Figure 1).

U.S. Climate Risks. The Fourth U.S. Climate Assessment also found that "Climate change creates new risks and exacerbates existing vulnerabilities in communities across the United States, presenting growing challenges to human health and safety, quality of life, and the rate of economic growth" and that "Without substantial and sustained global mitigation and regional adaptation efforts, climate change is expected to cause growing losses to American infrastructure and property and impede the rate of economic growth over this century."

The events described earlier did not just impact Texas. The winter storm in mid-February 2021 affected large regions of the southern U.S., including Texas, with sustained subzero temperatures and snow. These events are not anomalies; they represent the new norm. According to the National Centers for Environmental Information at the National Oceanic and Atmospheric Administration, the U.S. has sustained 291 weather and climate disasters since 1980 where overall damages/costs reached or exceeded $1 billion (including CPI adjustment to 2021). The total cost of these 291 events exceeds $1.9 trillion**.** The 1980–2020 annual average is 7.1 events (CPI-adjusted); the annual average for the most recent 5 years (2016–2020) is 16.2 events (CPI-adjusted).

2020 sets the new annual record of 22 events - shattering the previous annual record of 16 events in both 2011 and 2017**.** 2020 is the sixth consecutive year (2015-2020), in which there have been ten or more, billion-dollar weather and climate disaster events that have impacted the United States.[1] The costs of such events are highlighted in Figure 2 below that describes 2020 weather and climate- related events that caused $1 billion or more damage across regions in the U.S.

Figure 2. U.S. 2020 Billion-Dollar Weather and Climate Disasters



The Biden Administration is setting us on a new and accelerated course towards an economy with net zero greenhouse gas (GHG) emissions by mid-century. The U.S. has rejoined Paris and it is expected that at the Earth

[1] https://www.ncdc.noaa.gov/billions/

Day Summit, the Administration will release an updated ambitious Nationally Determined Contribution, setting a new interim target for GHG reductions by 2030. I look forward to working on ways the US can meet these increased ambitions and to highlight these and other U.S. actions at COP 26 in Glasgow later this year.

The Administration's actions are as warranted as they are critical. In the last two years, two of our largest states – Texas and California – have been devastated by the impacts of climate change. Wildfires in California forced the preemptive shutdown of large sections of the state's grid. Last August, a western US extreme heat wave forced rolling blackouts in California. These and other events suggest that weather and other risk profiles that have guided infrastructure protection, development, and investments are no longer adequate for risk assessment, associated policy actions, and infrastructure investments in the future. The number and magnitude of severe weather events increasingly fall outside historical ranges, e.g., the concept of a 100-year flood, may no longer be valid; the scope of adverse impacts has expanded due to the increasing interdependencies of infrastructures; and the geographic pattern of risks has changed due to changing climate. Simply stated, yesterday's weather is no longer a good guide for planning to meet tomorrow's weather extremes. We need new baselines for calculating climate risks.

Changes in the Work Environment. As we assess U.S. climate risk, we also need to consider the impacts COVID has had on work and the associated patterns of energy use. While no one knows for certain how the unprecedented experience of the pandemic will affect the work environment of the future, it appears likely that there will be dramatic increases in the numbers of people working from home. This could have significant implications for energy needs and the associated infrastructures to support the changed workplace.

First and foremost, it would likely increase demand for reliable and resilient electricity supplies across the entire grid as the productivity of highly decentralized working environments will be directly linked to power availability. It could also lower energy demand for transportation at the same time it could increase residential electricity demand; the time of day for peak electricity demand, a critical consideration in grid management, could change. In addition, it would require universal access to broadband to ensure all Americans have equal workplace flexibility options. The COVID crisis drove this point home: children without access to broadband could not "go to school". Businesses without access to broadband couldn't meet customer needs. Finally, the increased use of broadband and the internet to conduct business could increase concerns about cyber-security. Innovation investments should consider this changing profile and address these needs. An overarching point: continued electrification of the economy ups the ante for reliability, resilience, security and power quality of the electric grid.

Climate Risks and Responses will Vary Greatly by Region of the Country. The resources, infrastructures, emissions profiles, innovation, and policy needs vary greatly by region of the country—a "one size fits all" approach to climate risks will likely impede, not accelerate progress towards deep decarbonization. EV charging infrastructures will, for example, look very different in both rural and urban areas, where the typical "suburban EV model mindset" and its associated infrastructure will have little relevance to densely populated cities and sparsely populated regions of the country. Industrial centers in the U.S. will have ongoing need for high quality process heat that cannot easily be provided by electricity. Many regions have sequestration options, some do not. Offshore wind resources are clearly available only to those regions with coastlines, and onshore wind resources vary greatly across the country as do solar resources. They also have large seasonal variations.

Risks to Critical Infrastructures. Another critical finding in the Fourth Climate Assessment: "Changes in energy technologies, markets, and policies are affecting the energy system's vulnerabilities to climate change and extreme weather. Some of these changes increase reliability and resilience, while others create additional vulnerabilities. Changes include the following: natural gas is increasingly used as fuel for power plants; renewable resources are becoming increasingly cost competitive with an expanding market share; and a resilient energy supply is increasingly important as telecommunications, transportation, and other critical systems are more interconnected than ever."

Existing U.S. infrastructure, aging and in need of repair, is especially vulnerable to climate impacts. The American Society of Civil Engineers *2021 Report Card* gives America's infrastructure a C- overall and a C- for the energy

system. The *Report Card* notes that American dependence on electricity has increased as have grid investments over the last four years, "however weather remains an increasing threat." Among the 638 transmission outage events between 2014 and 2018, severe weather was the predominant cause, and "in the coming years, additional transmission and distribution infrastructure, smart planning, and improved reliability are needed to accommodate the changing energy landscape as delivery becomes distributed and renewables grow."

The Complex Interdependencies of Critical Infrastructures. The 2021 crisis in Texas is not surprising. Preliminary analysis of what went wrong in Texas, from a systems perspective, suggests that the natural gas, electricity, and water infrastructures were all affected by the extreme cold and that their interdependencies were major contributors to the electricity crisis.

We made energy infrastructure an early priority in my tenure as Secretary at DOE with the drafting and publication of the first installment of the Quadrennial Energy Review, or QER. The first installment of the QER focused on energy infrastructure. It was released in 2015 and included a section specifically focused on the growing interdependencies of the electricity and natural gas infrastructures highlighting the Big Chill in Texas and New Mexico in 2011 as an example. As noted earlier, this concern was borne out by the events in Texas 10 years later (see Text Box 2).

Text Box 2. QER 1.1 Highlighted Growing Gas/Electric Interdependencies

The Big Chill: A Disruptive Event Made Worse by Infrastructure Interdependencies[i]

The "Big Chill" of 2011 illustrates the complicated relationship between natural gas and electric power, which had compounding effects during a period of extreme weather.

During the first week of February 2011, the U.S. Southwest was hit by an arctic cold front that was unusually severe in terms of its low temperatures, gusting winds, geographic extent, and duration. From January 31 to February 4, temperatures in Texas, New Mexico, and Arizona were the coldest experienced within the region since 1971. Dubbed the "Big Chill" in the media, it overwhelmed the routine preparations for cold weather that had been put in place by electric generators and natural gas utilities located in those states.

Within the Electric Reliability Council of Texas (ERCOT) Interconnection, starting in the early morning hours of February 2, the cold temperatures and wind chill caused a significant number of outages at generating plants, with approximately one-third of the total ERCOT generating fleet unavailable at the lowest point of the event. With electricity demand soaring because of the cold weather, ERCOT and some utilities in New Mexico instituted rolling blackouts to prevent collapse of their electric systems. For the Southwest as a whole, 67 percent of electric generator failures (by megawatt-hour) were due directly to weather-related causes, including frozen sensing lines, frozen equipment, frozen water lines, frozen valves, blade icing, and low-temperature cutoff limits on equipment.

Gas producers and pipelines were also affected in Texas, New Mexico, and Arizona. Natural gas production was diminished due to freeze-offs and the inability to reach gas wells (due to icy roads) to remove produced water and thereby keep them in operation. When rolling electricity blackouts hit gas producers and gas pipelines, it had the effect of causing further losses to natural gas supply. The ERCOT blackouts or customer curtailments caused or contributed to 29 percent of natural gas production outages in the Permian Basin and 27 percent of the production outages in the Fort Worth Basin, principally as a result of shutting down electric pumping units or compressors on gathering lines. As a result of all these factors, natural gas deliveries were affected throughout Texas and New Mexico. More than 30,000 customers experienced natural gas outages at some point during this period.

The majority of the problems experienced by the many generators that tripped, had their power output reduced, or failed to start during the event were attributable, either directly or indirectly, to the cold weather itself. However, at least another 12 percent of these problems were attributed afterward to the interdependencies between gas and electricity infrastructures (such as lost electricity generation due to natural gas curtailments to gas-fired generators and difficulties in fuel switching).

[i] Federal Energy Regulatory Commission and North American Electric Reliability Corporation. "Report on Outages and Curtailments During the Southwest Cold Weather Event of February 1-5, 2011: Causes and Recommendations." August 2011. http://www.ferc.gov/legal/staff-reports/08-16-11-report.pdf. Accessed February 2, 2015.

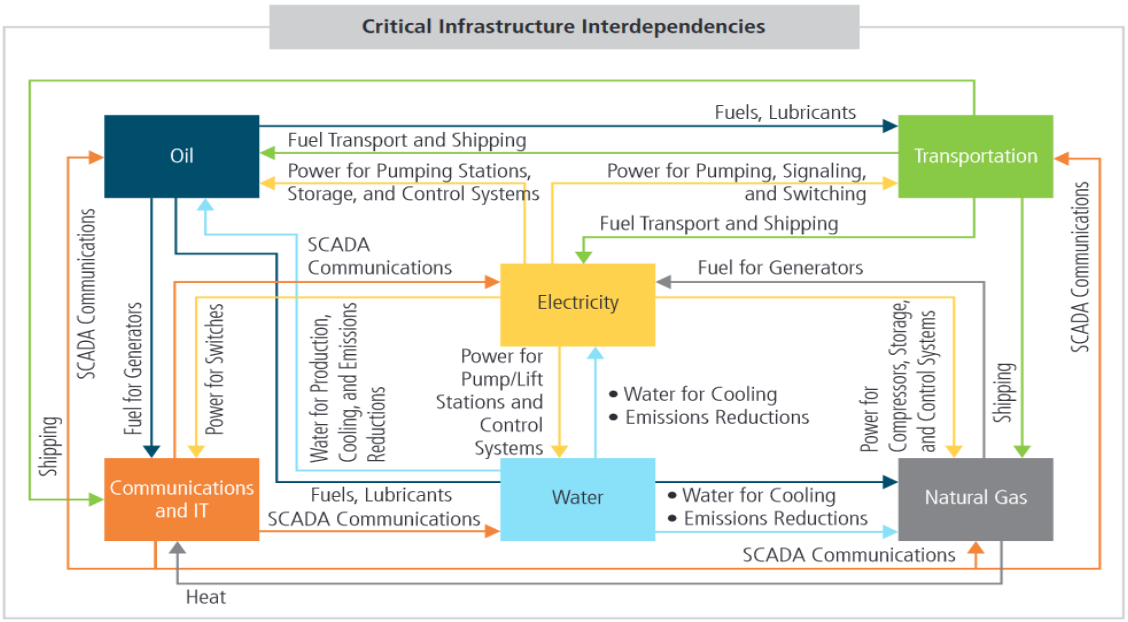
The second installment of the QER focused on the nation's electricity system. One of its many conclusions: the reliability of the electric system underpins virtually every sector of the modern U.S. economy. Reliability of the grid is a growing and essential component of national security. Standard definitions of reliability have focused on the frequency, duration, and extent of power outages.

With the advent of more two-way flows of information and electricity—communication across the entire system from generation to end use, controllable loads, more variable generation, and new technologies such as storage and advanced meters—reliability needs are changing, and reliability definitions and metrics must evolve accordingly.[v]

This reliance on electricity is illustrated in Figure 3, which illustrates the interdependencies between several of the nation's critical infrastructures. It's important to note that in this figure, IT/Communications and Electricity are connected to all of the critical infrastructures depicted in the figure. Not shown but also critical, is the financial sector. It too is connected to all critical infrastructures in this figure. Electricity, however, not only supports all the other infrastructures, it supports Finance and IT/Communications as well.

This figure also clearly illustrates the centrality of electricity as the "uber" infrastructure, essential to the U.S. economy and the health and welfare of our citizens. Making all of these critical infrastructures more resilient is essential. Electricity infrastructure, however, which is especially exposed to the impacts of climate change, supports virtually all economic, health and safety activities in the country; this raises the bar for both its reliability and its resilience. The centrality of electricity and the growing exposure of its infrastructures to the impacts of climate change, along with the associated risks, should be a major consideration as policies are being advanced to increase the electrification of the buildings and transportation sectors.

Figure 3. U.S. Critical Infrastructure Interdependencies: The Central Role of Electricity



Key critical infrastructure interdependencies represent the core underlying framework that supports the American economy and society. The financial services sector (not pictured) is also a critical infrastructure with interdependencies across other major sectors supporting the U.S. economy.

Acronyms: supervisory control and data acquisition (SCADA).

Source: Transforming the Nation's Electricity System: the Second Installment of the Quadrennial Energy Review

Risks to Conventional Energy Jobs Posed by the Clean Energy Transition. As the science of climate change has advanced and the impacts have become more obvious and severe, the Energy Futures Initiative's analysis has increasingly focused on policy and technology innovations that are central to any climate action plan that can both succeed in reaching the aggressive—but essential—net-zero goal and underpin a thriving economy in the U.S.

Achieving both climate and economic goals in the clean energy transition represents an enormous challenge. Technological revolutions have stimulated economic growth while leaving vulnerable workers behind. The First Industrial Revolution mechanized production, the Second introduced mass production, the Third brought automated production. The first two were enabled by new energy technologies, the third from electronics and information technology. The Fourth Industrial Revolution, already underway, is the digital revolution[2] which, like the others, can create opportunities as well as inequities and lost jobs. As noted, this past year, the economic divide associated with the digital revolution has become tragically and strikingly evident as work and education from home and tele-health have depended upon access to broadband and digital devices. It is imperative that we avoid such a divide as we transition to a clean energy economy.

It's a fact of the nation's changing energy profile: a number of energy jobs in key job classifications have been declining and will continue to decline. Coal jobs, for example, have been declining over the past two decades,

[2] https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/

along with the declines in the costs of wind, solar and natural gas technologies or supplies or both. Detailed data on these and other job classifications, numbers, and declines/increases can be found on the EFI website in several issues of the U.S. Energy Employment Report (USEER).

In this regard, EFI, in partnership with the National Association of State Energy Offices, has conducted an annual energy jobs survey that we started at DOE when I was Secretary. The previous Administration discontinued this survey. Understanding its importance, EFI and NASEO have sustained this critical work and released a five-year trend analysis of energy jobs last year. The data in this summary analysis (all pre-COVID) indicated that energy jobs were created at twice the rate of overall jobs in the economy, a critical consideration as we work on COVID recovery. I am pleased to tell the Committee that DOE has recently agreed to renew its support of this effort.

The USEER also documents the geographic concentration of many conventional energy jobs that are dependent on the location of key resources, generation technologies, refining and processing, etc. The largest percentage of energy jobs, however– efficiency jobs -- are ubiquitous, present in 99.8 percent of all counties in the U.S. Energy efficiency employment grew 20 percent, more than any of the energy sectors between 2015-2019, and represented 2.38 million Americans in 2019; 56 percent of these jobs were in the construction industry. It is important that we continue to support these jobs or create new, comparable employment as we consider the risks to conventional energy jobs inherent in the clean energy transition, we catalogue skillsets, support the translation of the skills to focus on clean energy opportunities, and invest in programs and incentives to mitigate these risks. Table 2 shows an EFI work product that starts this cross-walking, looking first at conventional infrastructures/technologies and how these might be used for clean energy production and use.

Table 2. Cross-walking Conventional to Clean Energy Infrastructures

Opportunities for Using Existing Carbon Infrastructure for Decarbonization					
	Oil Refineries & Gas Processing	**Natural Gas Generation**	**Oil & Gas Pipelines**	**Waterborne Transportation & Ports**	**Storage**
Biofuels	• Conversion of oil refineries to biorefineries • Upstream blending of oils with drop-in biofuels • Applying industry expertise	• See Renewable Natural Gas examples below	• Transporting biofuels in petroleum product pipelines • Leveraging pipeline rights-of-way	• Using fuel storage and transportation hubs	• Using underground storage tanks for biofuels and petroleum-biofuel blends
Hydrogen Fuel or Feedstock	• Leveraging industry expertise on hydrogen safely • Producing hydrogen • Redirecting hydrogen currently produced for refining petroleum to perform other energy services	• Co-firing hydrogen (up to 50 percent) with NG • Gas turbine combined-cycle plants with expected efficiency of ≥60 percent	• Doping in NG pipelines (≤15 percent with minor pipeline upgrades needed) • Leveraging pipeline right-of-way	• Using fuel storage and transportation hubs	• Using salt caverns and other geologic formations • Capitalizing on industry expertise with NG storage
Negative Emissions Technologies /Carbon Capture, Utilization, and Storage (CCUS)	• Applying industry expertise to CCUS technologies for direct-air capture (DAC) and bioenergy with carbon capture and storage (BECCS)	• Applying industry expertise: CCUS technologies for DAC and BECCS	• Using compression technologies similar to those in NG infra-structure for CO_2 • Rail and roadway = existing infrastructure • Leveraging pipeline rights-of-way	• Using industry expertise in lique-faction and trans-port of LPG/LNG for liquid CO_2 • Marine vessels for CO_2 using the same technology as existing LPG or LNG tankers • Port infrastructure for loading • Offshore facilities for subsea injection	• Using saline formations, depleted O&G reservoirs, un-mineable coal seams, basalt formations • Using industry expertise in large-scale CO_2 separation and sequestration • Applying technologies for drilling and injection, subsurface characterization, and site monitoring, same as in the O&G sector • Leveraging similarities with NG storage, acid gas disposal, and CO_2-EOR
Renewable Natural Gas (RNG)	• Processing technologies are similar to NG processing	• Minimal processing for using RNG for power generation in gas turbines	• Doping in NG pipelines • Leveraging pipeline rights-of-way	• Utilizing existing fuel storage and transportation hubs	• Leveraging industry expertise with NG storage
Smart Systems/ Platforms	• Applying process automation for improved refinery performance	• Creating smart generation solutions: NG-battery and NG-solar	• SCADA expertise • Improving the efficiency of transport of RNG, H_2, CO_2 • Enhanced leak detection	• Using transport management systems and other IoT applications • Data tracking of	• Optimizing revenues from grid-scale storage systems

Special attention also needs to be paid to providing the training needed as we transition from conventional to clean energy jobs. Again, offshore wind provides an example. The skills of oil and gas workers who have

experience with building and maintaining offshore drilling platforms can be transferred to offshore wind platform construction and maintenance. CCUS, hydrogen, engineered geothermal and carbon dioxide removal offer other opportunities to apply the subsurface and pipeline construction and maintenance knowledge and skills of oil and gas workers to work on large scale decarbonization infrastructures. Many of the "new energy" opportunities will also be located in regions with oil and gas production, thereby minimizing dislocation of the workforce.

This underscores some of the key reasons why we formed the Labor Energy Partnership (LEP) with the AFL-CIO last year. The LEP is a joint effort of both organizations, designed to develop a framework for the 21st Century energy system that creates and preserves quality jobs while addressing the climate crisis.

The LEP's four guiding principles demonstrate its approach to a range of issues, including grid modernization, offshore wind, CCUS, and hydrogen. These principles are: 1) Energy policy must be science-based; 2) We need an "all-of-the-above" energy strategy that is regionally focused, flexible, and preserves optionality; 3) preserving jobs, while creating new ones, is essential to climate policy; and 4) there are significant economic opportunities in the development and deployment of clean technologies and infrastructure.

The LEP is currently analyzing the policies needed to site and permit new electricity infrastructure projects in the near-term. It is also evaluating policy solutions to ensure rapid development of offshore wind resources along the east and west coasts, and in the Great Lakes region. In line with its wholistic approach to policy analysis, the LEP is considering local economic impacts, the opportunity to onshore the offshore wind manufacturing and supply chains, the social equity and environmental justice concerns, and the lessons learned from the existing global market. On Monday of this week, the LEP released a report detailing the highlights of a workshop it held on Offshore Wind and development of domestic supply chains, and also announced a set of five regional workshops, detailed in Figure 4.

Figure 4. Upcoming LEP Regional Workshops Announced April 19, 2021

Technology Risks Underscore the Need for an "All of the Above" Approach. The recent *Clean Energy Innovation Report* from the International Energy Agency provides a global context for immediate action on clean energy investment. The report emphasizes that while energy efficiency and renewable energy will be crucial, they are not sufficient to meet net-zero climate goals, especially in sectors like heavy industry and transportation.

The IEA Report also estimates that, on a global level, ***at least 40 percent of emissions reductions to reach net zero will rely on technologies not yet at commercial scale*** [emphasis added]—including known technologies such as end-use electrification, CCUS, hydrogen, and bioenergy. In the study, IEA also stresses that action is necessary immediately because past innovations, such as LEDs and lithium-ion batteries, took decades to reach full commercialization, and some energy-consuming infrastructure operates on refurbishment cycles of 25-30 years.

Also, there will be no single nor simple solution to meet net zero emissions. While the key technological near-term strategies to move towards net zero may be generally understood (policy support is a separate and less clear-cut issue), many that may be currently available could benefit from further improvements in performance and cost. In addition, ***many of the technology solutions needed to meet mid-century targets are not yet available,*** [emphasis added], a conclusion specific to California but with broad application, that was made in the EFI study, *Optionality, Flexibility & Innovation: Pathways for Deep Decarbonization in California,*'' released in May 2019.

Electricity storage is a case in point. Deployment of electricity storage systems is only in its earliest stage. Current commercial battery storage technology typically provides from 4-6 hours of storage; other options may provide longer duration storage but are site-specific, limited by geography or geology. Large scale deployment of intermittent carbon free electricity generation will require significant levels of longer duration storage capable of meeting daily, weekly, and even seasonal variations. The 2019 California study illustrates the challenges associated with limited-duration storage, seen in Figure 5. Long duration storage is one of those technology solutions that is "not yet available" but, with increased penetration of variable renewables, is needed to ensure system reliability.

Figure 5 . California Wind and Solar Generation for Each Day of 2017, CA Installed Storage Capacity, 2019

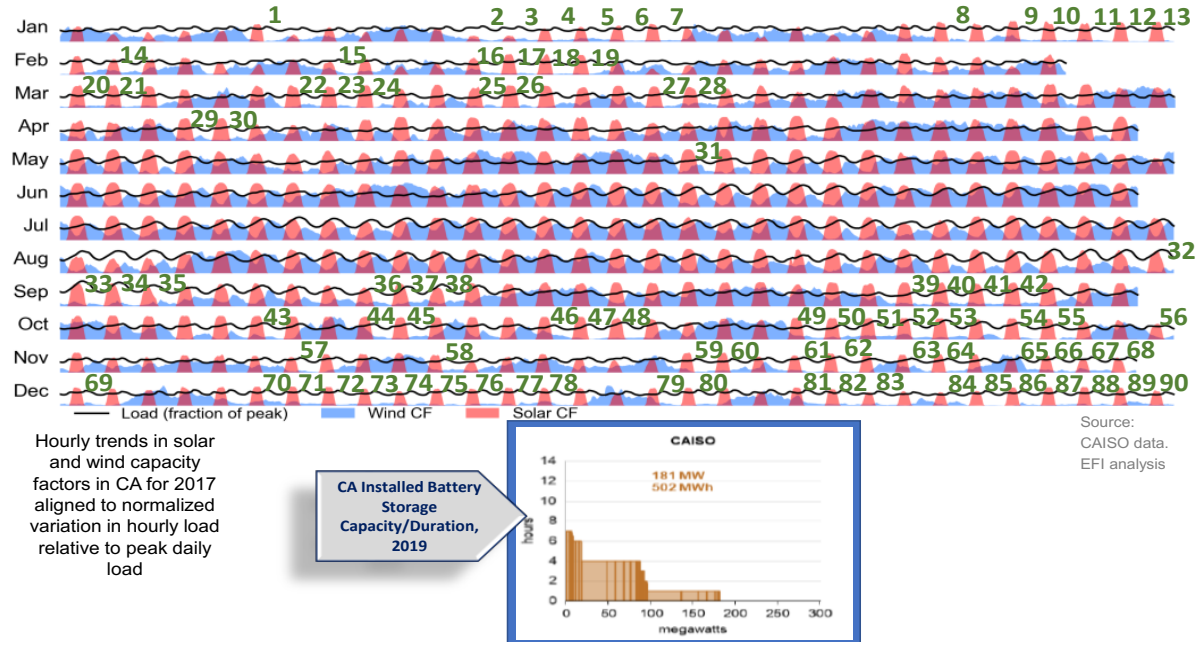


Figure 5 shows the hourly wind and solar generation for every day in 2017. Numbers in green count the days in the year where there was little to no wind generation in the state. The inset shows the installed battery storage capacity and duration in California which is currently insufficient to provide longer duration storage during multi-day periods with little to no wind generation.

To illustrate the degree of uncertainty about technology options, it is worth noting that in 2003, then chair of the Federal Reserve, Alan Greenspan, testified before Congress that the U.S. was facing an impending natural gas crisis, noting that, "Today's tight natural gas markets have been a long time in coming, and futures prices suggest that we are not apt to return to earlier periods of relative abundance and low prices anytime soon… As the technology of LNG liquefaction and shipping has improved, and as safety considerations have lessened, a major expansion of U.S. import capability appears to be under way. These movements bode well for widespread natural gas availability in North America in the years ahead."[3]

Eighteen years later, after a range of technology investments and supporting policies, the U.S. is now the number one producer of natural gas in the world because of hydraulic fracturing combined with horizontal drilling and is already the world's third largest LNG exporter. Technologies enabled this dramatic turnaround in the U.S. natural gas supply profile and the associated security of supply issues. One of DOE's earliest actions was characterizing shale basins. Research by the Gas Research Institute and a time-limited tax credit supported the development of shale gas (and oil) that has changed the U.S. energy profile in the last decade. This underscores the need for both a broad portfolio of technology innovation options that do not pick winners and losers, as well as policy support for demonstration and deployment.

The uncertainty and risks of the range of technology pathways and their successes suggests that there is on-going need for an "all of the above approach" to federal innovation investments, both for risk management and to accommodate the significant regional differences in the U.S. Developing a portfolio based on any single variable, such as cost or a policy preference, may be inadequate. Some sectors, such as aviation and manufacturing, are more difficult to decarbonize than others but will require significant attention, innovation spending, and other types of policy, regulatory, and business model support.

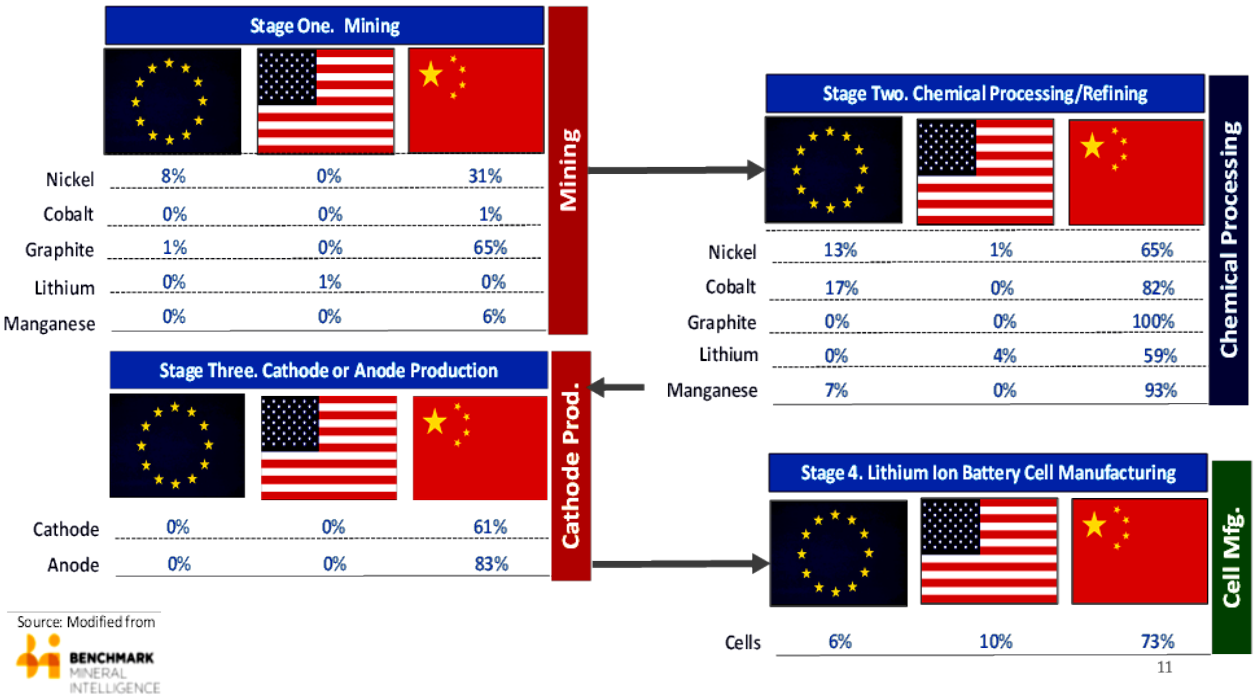
There are also significant systems integration needs that cannot be met if innovation investments are too narrowly focused. We must also not lose sight of the importance of fundamental R&D in platform technologies – AI, data analytics, additive manufacturing, robotics, materials by design, and many more – that become enablers of technological progress in multiple domains.

Supply Chain Risks for Clean Energy Technologies. Clean energy technologies introduce entirely new supply chain needs; there are corresponding and growing risks to those supply chains. Supply chain issues for new clean energy technologies must be evaluated and factored into policies. Clean energy technologies must accommodate potential material and process limitations, and the geopolitical risks that could, without policy support, delay or hinder U.S. and global decarbonization efforts.

Meeting the increased demand for critical metals and minerals will likely require a corresponding- increase in domestic mining, albeit to support deep decarbonization, this will need to be mining that employs environmentally sustainable practices. Targeted RD&D activities can supplement these strategies. Opportunities for materials substitution and materials recycling, as well as alternative approaches for materials processing and equipment manufacturing, should become a more prominent part of DOE funded RD&D for clean energy technology. Strategies for commercial deployment should take into consideration security and reliability of supply chains and develop appropriate acquisition strategies to accelerate market development. As an example, Figure 6 underscores these risks and the need for innovation throughout the supply chain for the metals and minerals needed for EV battery manufacturing.

[3] https://www.federalreserve.gov/boarddocs/testimony/2003/20030610/default.htm

Figure 6. Select Process for Key Metals and Minerals Needed for EV Battery Production: EU, US, and China Shares, 2019



The need to address these issues was underscored by President Biden's Executive Order 14017, America's Supply Chains, which notes that "More resilient supply chains are secure and diverse—facilitating greater domestic production, a range of supply, built-in redundancies, adequate stockpiles, safe and secure digital networks, and a world-class American manufacturing base and workforce. Moreover, close cooperation on resilient supply chains with allies and partners who share our values will foster collective economic and national security and strengthen the capacity to respond to international disasters and emergencies."

It is also worth noting that Title VII of the Energy Act of 2020 promotes a robust effort to rebuild domestic supply chains, emphasizing responsible production and efficient use, recycling, and development of alternatives for critical metals and minerals. In particular, the establishment of a robust program for assessment of critical metals and minerals is an essential first step. The Act also authorizes DOE to conduct a comprehensive program of RD&D as well as commercial application for critical materials, including development of alternatives, recycling and efficient production and use. These efforts should expand to include all materials vital to the clean energy transition. Onshoring offshore wind supply chains, for example, including raw material extraction, manufacturing, and final assembly could generate thousands of good jobs that would generate significant regional economic activity.

Protecting global supply chains, growing domestic industries and options, and investing in innovation are all critical to providing the energy and associated infrastructures for a clean energy future. This should, in fact, inform and broaden the definition of both energy infrastructure and energy security to help ensure policymakers are providing adequate direction and incentives to support the supply chains and industries needed for a clean energy future. In sum, the heavy reliance on foreign supply at key points in the supply chain point to the need for RD&D and associated deployment policies to support net-zero domestic mining, chemical processing and refining, and manufacturing of electric vehicle lithium-ion batteries. Policies and programs that could enhance US capacity and reduce supply chain risk in these areas include:

- protection of global supply chains for minerals/metals needed for wind, solar and batteries;
- an increased focus on trade relationships with South America and Africa;
- support for innovation to support new domestic, environmentally responsible, net-zero

mining activities for key minerals/metals, including associated infrastructures;
- an increase in the capacities, capabilities, and associated infrastructures needed for key mineral chemical processing/refining and battery manufacturing;
- significant recycling programs for key metals and minerals; and
- research into substitutions for key minerals by earth-abundant metals and minerals.

Corporate America is Investing in Clean Energy Technologies. Companies across America are also calling for strong climate targets and are committing to their own emission reductions. Responses to the climate crisis range from initial exploration to carbon net zero commitments. Many are incorporating climate risk to the business in their strategic planning and investing in clean energy technologies. Over 300 businesses and investors called on the Biden Administration to announce a 50% emissions reduction target by 2030.[4]

So far, over 200 US companies have made a public pledge to meet net-zero emissions by 2050.[5] The industrial sector is also starting to align on net zero climate plans. At the Davos World Economic Forum in January, for example, over 400 companies from aviation, aluminum, cement/concrete, chemicals, finance, shipping, steel and trucking, announced an agreement to work together to decarbonize by 2050.[6]

Oil and Gas Companies. According to S&P Global Market Intelligence, "Many of the largest oil and natural gas companies in the U.S. and Canada jumped on the train to combat climate change in the second half of 2020 as they began to more fully embrace the energy transition and started to adopt stricter goals to reduce emissions."[7] Eleven oil and gas companies with a market cap of over $450 billion, including seven large integrated companies, e.g., Shell and BP, have net zero targets. Two – Williams and Enbridge – are oil and gas storage and transportation companies, one is exclusively an exploration and production company, and one is a refining and marketing company. Nineteen other oil and gas companies do not have net zero targets but have a range of emissions reduction targets such as "plans to reduce greenhouse gas emissions per boe processed to 30% below 2014 levels by 2030," or "committed to reducing greenhouse gas emissions intensity by 25% and flaring intensity by 50% by 2020…".

Automakers. U.S. and global automakers are also changing their products to address consumer demand for lower emissions personal vehicles. More specifically:
- Ford announced a $29 billion investment in EVs and autonomous vehicles through 2025 and the majority of Ford vehicles will be electric.[8]
- General Motors as set a goal to stop making gasoline-powered vehicles by 2035, investing $27 billion in electric and autonomous vehicles by 2025.
- Tesla, the electric vehicle only car manufacturer, represented 79% of all EVs registered in the U.S. in 2020[9] and reached a valuation well over half a trillion dollars.
- Volkswagen is seeking to become the global market leader in e-mobility, investing 35 billion euros by 2025 and is planning to launch 70 pure e-models, having started on 20 already.[10]

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[4] https://www.wemeanbusinesscoalition.org/ambitious-u-s-2030-ndc/

[5] https://www.wemeanbusinesscoalition.org/companies/#country=USA&checkedOptions=Science%20Based%20Targets%20initiative

[6] https://www.reuters.com/article/climate-change-industry-int/heavy-industry-transport-sectors-to-align-on-net-zero-climate-plans-idUSKBN29W0EA; https://missionpossiblepartnership.org/join-us

[7] https://www.spglobal.com/marketintelligence/en/news-insights/latest-news-headlines/path-to-net-zero-climate-change-takes-center-stage-at-more-us-oil-companies-61440277

[8] https://www.caranddriver.com/news/a35432253/ford-ev-commitment-announced/

[9] https://www.cnet.com/roadshow/news/tesla-cars-ev-registrations-us/

[10] https://www.cleanenergywire.org/factsheets/dieselgate-forces-vw-embrace-green-mobility

- BMW has announced plans for half of its sedans, SUVs, and mini cars to be electrified in Europe by 2030, noting that currently 13.3% are either all electric or hybrid, compared to an average of 8% in Europe.[11]

Electric and Gas Utilities. Seventy percent of the top 30 largest electricity and gas utilities in the U.S. have net zero commitments, including giants like Duke, Southern, Sempra and PG&E. While the remaining nine do not have net zero commitments, many of their emissions reduction targets are significant. NextEra for example, has a 67% reduction target by 2025 from 2005 levels. Exelon has a 15% reduction by 2022 from 2015 levels and AEO has a 70% reduction by 2030 from 2000 levels (it also has a loose aspirational net zero goal by 2050).

CFTC Recommendation. With this background, the CFTC made a clear overarching recommendation: "The United States should establish a price on carbon. It must be fair, economy-wide, and effective in reducing emissions consistent with the Paris Agreement. This is the single most important step to manage climate risk and drive the appropriate allocation of capital." This is obviously a challenging recommendation, but it surfaces a critical point: if we are to meet ambitious goals for decarbonization in the mid-century time frame, we must address greenhouse gas emissions across the entire economy, not just in the electricity sector. At the same time, any such policy should respect the core principles of the Jim Baker – George Shultz proposal: the resources generated by a carbon emissions fee should be returned to the citizenry in a socially progressive manner, and a mechanism, such as a carbon border adjustment, should be put in place to counter moves to "leak" domestic manufacturing and jobs outside the United States.

The Investment Community: An Increased Focus on Climate Change Risks. Returning to the financial dimensions of climate risk, the U.S. Department of the Treasury's Financial Stability Oversight Council, at its meeting last month, discussed climate risk and the implications of this risk for the nation's financial systems. The Council is charged with identifying risks to the financial stability of the U.S. The U.S. Securities and Exchange Commission, Federal Reserve and the U.S. Commodity Futures Trading Commission are also analyzing options on disclosure of climate risks.

Specifically, the Federal Reserve is working to "…understand the potential implications of climate change for financial institutions, infrastructure and markets." These activities need to be supported by research to update climate risk assessments in order to better guide investment planning and disclosure requirements. These actions also reinforce the Environmental, Social, and Corporate Governance (ESG) focus of shareholders and institutional investors. Taken together, we anticipate profound shifts in corporate priorities in the direction of accelerating the response to climate change. The rationale for the Fed's role was succinctly summarized by Chairman Powell:

> The reason we're focused on climate change is that our job is to make sure that financial institutions, banks, particularly the largest ones, understand and are able to manage the significant risks that they take.
>
> Jerome Powell, Chair, Federal Reserve
>
> Economic Club of Washington, April 14, 2021

Chairman Powell's perspective is shared by major investors and corporations. In February, both the International Monetary Fund and World Bank committed to increase efforts to address climate change by examining climate-related financial stability risk. World Bank President David Malpass noted that the World Bank is launching new reviews to integrate climate into all its country diagnostics and strategies.

Similarly, this past January, IMF chief Kristina Georgieva, underscored that climate change posed a fundamental risk to economic and financial stability. Founded simultaneously under the 1944 Bretton Woods Agreement, the World Bank and International Monetary Fund are organizations responsible for significant investment pools.

[11] https://www.forbes.com/sites/neilwinton/2020/08/14/bmw-50-electrification-target-for-2030-is-ambitious-but-is-it-achievable/?sh=1d57ec5201fe

Governed by its 190 member countries, the IMF has the ability to lend $1 trillion. And by June 2021, the World Bank expects to have deployed up to $160 billion in the past 15 months.[12]

The private sector is also examining the role of climate risks and the associated impacts on investment strategies. At an important convening of oil and gas industry and other executives in 2019, the second meeting of this group, Pope Francis challenged the industry, saying that climate change is a threat to the future of humanity, and that "Time is running out…Deliberations must go beyond mere exploration of what can be done, and concentrate on what needs to be done. We do not have the luxury of waiting for others to step forward, or of prioritizing short-term economic benefits." The dialogue also focused on economic, environmental, and social justice and how solutions and responses to climate change could and should assist the world's poor.

At this summit, major oil producers pledged to support "economically meaningful" carbon pricing regimes. I was included as CEO of an NGO focusing on deep decarbonization as were leaders from the energy investment community. US oil and gas companies at the summit at the CEO level included ExxonMobil, Chevron, ConocoPhillips, and Occidental. US financial institutions were also represented, and included Vanguard, BlackRock, State Street and CALSTRS, among others. Obviously, these are major players in our economy. Participants signed a joint statement to reflect conclusions of the dialogue, noting that:

"As leaders in the energy sector, the global investment community, and other organizations, we recognize that a significant acceleration of the transition to a low-carbon future beyond current projections requires sustained, large-scale action and additional technological solutions to keep global warming below 2°C while advancing human and economic prosperity.

- Companies should provide clarity for investors about how they are planning and investing for the energy transition. This includes issuing disclosures that provide meaningful and material information consistent with the reporting obligations in their jurisdictions.

- Companies should be encouraged to work with investors on the evolving recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD), aligned with its four pillars of (1) governance, (2) strategy, (3) risk management, and (4) metrics and targets.

- Further, we support scenario analysis as an important and useful tool for assessing how resilient company strategies are to climate-related risks and opportunities pertaining to the 2°C or lower scenarios. We encourage companies to conduct a range of scenario analyses in line with the principles of TCFD.

- It is important that boards of directors assess climate-related issues as part of their risk oversight function, as well as management's role in evaluating and addressing these issues. These include sector and company-specific transition risks incorporating financial, policy and legal, technology, market, reputation and physical risks both acute and chronic. Opportunities such as resource efficiencies, new energy sources, new products and services should also be considered.

- Investors play a critical role through dialogue and feedback in supporting companies regarding appropriate disclosures on governance, strategy, and performance on climate-related risks."

Following up on the Vatican Summit, BlackRock, Vanguard, and State Street enhanced their ESG practices and leadership. Known as the "Big Three" they manage over $15 trillion in global assets, equivalent to 75% of U.S. GDP, and accounting for about 82% of the S&P 500's market capitalization.[13]

In his 2021 letter to CEOs, Larry Fink of BlackRock identified four issues pivotal to creating durable value: capital management, long-term strategy, purpose, and climate change. Fink made another statement that is

[12] https://www.dailysabah.com/business/economy/imf-world-bank-to-step-up-efforts-against-global-climate-risks
[13] https://www.thinkadvisor.com/2020/11/30/group-aims-to-limit-power-of-blackrock-vanguard-state-street/

fundamental to the point I wish to make at this hearing. He stated: "We know that climate risk is investment risk. But we also believe the climate transition presents a historic investment opportunity."[14]

Vanguard and Blackrock have both expressed support for the Sustainability Accounting Standards Board (SASB) and Task Force on Climate-related Financial Disclosures (TCFD) disclosure frameworks. State Street announced that beginning in 2022, they will vote against independent directors at companies that underperform according to SASB disclosures. *The Big Three and Corporate Carbon Emissions Around the World*, a paper to be published in the Journal of Financial Economics, examined the role of the BlackRock, Vanguard, and State Street Global Advisors on the reduction of global corporate carbon emissions. The authors found a "strong and robust negative association between the Big Three Ownership and subsequent carbon emissions among MSCI[15] index constituents."[16]

Regarding climate risk, Vanguard is placing greater focus on boards' "climate competency" and joined the "Net Zero Asset Managers Initiative" to cut the net GHG emissions of its funds to zero by 2050. BlackRock changed its thinking on shareholder resolutions, which were historically seen as a tool of last resort. Now, BlackRock characterizes shareholder votes as a "primary tool" for companies that are ESG laggards. In late 2020, State Street joined Climate Action 100+, which is an investor initiative focused on companies' plans to align with the goals under the Paris Agreement. This is the single most important step to manage climate risk and drive the appropriate allocation of capital."

Conclusion: The Need for New Climate Risk Frameworks and Methodologies.

Clearly, the private sector is moving rapidly towards climate risk disclosure as a fundamental pillar of investment decisions. The proliferation of expensive extreme weather events helps drive this. Governments and multilateral institutions, such as the G-20, are looking to incorporate such risk disclosure into their financial regulatory responsibilities to provide relevant information to investors. President Biden is expected to take executive action requiring financial institutions and companies to disclose climate risks, and a number of central banks are working on climate risk reporting and are preparing to stress-test the global financial system's response to such risks.

The IMF has a new "Climate Change Indicators Dashboard" that provides definition and information on a range of climate change issues, underscoring the increasing interest of financial institutions in climate risk. On a link on the dashboard entitled, Financial, Physical and Transition Risk Indicators," it notes that, "These indicators include green finance indicators to illustrate the financial support towards a low-carbon emission environment, such as carbon footprint adjusted loans for deposit takers and green bonds. Other indicators cover climate-related physical risk and transition risk." [17]

Another link on the IMF dashboard labeled, "cross border" climate indicators, notes that, "Indicators in this category examine how CO2 emissions from production in one economy can be used to meet demand at home or abroad as well as how they are impacted by the decisions of multinational enterprises on where to locate their production. They include CO2 emissions embodied in trade, measures of trade in environmental goods, and several indicators related to direct investment, including measures of emissions associated with tangible investments financed by direct investment and with value added of multinational enterprises."

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[14] https://www.blackrock.com/corporate/investor-relations/larry-fink-ceo-letter; https://www.forbes.com/sites/iese/2021/01/27/how-does-blackrock-measure-up-on-climate-change/?sh=6cfbcbc243e1

[15] The Morgan Stanley Capital International (MSCI) index measures equity market performance in global emerging markets, and represents 13% of global market capitalization.

[16] https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3553258;

[17] https://climatedata.imf.org/pages/go-indicators

It's clear that the global finance community is rapidly moving towards climate risk disclosures and the stakes are high both for the climate and for the financial relationships of countries, allies and adversaries alike in the geopolitical domain. For example, the EU is working on a border adjustment tariff for products with embedded emissions that could affect exports from the U.S. to Europe.

Closer to home, as noted earlier, the Commodities Futures Trading Commission, in an extensive analysis of climate change risk, made many recommendations on how to address threats to the Nation's financial systems. Important to this discussion, it recommended, "Financial regulators, in coordination with the private sector, should support the development of U.S.-appropriate standardized and consistent classification systems or taxonomies for physical and transition risks, exposure, sensitivity, vulnerability, adaptation, and resilience, spanning asset classes and sectors, in order to define core terms supporting the comparison of climate risk data and associated financial products and services. To develop this guidance, the United States should study the establishment of a Standards Developing Organization (SDO) composed of public and private sector members."[18]

It is critical that we develop a new, flexible climate risk profile for energy systems and the broader economy, including the associated analytical tools. This is an area that needs significant innovation investments in new models, techniques, and approaches for considering climate change-based risk into the system. We need to answer key questions about supply chain and Scope 2 and 3 emissions to ensure that the methodologies for any risk disclosures we develop are fair, focused on emissions and not favored products or technologies, accommodate regional differences, and that we maximize emissions reductions in all sectors. We also need to understand climate disclosure actions and activities of other regions and countries of the world to adequately assess their impacts on U.S. export markets.

It is also critical that multi-agency efforts, with support from universities, DOE's National Laboratories, and other research institutions continue to develop tools, programs, and partnerships that closely monitor climate conditions, feeding into decision making processes in both the public and private sectors. The risk profiles need to be developed with regional granularity not just for polar vortices but for the entire spectrum of weather and other climate change extremes. It is a major challenge and requires rapid action – but it is essential that we re-set how we assess climate risks and develop technologies and policies for reaching net zero emissions by mid-century.

Mr. Chairman, ranking member Toomey and members of the Committee, thank you for the opportunity to testify today and I look forward to your questions.

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[i] Energy Wire, April 19, 2021

[ii] https://nca2018.globalchange.gov/

[iii] https://www.ipcc.ch/sr15/chapter/spm/

[iv] https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx

[v] Transforming the Nation's Electricity System: the Second Installment of the Quadrennial Energy Review, released by the Department of Energy, January, 2017

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[18] https://www.cftc.gov/sites/default/files/2020-09/9-9-20%20Report%20of%20the%20Subcommittee%20on%20Climate-Related%20Market%20Risk%20-%20Managing%20Climate%20Risk%20in%20the%20U.S.%20Financial%20System%20for%20posting.pdf