ENERGY FUTURES INITIATIVE

Statement of the Honorable Ernest J. Moniz
Secretary of Energy (2013-2017)
Founder and CEO
Energy Futures Initiative, Inc.

before the
U.S. House Energy and Water Development Appropriations Subcommittee
on
The Role of the U.S. Department of Energy in Addressing Climate Change
November 20, 2019

Chairwoman Kaptur, Ranking Member Simpson and Members of the House Appropriations Subcommittee on Energy and Water Development, thank you for the opportunity to appear before you today to discuss the imperatives of climate change and the importance of clean energy innovation. When I was Secretary, I very much appreciated the opportunity to work with you in a bipartisan fashion to advance DOE's important missions. And I take this opportunity to once again congratulate the Chairwoman for being the longest-serving woman in the history of the U.S. House of Representatives and thank Congressman Simpson's for his support of the Idaho National Laboratory, the nation's lead lab for nuclear energy research and development.

Let me deliver the punch line up front: the scale and pace needed for the low-carbon energy transition have come to be understood as even greater than was put forward just four short years ago at the Paris COP21 meeting, and DOE stands at the center of the energy science and technology innovation ***solutions*** that will position the United States for economic, environmental and security success in that transition.

The Energy Futures Initiative

My testimony will draw heavily from the data- and analysis-based work of the Energy Futures Initiative (EFI). In June 2017, I launched EFI together with my former colleagues at the U.S. Department of Energy: Melanie Kenderdine, founding Director of the Office of Energy Policy and Systems Analysis; and Joseph Hezir, the former Chief Financial Officer. EFI is dedicated to harnessing the power of innovation – both in technology and policy – to create clean energy jobs, grow the economy, enhance national and global energy security, and address the imperatives of climate change. We believe it is possible to build a secure, affordable, low-carbon energy future through the power of clean energy innovation and policies based on independent, unbiased, fact-based energy analysis.

To fulfill this mission, EFI produces rigorous analytical reports that offer new insights into emerging energy issues and recommendations for policymakers, and by leading stakeholder engagements that focus on elucidating the important technical, policy, economic, social and financial considerations for the energy sector. EFI seeks to achieve the maximum impact by identifying solutions that are effective, realistic and

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sufficiently robust for adoption in these uncertain times. In just over two years, we have published 11 reports:

1. *The U.S. Nuclear Energy Enterprise: A Key National Security Enabler* (August 2017)
2. *Leveraging the DOE Loan Programs: Using $39 Billion in Existing Authority to Help Modernize the Nation's Energy Infrastructure* (March 2018)
3. *The 2018 and 2019 U.S. Energy and Employment Reports* (March 2019 & June 2018), with the National Association of State Energy Officials
4. *Promising Blockchain Applications for Energy: Separating the Signal from the Noise* (July 2018)
5. *Advancing Large Scale Carbon Management: Expansion of the 45Q Tax Credit* (May 2018)
6. *Investing in Natural Gas for Africans: Doing Good and Doing Well* (November 2018)
7. *Advancing the Landscape of Clean Energy Innovation* (February 2019), with IHS Markit
8. *More Funding Needed for Carbon Removal Technologies* (April 2019), with the Bipartisan Policy Center
9. *Optionality, Flexibility & Innovation: Pathways for Deep Decarbonization in California* (May 2019)
10. *The Green Real Deal: A Framework for Achieving a Deeply Decarbonized Economy* (August 2019)
11. *Clearing the Air: A Federal RD&D Initiative and Management Plan for Carbon Dioxide Removal Technologies* (September 2019)

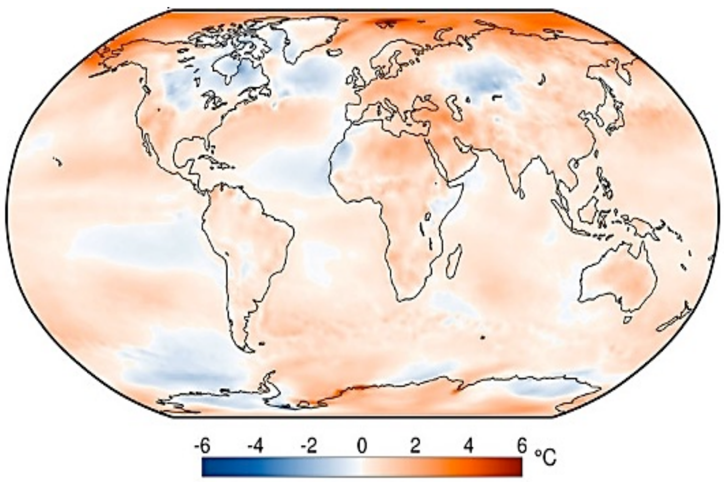
A twelfth report on regional innovation systems should be published next month. The analysis and conclusions of our reports solely those of EFI. All EFI reports are available to the public at no charge at: https://energyfuturesinitiative.org/efi-reports.

The Urgency of the Climate Issue and Need for Action

The threats posed by climate change to the world, our nation, and our way of life present an unprecedented and urgent challenge. The evolving climate science indicates the need to move toward a more stringent temperature limit of 1.5°C rather than 2°C. Yet as of 2018, two-thirds of the major carbon-emitting countries were not on track to meet the Paris target of 2°C,[1] and even if fully implemented, the Nationally Determined Contributions (NDCs) would achieve only one-third of the needed emissions reductions for a least cost pathway to 2°C.[2] Meanwhile, global carbon dioxide (CO_2) emissions rose 1.6 percent in 2017.[3] Preliminary estimates for 2018 suggest that global CO_2 emissions rose again at a rate of more than 2 percent.[4] The U.S. is no exception. In 2018, its CO_2 emissions from fossil fuel combustion rose 2.7 percent while economywide emissions likely increased by 1.5 to 2.5 percent.[5]

The United Nation's 2019 Climate Action Summit brief noted that "[t]he last four years were the four hottest on record, and winter temperatures in the Arctic have risen by 3°C since 1990". Arctic sea ice volumes in September 2018 compared to 1979 have declined by 75 percent.[6] Climate scientists have also expressed growing concerns about climate "tipping points"—irreversible changes in the climate system with uncertain triggers—after record-high global emissions in 2018.

Temperature Differences Between 2018 and 1980-2010 Average



2015-2018 were the four hottest years on record. Orange shaded locations were above average overall in 2018 and blue shaded areas were below average. Source: The Weather Channel, 2018

The growing intensity and frequency of floods, hurricanes and droughts across the country and around the world have underscored both the ferocity and costs of a changing climate. The recent wildfires in California offer a case in point: 12 of the state's 15 largest wildfires have occurred since 2000 and estimates of the costs of a single fire—the 2018 Camp Fire—are as high as $16.5 billion.[7] While Earth 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 fossil energy production and use. These trends are consistent with decades of forecasts and predictions.

A warning on the costs of prolonged inaction is found in the Fourth National Climate Assessment, whose contributors include representatives from eleven Cabinet-level agencies, NASA, USAID and the National Science Foundation. The Assessment highlights the extremely high cost of inaction on climate change to the U.S. economy[8]:

> *[R]ising temperatures, sea level rise, and changes in extreme events are expected to increasingly disrupt and damage critical infrastructure and property, labor productivity, and the vitality of our communities. Regional economies and industries that depend on natural resources and favorable climate conditions, such as agriculture, tourism, and fisheries, are vulnerable to the growing impacts of climate change…continued warming…without substantial and sustained reductions in global greenhouse gas emissions is expected to cause substantial net damage to the U.S. economy throughout this century…annual losses in some economic sectors are projected to reach hundreds of billions of dollars by the end of the century—more than the current gross domestic product (GDP) of many U.S. states.*

The Assessment indirectly underscores the social equity dimension of climate change: the high costs of inaction are disproportionately borne by those who can least afford them. These costs should be considered in the context of the Paris Agreement's targets of a 2°C increase in global temperatures by 2050, as well as its more desirable target of 1.5°C increase. The difference between the two targets presents very significant consequences. According to the European Geosciences Union, "the additional 0.5°C would mean a 10-cm-higher global sea-level rise by 2100, longer heat waves, and would result in virtually all tropical coral reefs being at risk."[9]

In short, *every tenth of a degree matters* in the fight against global warming, no matter where we are in our progress to limit the rise of global temperatures. Concerns about tipping points also reinforce the need for an additional focus on the "tenth of a degree" solutions and contributions: any and all incremental carbon reductions, whether above or below the multinational targets, reduce the risks of the most catastrophic impacts from global warming caused by Earth's feedback loops.[10] *Clearly, we are in a climate crisis.*

The energy transition must also respect issues of social equity and allow for truly common but differentiated responsibilities for the developed and developing world. In many regions of the world, energy access is fundamentally a human rights issue that must be addressed on the path to decarbonization.

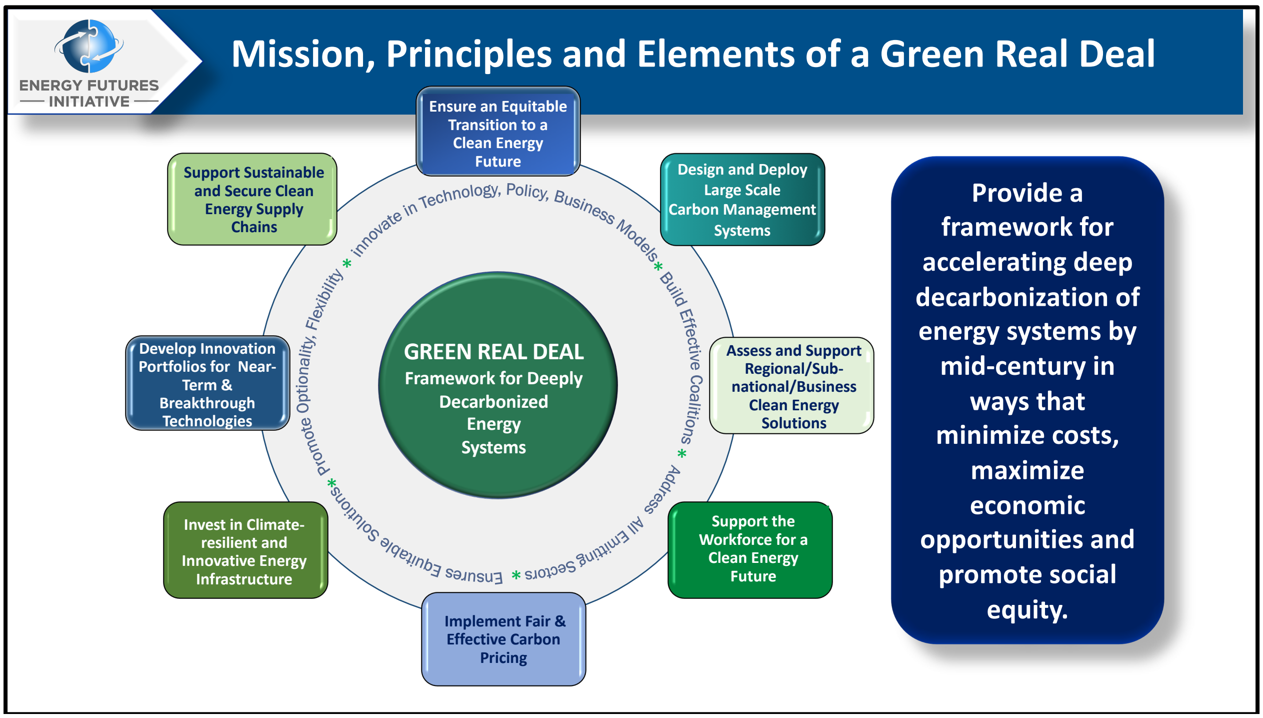
The U.S. withdrawal from the Paris Agreement is the latest step in the abandonment of American leadership to address the climate crisis. While efforts to curtail emissions continue in states and cities, and many companies are reducing emissions and building their strategic plans around the coming energy transition, the world needs the federal government to play the key role in building broad coalitions and creating actionable frameworks to transition to a low-carbon global economy. It must also continue and indeed expand its role in energy RD&D innovation.

Advances in science and observed environmental changes in the short time since Paris have, however, caused a reevaluation of the stringency of the targets. A 40 percent economywide emissions reduction target by 2030 and ***net***-zero greenhouse gas emissions by 2050 are increasingly seen as the needed objectives. The net-zero requirement suggests the importance of major negative carbon technology deployment by mid-century, such as carbon dioxide removal (CDR) from the atmosphere and possibly from the oceans. CDR systems can help address CO_2 already emitted in the environment and could greatly reduce the level of difficulty in reaching net zero by avoiding the requirements of a zero-emissions energy system.

The Green Real Deal: A Framework for Achieving a Deeply Decarbonized Economy

The Green New Deal has focused attention on the urgent need to act on climate change. It is, however, aspirational and includes many provisions that are not energy or climate specific. Its core principles for the energy transition are the need for deep decarbonization and the importance of addressing social equity during the transition. A wise and just transition to a low-carbon economy, moving as fast as is technically and socially possible, must minimize stranded physical assets as well as stranded workers and communities. It must be based on practicality, not ideology. The need for urgency and the serious impacts of inaction underscore the dangers of magical thinking–the deniers and the prescribers—at either extreme.

To translate the aspirations of the Green New Deal into practical and timely actions, EFI has developed the *Green Real Deal (GRD)*, a framework for a strategy for deep decarbonization of U.S. energy systems by mid-century in ways that minimize costs, maximize economic opportunities and promote social equity.



The Green Real Deal Principles are represented in the inner blue ring. Its Elements are represented by the outer ring. Source: EFI, 2019.

Principles and Elements of the Green Real Deal

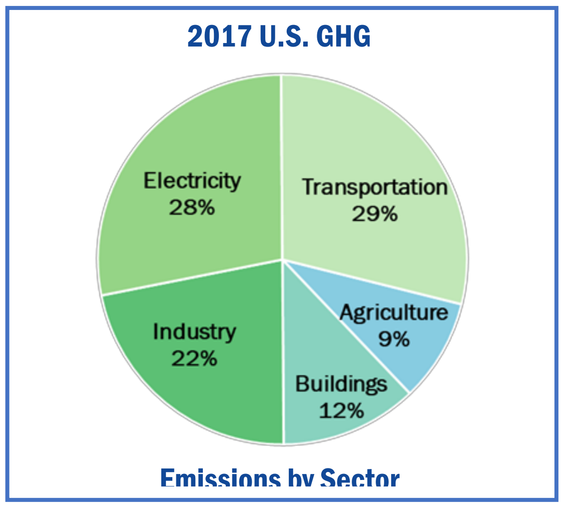
The Green Real Deal rests on five fundamental principles: a strong, ongoing commitment to and reliance on innovation; the need to attract and build strong and inclusive coalitions; a commitment to social equity in all deep decarbonization policies; economywide solutions to the climate challenge that are both sector specific and crosscutting; and technology and regional innovation options and flexibility supported by policies that enable each. Above all, the GRD is pragmatic in aiming for deep decarbonization as rapidly as is possible while preserving adequate, reliable and resilient energy systems.

- ✓ **Technology, Business Model, and Policy Innovations Are Essential.** Innovations in technology, business models, and policy are essential for meeting deep decarbonization targets by midcentury. Incremental and breakthrough innovations must be developed to meet the challenges of deep decarbonization, including the rising marginal costs of GHG abatement.

✓ **Broad and Inclusive Coalitions Must Be Built.** Solutions for addressing the climate challenge cut across all portions of the economy and require participation of businesses, consumers, workers, governments and advocacy groups. Finding common cause, proactively addressing conflict and ensuring all members of society benefit from a transformation to a low-carbon economy will put wind in the sails of meaningful action.

✓ **Social Equity Is Essential for Success.** The transformation of energy and associated systems must also improve lives, grow public acceptance of the widespread change required to address climate change, and provide meaningful, well-paying jobs. The GRD subscribes to the National Academy of Public Administration's definition of social equity: "The fair, just and equitable management of all institutions serving the public directly or by contract, and the fair, just and equitable distribution of public services, and implementation of public policy, and the commitment to promote fairness, justice, and equity in the formation of public policy."

✓ **All GHG Emitting Sectors Must be Addressed in Climate Solutions.** Much of the academic and policy carbon abatement work to-date has focused on the electricity sector. Electricity produces, however, only 28 percent of U.S. emissions and is arguably the easiest to decarbonize. Sectoral analyses—electricity, transportation, industry, buildings and agriculture—will be central to identifying solutions and advancing innovation and net zero emissions targets. Reaching economywide emissions reductions targets will require progress in *every* sector of the economy, including those that are difficult to decarbonize due technical, cost and performance barriers.



✓ **Optionality and Flexibility are Needed for Technologies, Policies, and Investments.** There are no clear "silver bullet" solutions to decarbonization at the present time. Multiple clean energy technology options are needed for each sector of the economy and region of the country—this requires technology and policy options and flexibility. Optionality in the energy space is best described as "thinking through the various scenarios that might follow a decision, not just Plan A, and placing appropriate value on possibilities opened-up or shut down by each path… Optionality allows a company to embrace new opportunities first at the margin, but eventually at the heart of operations."[11] An all-of-the-above approach to deep decarbonization is inherent in an approach with maximum optionality and flexibility.

The five core principles of the GRD inform its eight key elements. These include:

✓ **National Technology, Policy, and Business Model Innovation Program Portfolios.** Innovation is at the core of the Green Real Deal. Technology innovation opens new doors to new cost effective decarbonization options, enabling greater ambition and creativity in policymaking. Meeting the decarbonization goals of the GRD requires acceleration of current public and private sector energy innovation programs. The focus of these efforts should be to further reduce the cost of current technologies as well as to pursue aggressive programs focused on technology areas with breakthrough potential to transform the nation's energy systems.

- ✓ **Subnational and Corporate Decarbonization Strategies.** Many states, cities and businesses are developing strategies and action plans to implement their "We are still in" commitments. These efforts could benefit from information-sharing on common issues, such as baseline definition and best practices, as well as external expert reviews to help identify new and creative approaches. This element focuses on techno-economic and policy assessments of the bottom-up multi-sectoral pathways needed to meet challenging decarbonization objectives in the 2030 to 2050 timeframe. This approach builds upon the previous work conducted by EFI on the California Decarbonization study as well as current on-going work.

- ✓ **Social Equity in the Distribution of the Costs and Benefits of Deep Decarbonization.** Transformation of the energy economy will incur cost, but these costs can be minimized through innovation combined with effective policy measures that enhance social equity. Families at lower income levels typically pay a higher proportion of their household budgets on energy than those at higher levels. Innovation in wind and solar energy have led to significant cost reductions, and many energy efficiency measures reduce consumer costs, but many decarbonization measures currently have higher costs, exacerbating the regressive impacts of energy costs. Environmental justice issues also arise in the consideration of the location of new energy infrastructures or the repurposing of existing assets.

- ✓ **Fair and Effective Carbon Pricing** Economywide carbon charges have been advocated by economists as the most cost-effective approach for achieving deep decarbonization. An economywide charge will mobilize market forces to pursue least cost solutions, and also will motivate innovators to develop and provide new solutions. In the near term, it is unlikely that policy makers will support carbon pricing regimes at levels that will induce technology-shifting across all sectors of the economy. This means other policy measures, such as CAFE and low-carbon fuel standards, industrial decarbonization, and CO_2 sequestration tax credits will need to be continued as companion policies. Carbon pricing can work in concert with other policy measures. For example, some states currently have carbon cap-and-trade programs (a form of shadow carbon pricing) in addition to sector specific mandates and incentives. Also, many private sector entities already have included carbon shadow prices in their analysis of long-term investments. While there have been a number of modeling studies on the impact of carbon pricing on decarbonization, several important elements require further examination.

- ✓ **Workforce for a Clean Energy Future** Clean energy innovation, including deployment, has also been important for the creation of U.S. jobs. The U.S. Energy and Employment (USEER) report from January 2019, produced by EFI in partnership with NASEO and BW Research, indicated that in 2018 there were nearly two million workers directly employed in Electric Power Generation and Fuels technologies; 800,000 of them were working in low-carbon emission generation technologies, including renewables, nuclear, and advanced/low-emission natural gas. The greatest increases in this category were in advanced/low-emissions natural gas, wind, and CHP generation jobs, which grew by 7 percent, 3.5 percent, and 7.4 percent, respectively. Energy efficiency jobs, which include design, installation and manufacture of energy efficiency products and services, increased 3.4 percent from 2017 to 2018 with over 2.35 million total jobs in 2018. The transformation of the energy economy will require new workforce skills. To ensure policymakers are doing everything possible and the right things, these trends in job growth need to be understood and analyzed from the perspective of needs, requirements, and the necessary innovation infrastructure to support jobs.

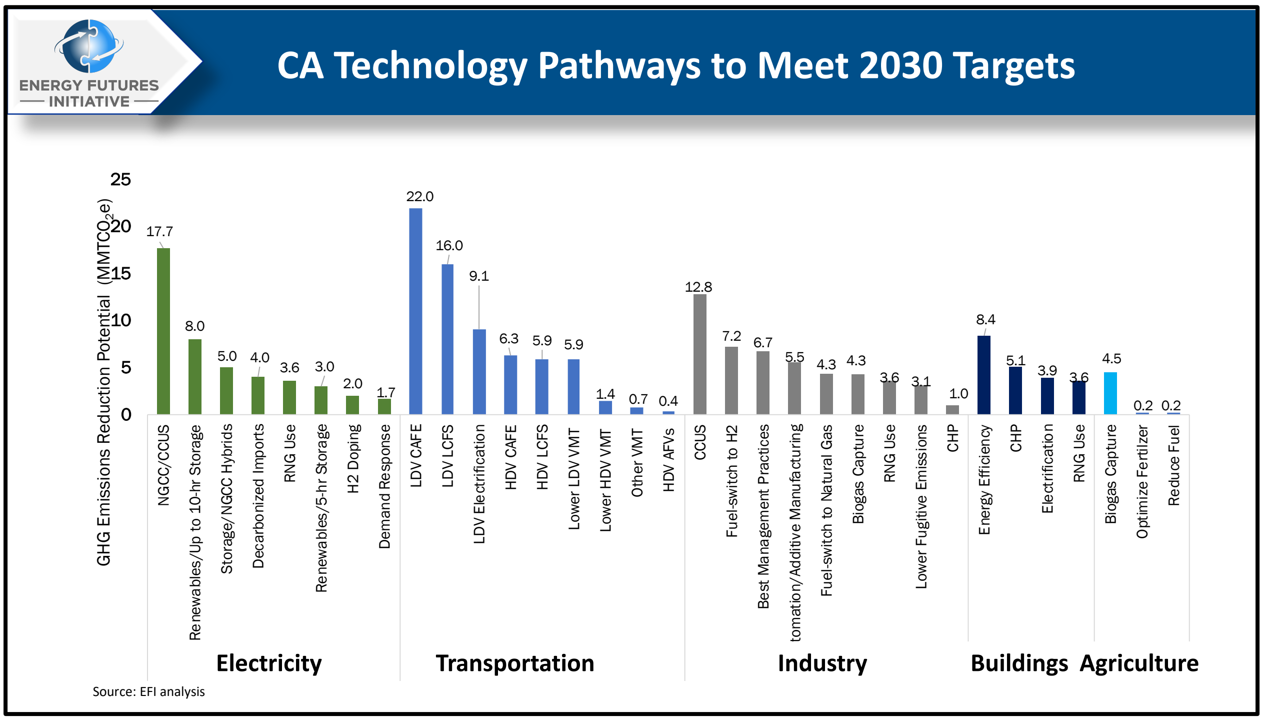
- ✓ **Large-Scale Carbon Management Systems.** The urgent need for action and the transition to a deeply decarbonized economy will likely require the ongoing use of some fossil fuels. Natural gas, in particular, will continue to play for some time an important role in providing dispatchable electric power generation and high-temperature industrial process heat—applications that are not readily amenable to non-fossil fuel options. Carbon capture, utilization and storage (CCUS) opportunities will be needed to enable continued use of natural gas and for high efficiency coal-fired power generation, as well as decarbonizing a number of industrial facilities. CCUS technology solutions are available today, but implementation is limited due to constrained financial incentives under the current 45Q tax credit and long-term uncertainty of compliance with regulatory requirements for carbon sequestration. Climate science is providing increasing evidence for the need to achieve carbon neutrality, which will require measures with negative CO2 emissions. These pathways for carbon dioxide removal (CDR) will involve new technological approaches to remove carbon already in the atmosphere and oceans. There have been several recent studies identifying research needs for CDR, including large scale biological sequestration, and these need to be translated into functional RD&D programs that will be an important element of the technology innovation agenda. The recent EFI report on CDR does this.

- ✓ **Modernized, Innovative and Climate Resilient Energy Infrastructures.** Numerous studies have documented the significant investment needs for modernization of energy and energy-related publicly and privately-owned infrastructures. These estimates primarily focus on the need to replace aging infrastructure while managing the influx of “smart” and connected devices. These requirements are compounded by the need to make energy infrastructure more reliable and more climate resilient. Deployment of new clean energy technologies, such as battery and fuel cell zero-emission vehicles, will require entirely new energy infrastructures for charging and fueling. Widespread deployment of smart and distributed electricity generation and storage systems also will require new infrastructure investment in transactive transmission and distribution systems enabled by digital control systems, and sophisticated energy management systems supported by broadband communication capabilities. Finally, the impact of climate change will require that new infrastructures have enhanced resiliency. Meeting these needs will require substantial increases in investment as well as innovation in the architecture of infrastructure systems.

- ✓ **Sustainable and Secure Clean Energy Technology Supply Chains.** Widespread deployment of clean energy technology solutions will require that those technologies be supported by sustainable and secure supply chains. Critical materials supply chains for new clean energy technologies are emerging as the energy security challenge of the coming decades. Many clean energy technologies, for example, rely upon new or critical materials that may not be readily sourced domestically. According to the World Bank, “Global demand for strategic minerals” such as lithium, graphite and nickel will skyrocket by 965 percent, 383 percent, and 108 percent respectively by 2050.”A 2017 World Bank study of the mineral and metals needed for wind, solar and battery technologies concluded that: “Simply put, a green technology future is [materials] intensive and, if not properly managed, could bely the efforts and policies of supplying countries to meet their objectives of meeting climate and related Sustainable Development Goals."

EFI's California Study Underscores Key Principles and Elements of the Green Real Deal

In June 2019, EFI published a study, *Optionality, Flexibility, and Innovation: Pathways for Deep Decarbonization in California*. The study is not a policy analysis; it assumes California's key policy targets for 2030 and mid-century and, where possible, identifies technology pathways to achieve those targets. Its title underscores key objectives and elements of the Green Real Deal – optionality, flexibility and innovation are all essential for a deeply decarbonized economy.

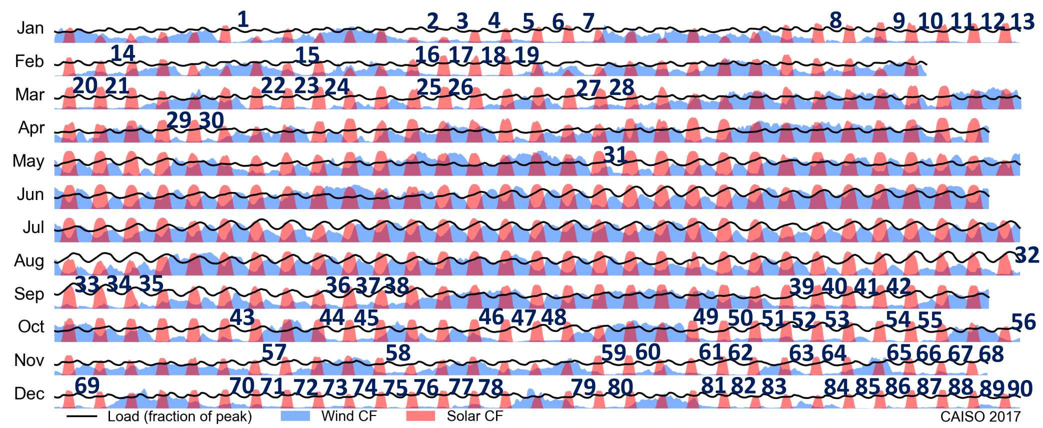


For the 2030 targets (40 percent economywide CO_2e reductions and 60 percent renewable electricity), a comprehensive, sectoral analysis was performed that identified a portfolio of 33 clean energy technology pathways. For context, the 40 percent economywide target calls for a reduction of over 160 million tons of CO_2-equivalent; the figure notes reduction potential in millions of tons. The high-level conclusion is that the target can be reached but only if there is success pretty much across the board. The analysis demonstrates the importance of developing technology options optionality and ensuring sufficient policy flexibility to enable the broadest use of the available options. The single largest pathway for all sectors was CAFÉ standards for light duty vehicles, but the future of these state standards is the subject of a sharp disagreement with the Administration. Certain pathways, such as carbon capture, utilization and storage offer surprisingly large emissions reduction potential in the decadal time frame (roughly 30 million tons) but is not sufficiently supported today in California to be deployed at this scale and pace. To pursue this reduction potential will require prompt action in order to capitalize on the 45Q tax credits.

Analysis concluded that managing and operating a deeply decarbonized electricity system based largely on variable renewables is technically very difficult. A detailed review of the state's regional attributes found that managing California's electric grid even at current levels of intermittent renewables is especially challenging. In 2017, there was a total of 90 days with little-to-no wind and periods where there were 5-10 days in a row with little to no wind generation. Current battery storage technologies are generally for a few hours duration.

Challenges with Integrating Intermittent Renewables

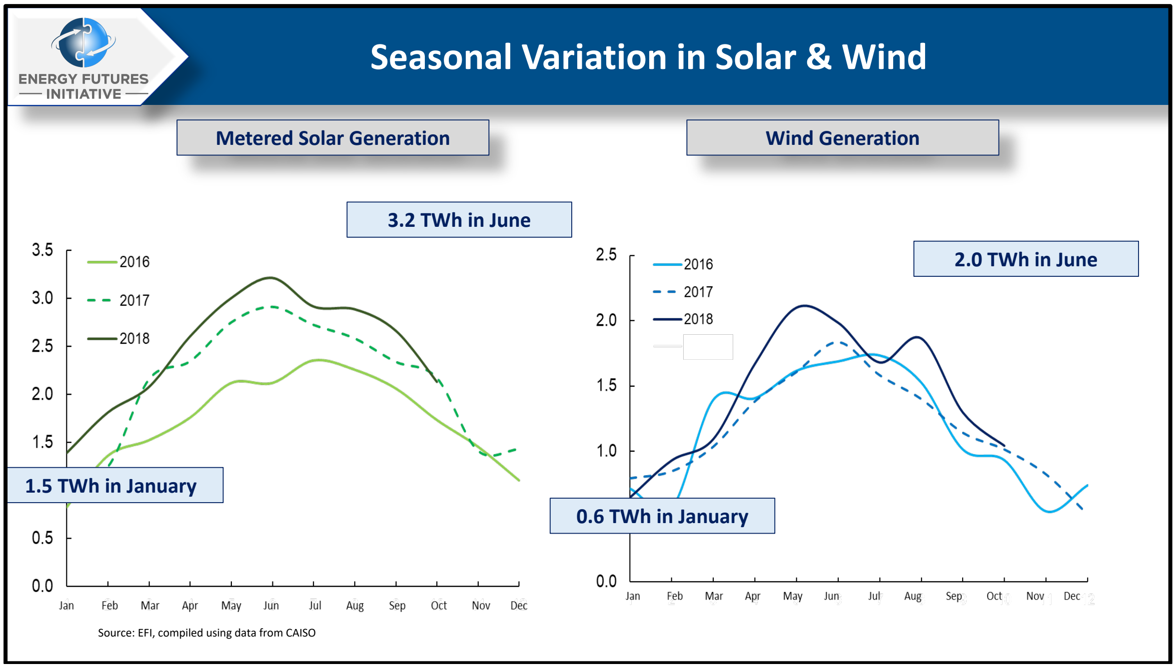
Over the course of a year large-scale dependence on both wind and solar will result in significant periods requiring very large-scale back-up options



Source: CAISO data, EFI analysis

Hourly trends in solar and wind capacity factors in CA for 2017 aligned to normalized variation in hourly load relative to peak daily load

In addition, seasonal variation of both solar and wind results in roughly a factor of two greater resource in the summer compared with the winter. Consequently, if the system becomes dominated by these variable renewables, the problem of practical and economic seasonal storage will need to be addressed. Current energy storage technologies are inadequate to address these weather-related phenomena.



Meeting California's long-term decarbonization targets—including an 80 percent GHG reduction or net-zero by 2050 and carbon-free electricity by 2045—is not possible without breakthrough innovations. In addition to the 33 technology pathways to help meet 2030 targets, the study identified eleven potential breakthrough technologies needed to meet 2050 targets, based on resources, energy system and market needs, and other distinct regional features that help position California as a technological first mover and global leader. The technology priorities identified for California (these will vary by state or region) include hydrogen production from electrolysis, seasonal storage, advanced nuclear, green cement, floating offshore wind, smart cities, and direct air capture, among others. These technologies, and many others with breakthrough potential, must be developed and deployed at scale by midcentury, with investments in innovation that must start today. In particular, a large scale low- to no-carbon hydrogen economy to complement zero-carbon electricity offers a possible solution, but major challenges of cost and infrastructure development will need to be solved. This would be alleviated considerably if CDR can be implemented at scale, as will be discussed below.

The Importance of Energy Innovation

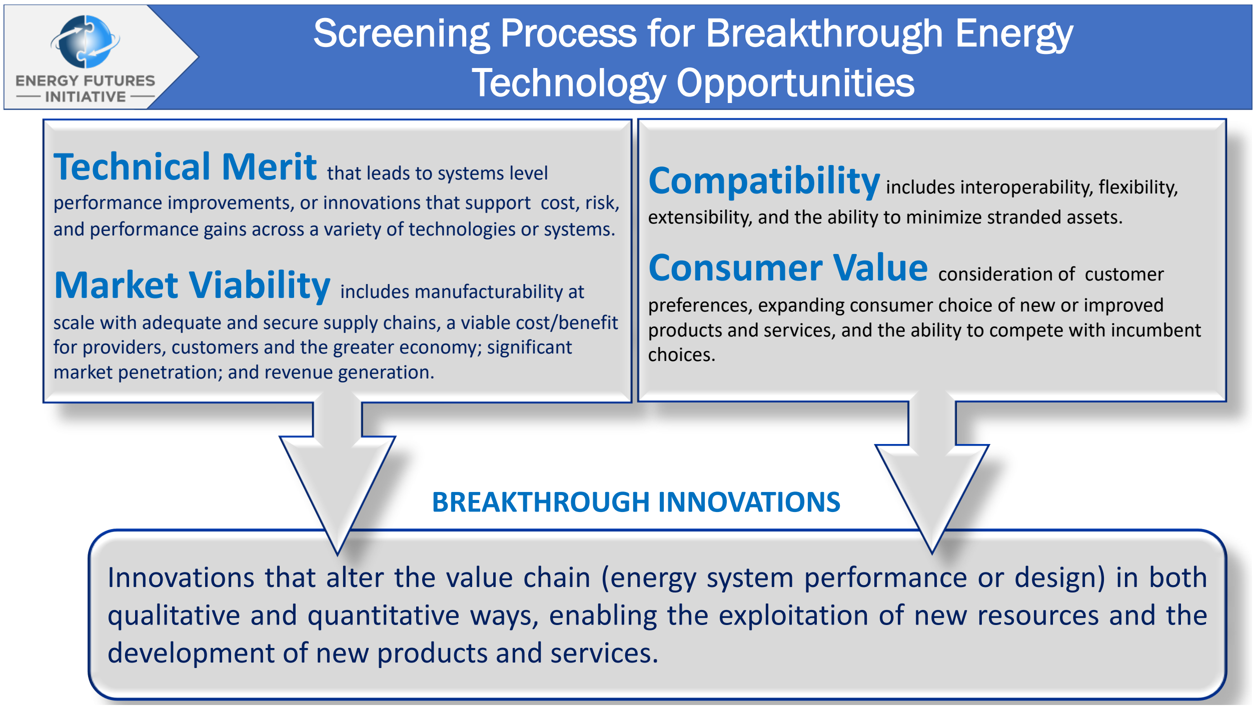
For the past seven decades, the United States has been the global leader in technology and energy innovation. Central to U.S. leadership in innovation is our unparalleled innovation ecosystem, which includes the Federal, state, local and tribal governments; national laboratories; research universities; the private sector; nonprofits and philanthropies. Our ability to innovate is at the heart of American economic success and optimism. Innovation drives job creation, contributes to national security, addresses complex societal challenges and improves our quality of life. U.S. innovation has led not only to new products but also to entirely new industries. The challenges to our leadership in technology innovation are considerable, especially from China, where huge markets present an advantage.

Key Green Real Deal elements are reinforced by the results of another EFI analysis (carried out with IHS Markit), *Advancing the Landscape of Clean Energy Innovation,* which emphasized the need to effectively navigate the technical, economic, regional and social realities of decarbonizing the energy system: the energy system must provide essential services reliably at all times; energy delivery infrastructure must be available, reliable and secure as the system transforms; affordable negative emissions technologies will be important at large-scale for deep decarbonization; and success will require aligning the interests and commitment of a range of key stakeholders. These boundary conditions shaped each clean energy pathway, revealing both opportunities and gaps for future efforts.

A key finding in A*dvancing the Landscape of Clean Energy Innovation* was the emergence of new technologies outside the energy arena that can enable further innovation in energy applications. Technological developments in digitalization, big data analytics, advanced computing, smart systems, additive manufacturing and robotics have opened the door to a potential new wave of innovation in the energy economy. Combined with socio-economic trends in urbanization and flattening of energy demand, they point to new opportunities for energy innovation, for the emergence of new companies and whole new industries in the energy sector, creation of new and better jobs, new consumer services, more cost-effective energy use and a deeply decarbonized 21st century energy economy.

Why More Investment Is Needed

Another key finding of *Advancing the Landscape of Clean Energy Innovation*: the need for increased, and better targeted, public and private sector investment in energy innovation across all stages of the innovation spectrum from fundamental research through commercial scale demonstrations. The report examined more than 100 cutting edge energy technologies, focusing on the candidates with significant breakthrough potential, including: advanced energy storage technologies; advanced nuclear reactor technologies; new approaches to decarbonization of industrial processes; electricity systems modernization with a focus on the role of grid modernization in enabling smart communities; and large scale carbon dioxide utilization and management, including new approaches for carbon dioxide removal from the environment where emissions are not otherwise averted or mitigated.



Concerns about the inadequacy of collective emissions mitigation efforts, a growing body of scientific evidence and current emissions trajectories are reflected in the actions of many foreign governments, including many U.S. states and cities, in their movement towards “net-zero” emissions targets to balance GHG emissions with an equivalent amount of carbon removal and sequestration. The growing number of national, state and subnational entities that have committed to net-zero emissions puts additional pressure on innovators to develop a range of technologies that go beyond the scope of conventional mitigation options, including net negative carbon technology. Such technologies will also make possible, in the long term, a reversal of ever increasing GHG concentrations in the atmosphere, thereby reducing the impact of past actions.

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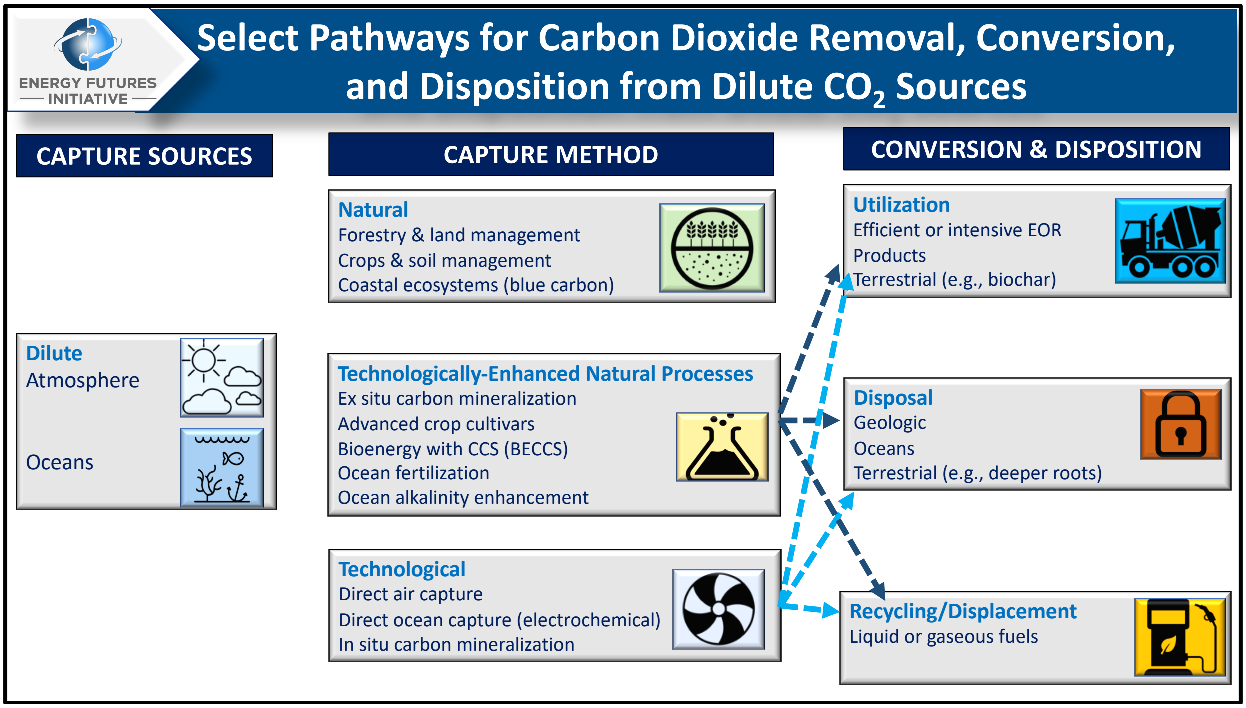
Illustrative Energy Technologies with Breakthrough Potential

- ✓ **Applications for the Difficult to Decarbonize Sectors (Industry, Buildings)**
  - **Hydrogen and Clean Fuels**
  - **Advanced Manufacturing Technologies**
  - **Building Energy Technologies**
- ✓ **Electricity Systems and Smart Cities**
  - **Electric Grid Modernization, Communications, IT and Smart Cities**
  - **Transportation Electrification, Clean Fuels and Systems**
  - **Energy Storage and Battery Technologies**
  - **Advanced Nuclear Reactors**
- ✓ **Deep Decarbonization: Large Scale Carbon Management**
  - **Carbon Capture, Use, and Storage (CCUS) at Scale**
  - **Biological Conversion (Sunlight to Fuels) and Sequestration**
  - **Carbon Dioxide Removal (CDR)**

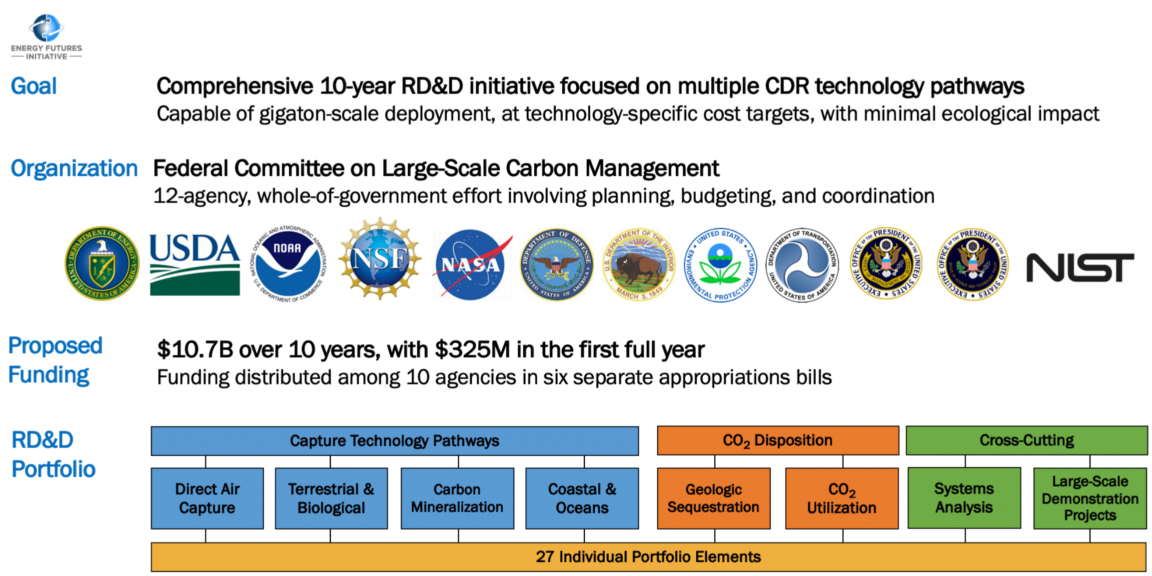
EFI's most recent report, *Clearing the Air: A Federal RD&D Initiative and Management Plan for Carbon Dioxide Removal Technologies,* is an excellent example of how the U.S., particularly the U.S. Department of Energy, can successfully establish an expanded federal research, development, and demonstration (RD&D) program to address climate change. The report provides a set of recommendations and detailed implementation plans for a comprehensive, 10-year, $10.7 billion RD&D initiative in the United States to bring new pathways for technological (including technology-enhanced natural) CDR to commercial readiness. Natural CDR processes, such as tree planting, can also make a substantial impact.

The CDR RD&D initiative encompasses a broad range of technological pathways and technologically-enhanced natural processes that can remove CO_2 from the environment including direct air capture (DAC); technologically-enhanced carbon uptake in trees, plants, and soils; capture and isolation of CO_2 in coastal and deep ocean waters; and carbon mineralization in surface and subsurface rock formations. Geologic sequestration and CO_2 utilization will also be included in the CDR RD&D initiative to provide CO_2 disposition options for CDR pathways such as DAC and bioenergy with carbon capture and sequestration (BECCS).



The wide range of scientific challenges requires a whole-of-government approach that reaches the mission responsibilities and research expertise of 12 federal departments and agencies, with DOE, the Department of Agriculture, and the National Oceanic and Atmospheric Administration playing key roles. The planning, budgeting, execution and performance aspects of the CDR RD&D initiative will require effective coordination led by the Office of Science and Technology Policy and the Office of Management and Budget within the Executive Office of the President. A practical appropriations strategy could be to start with the DOE and USDA portfolios for atmospheric CDR, since these will have the largest resource needs, and then building out the rest of the portfolio over a couple of years.

Overview of CDR RD&D Initiative



The CDR RD&D initiative is proposed to span 10 years and involve multi-agency collaboration and coordination.
Source: EFI, 2019.

At an international level, the CDR RD&D initiative should seek to collaborate with similar efforts in other countries under an expanded Mission Innovation initiative, which was launched at COP21 in 2015.

DOE's Role in Addressing Climate Change

The DOE is the largest single funder of energy R&D and viewed as the steward of the nation's energy technology innovation portfolio. For example, in FY 2016, the Department of Energy administered three-quarters of Federal investment in clean energy innovation.

During my tenure as Secretary from 2013-2017, I advanced clean energy innovation as the cornerstone of our national energy policy. We combined the science and applied energy R&D portfolios under a single Under Secretary for Science and Energy to enable more seamless translation of fundamental science into new energy technologies.

We incorporated innovation into the two installments of the Quadrennial Energy Review, a government-wide effort that integrated the energy-related interests of 22 federal agencies. Congressional action on many of the energy infrastructure recommendations demonstrated the broad appeal of analytically grounded policy development. We also updated the Quadrennial Technology Review into a comprehensive look at the innovation opportunities for guiding and accelerating the energy transition.

We placed particular focus on the role of the DOE National Laboratory system. We created a Laboratory Policy Council to engage the Laboratories in a stronger strategic relationship with Departmental policies and programs, established a Laboratory Operations Board to promote more efficient and effective laboratory operations, created the Office of Technology Transitions to accelerate the transfer of new technologies to the private sector and produced the first State of the National Laboratories report. We analyzed the importance of regional innovation systems and our last budget request sought funding for regional structures. The Undersecretary for Science and Energy had 13 of the 17 national labs under his responsibility; with the cooperation of the Undersecretaries for Nuclear Security (three labs) and for Management and Performance (one lab), he was able to steward cooperation and collaboration across the entire national lab system.

On the international side, DOE led efforts to revamp and modernize the G-7 and European Union Energy Security Principles, which emphasized energy security as a collective responsibility and provided a focus on the importance of clean energy to energy security. It also promoted the role of functioning markets and extensive infrastructure as a key to energy security.

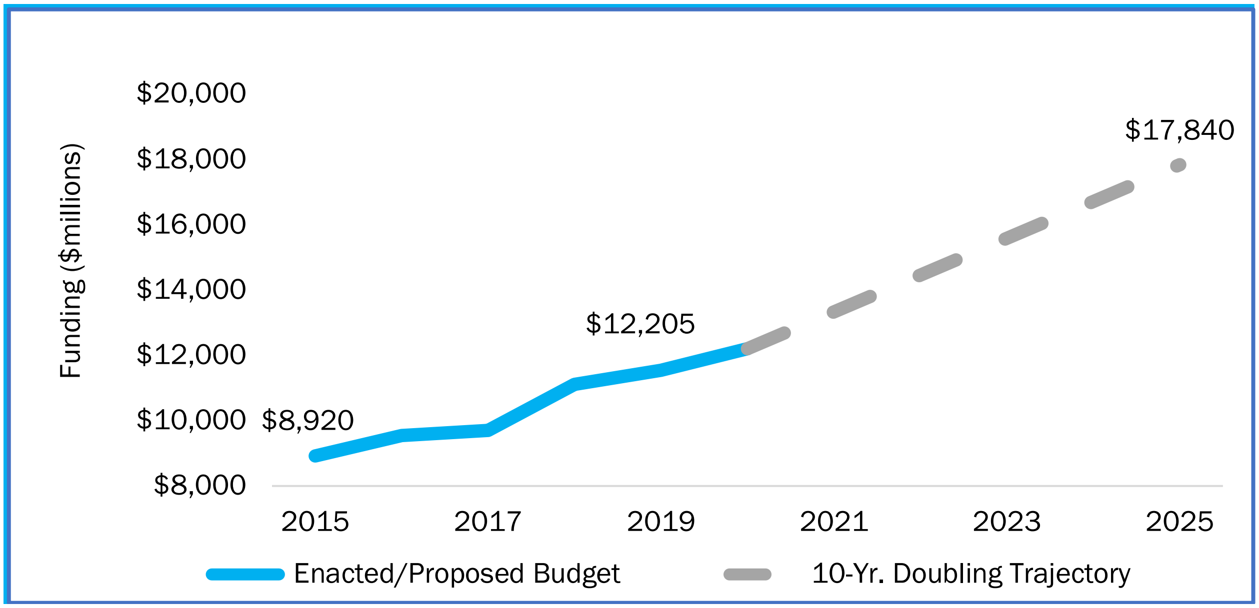
DOE also was in the forefront of the establishment of Mission Innovation, a global initiative started at the 2015 Paris COP21 with leaders of twenty countries committing to double the level of public investment in energy technology innovation over five years. Today, Mission Innovation has 24 countries and the EU. The establishment of Mission Innovation put clean energy technology innovation at the center of global climate solutions.

Another important feature of the Mission Innovation launch was that Bill Gates represented a coalition of wealthy international investors who pledged to invest significant resources in clean energy commercialization, taking advantage of the increased public investments in earlier stage RD&D. The resulting Breakthrough fund has been realized as a parallel activity to Mission Innovation.

Congress has been supportive of increased investment in energy R&D but at a slower pace. Congressional appropriations for the total DOE science and energy R&D program portfolio have increased by 30 percent over the past 5 years, putting the DOE budget on a track to nearly double over 10 years. Achieving the larger step-change in funding to support an accelerated energy innovation program may require augmentation of the current federal annual appropriations process with dedicated funding from new funding sources.

The idea of doubling or tripling the clean energy innovation budget goes back almost a decade. In 2010, the American Energy Innovation Council, composed of prominent CEO's in the US, called for a three-fold increase in its "Business Plan for America's Future". Later that year, the President's Council of Advisors in Science and Technology (PCAST) issued its "Report to the President on Accelerating the Pace of Change in Energy Technologies through an Integrated Federal Energy Policy" reached a similar conclusion. The latter report offered a top-down rationale for the scale of the increase but also emphasized that the innovation portfolio would need to be built bottom up. However, the scale is important for constructing the portfolio. For example, when I was Secretary, the Secretary of Energy Advisory Board (SEAB) analyzed the needs for a DOE program that could properly take an innovative Generation IV nuclear technology through all stages to deployment. They concluded that roughly a billion dollars a year would be needed, an amount that cannot be credibly expended within the current nuclear energy budget but could be with a doubled budget. So that portfolio could look quite different if long range planning to a significantly increased budget could go forward responsibly.

Doubling the DOE Science and Energy R&D Budget



DOE science and energy budget could be on a 10-year doubling trajectory by 2025. Source: EFI, 2019.

As highlighted in *Advancing the Landscape of Clean Energy Innovation*, the process of annual appropriations introduces large uncertainties into the process of planning and executing the energy innovation portfolio, due to the uncertainties and delays associated with annual budget cap negotiations and the resulting dependence on stop-gap and sometimes longer Continuing Resolutions. Large swings in year-on-year President's budget requests and funding—evidencing an underlying lack of a consensus on innovation policy—is also a significant factor leading to inefficiencies in the way Federal energy R&D funds are deployed. Continuing Resolutions inherently impede innovation portfolio development.

While Congress likely will continue to rely on the annual appropriations process to fund energy innovation, there are alternative funding models that can supplement this process to increase the pace of investment in energy innovation and achieve better innovation performance than likely would have been attained if funded through annual appropriations alone.

One approach is to supplement annual appropriations with advance appropriations to provide funding certainty for large, multi-year projects. The DOE Clean Coal Technology Program in the 1980s and 1990s, for example, was funded through advance appropriations that automatically became available in future fiscal years. This led to greater certainty in cost-sharing arrangements and more successful demonstration project outcomes. The practice of advanced appropriations has since been prohibited by Congress, except in a few grandfathered circumstances.

Another approach is to earmark specific revenue streams as an offset to appropriations, so that the net appropriation is not scored against appropriation caps. In 2015, Congress authorized a special funding mechanism for modernization of the Strategic Petroleum Reserve (SPR). The Bipartisan Budget Act of 2015 authorized annual appropriations totaling $2 billion for SPR modernization, offset by the sale of SPR oil.

While annual funding levels are set in appropriations acts, the use of a dedicated offset isolates the program from the uncertainties and constraints of the non-defense discretionary caps. This mechanism has been successfully implemented over the past three years, and I note that it is again included in the pending FY 2020 appropriations bills.

A similar mechanism was authorized by Congress in 2005 for The Ultra Deepwater and Unconventional Natural Gas and Other Petroleum Fund. This fund was not only financed solely from a set aside of federal oil and natural gas royalties, it also was not subject to annual appropriations, although Congress exercised oversight through review of the annual program plan. Because the research program was intended to provide new technologies to expand natural gas and petroleum production from Federal lands, it offered the possibility to eventually become self-sustaining.

Another approach is for Congress to authorize appropriations outside of the discretionary spending caps. In 2016, Congress enacted the 21st Century Cures Act, which sought to increase funding for NIH research programs by authorizing an increment of annual appropriations totaling $4.8 billion over 10 years, outside of the discretionary spending caps. The funds were intended to increase the level of annual funding normally appropriated to NIH. To comply with budget scoring rules, the new funding (outside the cap) was offset by the sale of oil from the SPR.

Finally, Congress may wish to consider providing a stable source of funding to supplement annual appropriations through the establishment of new user charge. One possible approach would be to institute a national public benefits charge on electricity, implemented through some form of "wires charge" or upstream charge on fuels for electricity. Several states currently use public benefits charges as a mechanism to accelerate deployment of innovative technologies. Another model that could be considered would be a non-governmental entity to manage the R&D program or a "all-of-the-above" demonstration project program but funded through a governmentally controlled charge. The Gas Research Institute (GRI) and the Electric Power Research Institute (EPRI) provide examples of R&D funding approved by Federal and state regulators, respectively:

- GRI was a non-profit, non-governmental entity established by the natural gas industry in 1976. It was funded by a mandatory surcharge placed by the Federal Energy Regulatory Commission on natural gas volumes in interstate commerce. At its peak annual funding level in the early 1990s, the GRI annual budget was more than $200 million, financed by a surcharge of about 1.5 cents per thousand cubic feet of gas transported by interstate pipeline companies. The mandatory surcharge was phased out over a seven-year period by FERC beginning in 1998. The Gas Technology Institute (GTI) is the successor organization to GRI and is currently funded from voluntary contributions from natural gas utilities. GTI revenues totaled $103 million in 2016.

- EPRI is a non-profit, non-governmental entity established by the electric power industry in 1973. It was originally funded through a voluntary charge placed on sales revenues and approved by state public utility commissions. The suggested charge was 0.1 mills per kilowatt-hour (kWh) of electricity. EPRI restructured its program around 2000 to a business model that was project-based, with voluntary cost sharing from interested companies on a project-by-project basis. Revenues in 2015 totaled approximately $407 million. Based on the prior charge regime, in 2016

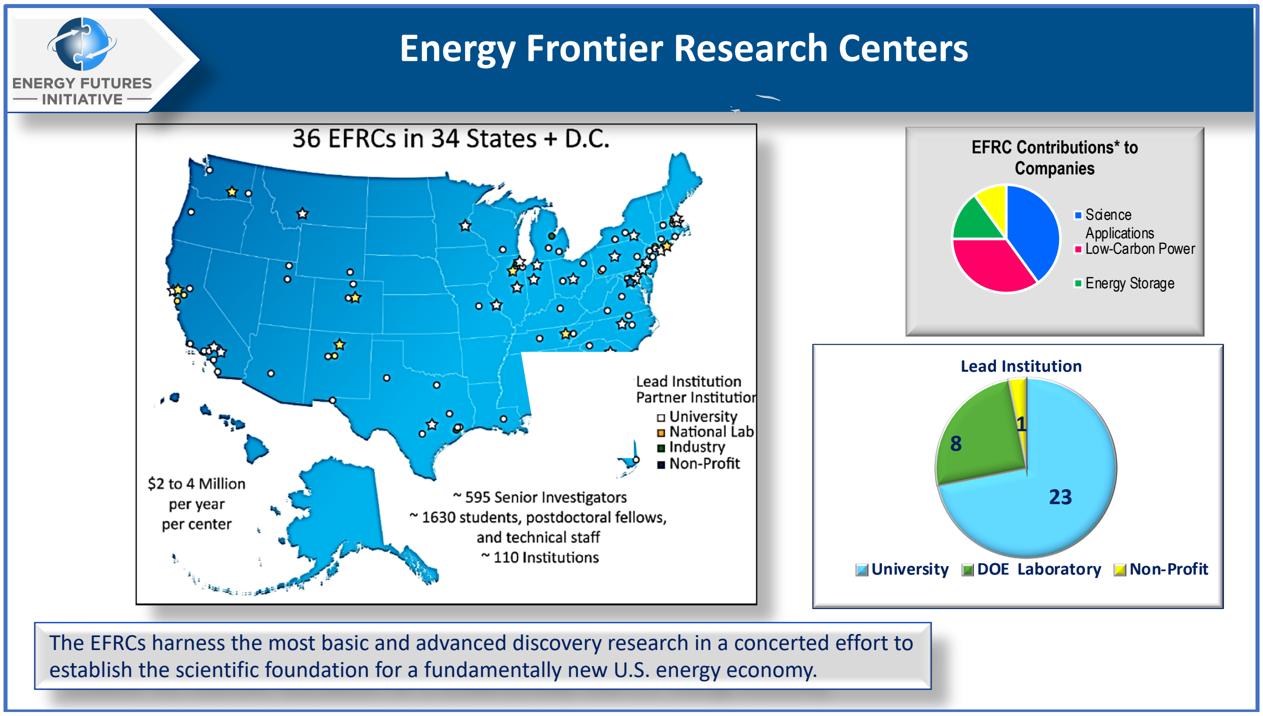
EPRI's budget would have been $3.76 billion, if 0.1 mills had been collected for every kWh consumed at retail nationwide.

Movement toward a more assured funding structure for energy innovation could provide a significant boost to the pace and effectiveness of the innovation process. Such a structure could supplement current annual appropriations to accelerate the pace of energy innovation investment, while retaining a comparable degree of Congressional oversight. Much work would need to be done to develop a new funding mechanism that would be supported by stakeholders and acceptable under current budget scoring rules.

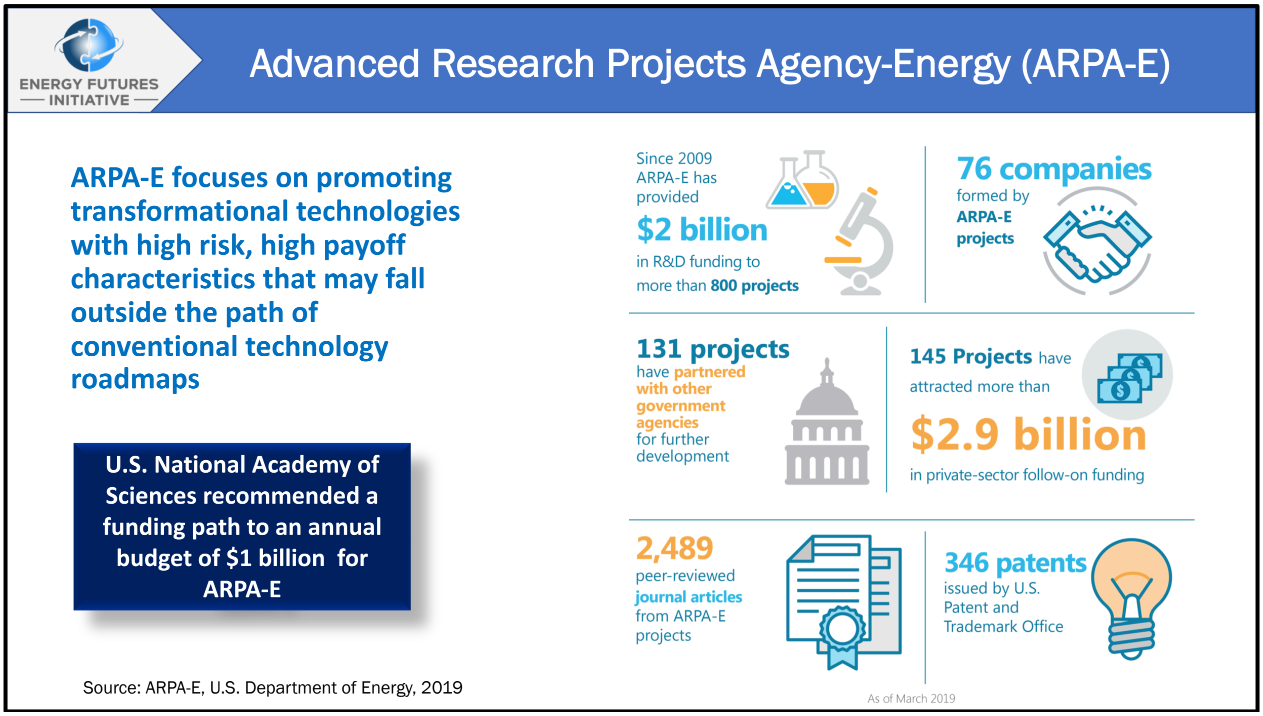
Energy Innovation Investments Have Reduced the Costs of Clean Energy Technologies

Breakthrough innovations generally take decades of support from multiple stakeholders along the innovation chain. The DOE has long sponsored R&D of breakthrough technologies, such as solar photovoltaics and hydraulic fracturing of oil and gas resources.

Hydraulic fracturing technology also began with decades of R&D linked to DOE. In 1975, a DOE-industry joint venture drilled the first Appalachian Basin directional wells to tap shale gas. Between 1978 and 1992, DOE invested about $137 million in the Eastern Gas Shale Program to help demonstrate and commercialize many of the technologies in use today, including directional drilling, micro-seismic monitoring and hydraulic fracturing treatments, and modeling.[12.] GRI, working with companies, carried out essential demonstration projects, and Congress supported the effort through a time-limited tax incentive. Years of sharing knowledge and resources along the energy innovation chain made the "shale revolution" possible.



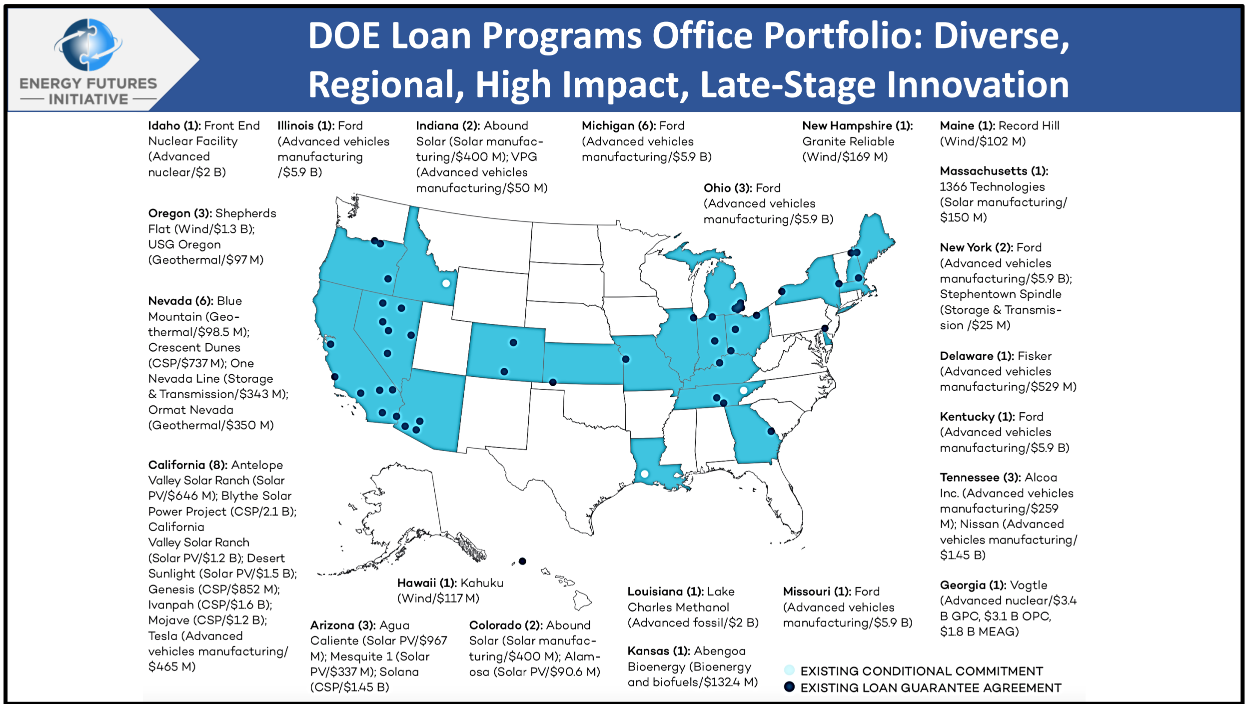
DOE continues to have impact along the innovation chain. At the basic research level, in addition to providing key tools for the American research community (such as synchrotron light sources and neutron sources for advanced materials research), the Department established a set of Energy Research Frontier Centers (EFRC). These are typically $2-4M/year, multi-investigator centers focused on one of the breakthrough science challenges that need to be met for innovative energy technology development. The challenges were defined through an exemplary community process organized by the DOE Basic Energy Sciences office during the George W. Bush administration, and then the program was implemented early in the Obama administration. The majority of the 36 centers (in 34 states and DC) are at universities. Budget constraints have decreased the number of EFRC's since their establishment, since about a third of the original funding was from the one-time American Recovery and Reinvestment Act of 2009. The scale of the program deserves revisiting.



The Energy Advanced Research Projects Agency (ARPA-E) focuses on promoting transformational technologies with high risk, high payoff characteristics that often fall outside the path of conventional technology roadmaps, bridging the gap between the university and national lab work on basic science and DOE's programs that support pilot and commercial scale projects. Between 2009 and 2017, ARPA-E supported technologies have set global efficiency records and raised substantial private investor funding for startup companies. In 2017, the National Academies of Sciences, Engineering and Medicine conducted an assessment[13] of ARPA-E, noting that:

> ARPA-E is in many cases successfully enhancing the economic and energy security of the United States by funding transformational activities, white space (technology areas that are novel or underexplored and unlikely to be addressed by the private sector or by other federal research programs), and feasibility studies to open up new technological directions and evaluate the technical merit of potential directions.[14]

The DOE Loan Programs address the opposite end of the technology innovation roadmap—late stage innovation.



As noted in *Advancing the Landscape of Clean Energy Innovation*, the Loan Programs Office (LPO) was instrumental in seeding the U.S. utility scale photovoltaic (PV) market. In 2009, there were only 22 megawatts (MW) of installed utility-scale PV capacity domestically, and the U.S. Energy Information Administration (EIA) forecast only 126 MW of total utility-scale PV solar capacity to be installed by 2015. Solar developers were unable to secure the necessary financing for construction of large projects, even with firm offtake contracts and substantial equity in hand.

In 2011, LPO provided more than $4.6 billion in loan guarantees to support the first five utility-scale solar PV facilities larger than 100 MW.[15] Since then, the private sector has taken over, financing 590 new utility-scale PV projects by the end of 2017.[16] By the end of 2018 there were over 30,400 MW of solar PV capacity installed at utility scale, an increase of more than 1,900% since 2011.[17] Many of the banks that financed these projects, such as John Hancock, Bank of America, and Citigroup, were banks that worked with LPO through the Financial Institution Partnership Program (FIPP) in financing the first five utility-scale PV projects.[18] The launch of the domestic utility-scale PV industry demonstrates the critical role LPO plays in reducing risk for innovative technologies and creating a financing model that can be adopted by the private sector.

Again, the key point is that DOE has and does play a very important role in the entire U.S. energy science and technology innovation system. A multiplier effect is the large number of students and young researchers and entrepreneurs who got their start through DOE programs and have gone on to be the backbone of the American innovation enterprise.

Conclusion

The threats posed by climate change, and the resulting need to decarbonize the economy, create even more urgency for the U.S. to rapidly expand and accelerate its efforts in clean energy innovation. The growing intensity and frequency of floods, hurricanes, and droughts across the country and world have underscored the moral, economic, social and environmental imperatives of addressing climate change. As such, the country is becoming increasingly aligned on the need for action, especially as global greenhouse gas emissions continue to increase. Economywide decarbonization will likely depend on multiple technology breakthroughs that address key issues in the energy sector. The time is here and now for the U.S. to step up as the global leader in clean energy innovation by leveraging the full potential of its innovation ecosystem.

Chairwoman Kaptur, Ranking Member Simpson and Members of the House Appropriations Subcommittee on Energy and Water Development, thank you for the opportunity to appear before you today to discuss the imperatives of climate change and the importance of clean energy innovation. I look forward to your questions.

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