ITIF | INFORMATION TECHNOLOGY & INNOVATION FOUNDATION

Information Technology and Innovation Foundation

Response to the
House Select Committee on the Climate Crisis

Request for Input on Key Considerations for U.S. Climate Policy

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700 K STREET NW | SUITE 600 | WASHINGTON, DC 20001
MAIL@ITIF.ORG | (202) 449-1351

INTRODUCTION

Thank you for the opportunity to provide input on key considerations for U.S. climate policy. The Information Technology and Innovation Foundation (ITIF) is a non-profit, non-partisan research and educational institute focusing on the intersection of technological innovation and public policy. ITIF's mission is to formulate and promote policy solutions that accelerate innovation and boost productivity to spur growth, opportunity, and progress. Innovation is central to addressing global climate change while increasing economic growth, boosting international competitiveness, and eliminating energy poverty. ITIF research in clean energy focuses on policies to encourage innovative energy research, development, demonstration, and deployment; clean-tech trade; and clean energy manufacturing.

ITIF previously provided comments in response to the House Energy and Commerce Committee's request for input as they develop policies to reduce U.S. greenhouse gas emissions to zero by 2050. We believe the principles and recommendations from our comments would also be useful to the House Select Committee on the Climate Crisis as it seeks to identify a broader set of policy tools—across a wider range of committee jurisdictions—for mitigating greenhouse gas emissions by accelerating clean energy innovation, and provide a brief summary of key principles for developing comprehensive climate policy below:[1]

1. Climate change is a global challenge that requires global action. That action will remain limited until clean energy is less costly and as reliable as carbon-intensive energy. U.S. climate policy should mobilize America's innovation system and lead other nations in developing clean energy systems that are cheaper and better than dirty ones.
2. Today's technologies are not sufficient to serve as the infrastructure of a low-carbon energy economy. Energy innovation should be a central pillar of U.S. climate policy.
3. Comprehensive climate policy should cover all sources of emissions and all sectors of the economy.
4. Markets will not produce the needed level of innovation on their own. Government must invest in clean energy innovation as well as create conditions under which firms will innovate.
5. Complement "supply-push" policies with "demand-pull" policies. "Demand-pull" policies such as government procurement and time-limited tax incentives that increase market demand for nascent clean technologies are valuable complements to the technology "supply-push" provided by federal research, development, and demonstration (RD&D) investments.
6. Invest in innovation at a scale that is commensurate with the climate challenge.
7. Congress should adopt a technology-inclusive portfolio approach to climate policy in order to manage risks and uncertainty.

These principles lead us to one overarching recommendation, which informs our response to all the questions:

- **All climate policy should be viewed through an innovation lens**. Energy innovation must be a central pillar of U.S. climate policy. An innovation agenda should lower the costs and improve the performance of existing clean technologies, and develop new clean energy options that address innovation challenges in harder-to-decarbonize sectors. But there is a tendency to equate innovation policy with research and development (R&D). In fact, all policy has the potential to accelerate or deter innovation. Technology-prescriptive codes and standards lock in incumbent technologies while reducing the incentive to innovate, whereas performance-based codes and standards open the door to new technologies. Tax incentives can create early niche markets that help pull technologies down the learning curve, but poorly designed incentives that last too long can subsidize deployment of mature technologies while freezing out further innovation. An innovation lens can avoid the negative consequences of otherwise well-intentioned policy, while accelerating innovation and enabling the adoption of new technologies. An innovation agenda should also encourage business-model and regulatory innovation that complements technological innovation.

The remainder of the comments focus on the innovation & competitiveness aspects in each of the policy areas outlined by the Committee.

SECTOR-SPECIFIC POLICIES

1. What policies should Congress adopt to decarbonize the following sectors consistent with meeting or exceeding net-zero emissions by mid-century? Where possible, please provide analytical support that demonstrates that the recommended policies achieve the goal.

a. Transportation

Light-Duty Vehicles

Recommendation 1: Significantly increase government RD&D funding for clean transportation technologies. Key focus areas include next-generation batteries with improved performance and lower costs than the dominant lithium-ion batteries in use today, fuel cell power systems, electric drivetrains, fast-charging systems, and vehicle-grid integration. These programs should set ambitious targets, rather than the business-as-usual targets that have too often been adopted in recent years. As technologies such as conventional lithium-ion batteries have achieved a critical mass of support from private R&D funders and are approaching the limits of technological performance, federal programs should focus on next-generation battery chemistries.[2] The Department of Defense, along with the Departments of Energy and Transportation, should play an important role in programs advancing key technologies, such as fuel cells and wide bandgap semiconductors for power electronics.[3]

Recommendation 2: Lift the per-manufacturer cap on the tax credit for electric vehicles and allow the credit to be carried forward by taxpayers. Electric vehicles powered by lithium-ion batteries are poised to become cost-competitive with conventional vehicles within the next decade. Tax credits will accelerate their progress through the takeoff stage and nurture a virtuous cycle between deployment and privately funded innovation. The current incentive structure penalizes innovators and early movers like Tesla and General Motors, which have already reached the current cap of 200,000 vehicles. It also limits opportunities for low-income households that have a federal tax liability in any single year that is less than the amount of the credit to benefit from it.[4]

Recommendation 3: Raise the gas tax. The gas tax increases the price of high-carbon fuels relative to low- and zero-carbon fuels, encouraging drivers to adopt low- or zero-carbon options. Very low fuel taxes strengthen dependence on petroleum-powered vehicles, whereas the transition to electric vehicles is eased when fuel taxes make them more attractive options. The United States has among the lowest fuel taxes in the world, which could lead to a situation in which America lags behind other nations in the transition to zero emissions vehicles.[5] Raising fuel taxes will accelerate the transition to zero emissions vehicles, as well as reduce the Highway Trust Fund deficit.

Recommendation 4: Establish a national initiative on energy storage involving multiple federal agencies, states, the private sector, and academia. Batteries that are non-flammable, rely on abundant materials, provide 500 miles or more travel on a charge, last for at least a decade, and are easily recharged and recycled, will make electric vehicles far more attractive to U.S. consumers. The development of such batteries, along with a variety of other energy storage technologies, would also contribute to the achievement of clean energy goals in the electricity and industrial sectors. The proposed initiative should be modeled on past successes, such as the human genome and nanotechnology initiatives. Although the global race to advance energy storage technology is intense, the United States possesses many strengths that would allow its effort to succeed, such as outstanding research capabilities at universities and national laboratories, a vibrant start-up scene, and a strong industrial sector.[6] However, the U.S. should learn from past mistakes (such as solar) where it led in innovation only to have China capture the lion's share of production, mostly through unfair mercantilist means.[7]

Recommendation 5: Support the domestic auto manufacturing industry as it transitions to low- and zero-emission vehicle production. The auto industry is the largest U.S. manufacturing sector, directly employing about one million workers and indirectly some five to seven times that many. The clean transportation transition will have a significant impact on domestic auto employment, shifting the skills demanded and probably reducing the number of production jobs. The transition could also disrupt the global balance of trade and investment in this sector, as China, Germany, and other foreign producers seek to seize competitive advantage, with assistance from government policy. The federal government must ensure that domestic producers have the resources to sustain their competitiveness and the incentives to stay at the cutting edge of innovation, utilizing policy tools like loan guarantees and public procurement, within the constraints of a rules-based global trade and investment regime.[8]

Recommendation 6: Provide financial and technical assistance to states and localities as they deploy charging infrastructure, integrate electric vehicles with distribution grids, and undertake regulatory reforms. Charging electric vehicles on a large scale will create new patterns of electricity demand. These new patterns could be disruptive, especially in residential areas, but they also create opportunities for much-needed flexibility. With appropriate infrastructure and incentives, EV batteries could charge and discharge in response to variability in other resources, such as solar and wind power, balancing the grid and making it more reliable. Because each local and regional grid is unique, the federal government has an important role to play in developing generic solutions, sharing lessons, and strengthening the capabilities of state and local agencies.[9]

Recommendation 7: Tighten vehicle greenhouse gas emissions standards in a predictable, innovation-inducing manner. A full transition to zero-emission vehicles will be necessary over the long-term, but tighter emissions standards over the intermediate-term can reduce cumulative emissions along the path and accelerate the transition. Such standards should be performance-based, developed through an open exchange of information with industry, set with substantial lead time, and firmly adhered to and enforced. They should also include incentives for going beyond the standard, such as multipliers that reward companies disproportionately for deploying innovations such as zero-emission vehicles.[10]

Hard-to-Electrify transportation: long-distance road transport, aviation, and shipping

Recommendation 8: Create new RD&D programs for hard-to-electrify transportation sectors, including aviation, shipping, and long-distance road transport. These programs should focus on developing carbon-neutral fuels—including clean hydrogen, ammonia, synthetic hydrocarbons, and advanced biofuels—that are cost-competitive with conventional petroleum-based fuels. ITIF has developed the following recommendations to accelerate innovation in carbon-neutral fuels:[11]

- Establish an innovation hub focused on hydrogen and ammonia production methods that do not use fossil fuels as feedstock.
- Expand R&D into applications of hydrogen and other carbon-neutral fuels in hard-to-electrify transportation sectors, including aviation, shipping, and long-haul trucking.
- Implement the recommendations from the recommendations from the recent National Academies report on carbon utilization that focus on chemical and biological pathways for the conversion of carbon dioxide into fuels and chemicals.

b. Electric power. The Select Committee would like policy ideas across the electricity sector:

Recommendation 9: Expand research, development, and demonstration (RD&D) programs in "firm" low carbon dispatchable electricity generation. Firm electricity refers to electricity that can be generated and dispatched as needed in all seasons and over periods of weeks or longer, and ITIF analysis has identified firm low-carbon electricity as one of six key harder-to-decarbonize sectors.[12] Maintaining reliable grid operations will require new, low-carbon suppliers of firm, dispatchable electricity. Options include long-duration energy storage that can store large quantities of electricity on weekly and seasonal timescales; nuclear power plants that are operated flexibly; and fossil fuel power plants equipped with CCUS technologies. ITIF makes the following recommendations to advance innovation in firm, low-carbon electricity:[13]

Advanced Nuclear Energy:

- Re-prioritize DOE's Office of Nuclear Energy (NE) to focus on advanced nuclear reactor technologies, and commit to the demonstration of at least one advanced reactor design.
- Expand linkages between basic science research in the DOE Office of Basic Energy Sciences and National Science Foundation, and the applied RD&D at the NE and Department of Defense.

- Commit to constructing the Versatile Test Reactor to enable testing of materials and fuel designs in a fast neutron environment.
- Develop a domestic supply of high-assay, low-enriched uranium (HA-LEU) that is compatible with fueling requirements for advanced reactor concepts.

Long-Duration Grid Storage

- Establish a second innovation hub modeled on Joint Center for Energy Storage Research (JCESR) to pursue science and technology for long-duration grid storage.
- Expand investments by DOE's applied energy offices and ARPA-E in grid storage RD&D, and focus them on long-duration problems.
- Expand DOE funding for long-duration grid storage technology demonstration projects in partnership with other stakeholders, and maintain funding for the new Grid Storage Launchpad.
- Establish an interagency working group on long-duration grid storage within the National Science and Technology Council (NSTC) to facilitate interagency information exchange and coordination.
- Propose and lead a new innovation challenge on long-duration grid storage within the international Mission Innovation framework.

Carbon Capture, Utilization, and Storage (CCUS)

- Establish a carbon capture demonstration program that funds first-of-a-kind demonstration projects for carbon capture at natural gas power plants and other industrial sources of carbon dioxide.
- Establish a single carbon capture R&D program—outside the coal program office—that includes carbon sources across all sectors, including natural gas and industrial sources.
- Expand the carbon utilization R&D program to address the research needs identified in the National Academies report on carbon utilization.
- Continue to support R&D and demonstration in geologic storage in saline aquifers and depleted oil and gas fields, and expand storage R&D to include basalt and other carbon-absorbing mineral formations.

i. If you recommend a Clean Energy Standard, how should it be designed?

Recommendation 10: A Clean Electricity Standard (CES) should be inclusive of all low-carbon technologies, with carve-outs for emerging technologies—such as non-crystalline silicon solar PV, concentrating solar power (CSP), off-shore wind power, and other nascent technologies—that decline as technologies approach maturity. A CES is a flexible, market-based policy designed to increase the share of electricity sales met from clean energy sources. Typically, a CES sets a target for electricity sales from clean generation—e.g., by 2030, 50 percent of electricity sales must be met via clean electricity sources.[14] In that sense, a CES is similar to state renewable portfolio standards (RPS), with the distinction that a CES is generally inclusive of a broader set of clean electricity generation, including renewables, nuclear power, and fossil fuels with carbon capture and storage. If Congress pursues a CES as a means of reducing emissions from the power sector, ITIF recommends that Congress:

- **Use a performance-based emissions standard**, in order to provide maximum flexibility and allow a broad range of clean energy sources to qualify. Technology-prescriptive standards that specify which technologies are allowed for compliance inhibit innovation and are generally more costly. ITIF assessment of regulatory design has found performance standards are more likely to induce regulated firms to both innovate themselves and adopt innovations developed elsewhere.[15]
- **Provide carve-outs for emerging technologies that decline as technologies approach maturity**. When state RPSs were first enacted, they historically favored the development of wind energy, because wind had the lowest cost and was closest to being competitive with conventional energy sources. When faced with a mandate to provide clean energy, firms will focus their innovative efforts on the technologies that are already closest to market.[16] A critical component of many early state renewable portfolio standards was a solar carve-out that set specific targets for solar, providing an additional level of policy support without which solar would have been wiped out by wind in the state renewable energy credit market. In order to avoid technology lock-in and stimulate innovation across a broader range of technologies, we recommend carveouts that provide additional market support for innovative technologies that are further from commercialization, including thin-film solar PV, concentrating solar power (CSP), off-shore wind power, and other nascent technologies. As technologies mature, this additional policy support should phase out.

c. Industry

Recommendation 11: Expand the mandate of DOE's Advanced Manufacturing Office (AMO) to include decarbonization. AMO is currently the only RD&D program within DOE that focuses on the industrial sector, but its actions are focused primarily on reducing the energy intensity of manufacturing. For example, it has produced a series of "energy bandwidth" studies across 16 industrial sectors that identify energy efficiency opportunities across each sector.[17] Congress should expand AMOs mandate to encompass all decarbonization opportunities, including energy efficiency as well as fuel switching to low-carbon fuels and carbon capture.

Recommendation 12: Increase investment in industrial RD&D programs, particularly in DOE's Advanced Manufacturing Office (AMO). The industrial sector accounts for 22 percent of direct U.S. greenhouse gas emissions, but AMO accounts for only 6 percent of DOE's total applied energy RD&D investments.[18]

Recommendation 13: New funding (Recommendation 12) for industrial RD&D should address harder-to-abate sectors, including cement, steel, and chemicals. Congress should direct DOE to establish new RD&D programs that focus on decarbonization challenges in the industrial sector, especially for crosscutting challenges such as process emissions from chemical transformations and high-temperature heat.

Recommendation 13a: Establish a carbon capture RD&D program for industrial sectors. Industrial "process" or "feedstock" emissions result directly from chemical transformations and are independent of the source of energy used to drive the process. For example, the calcination of limestone to make cement releases carbon dioxide directly, regardless of the source of energy used. Carbon capture, utilization, and storage (CCUS) may be the only option for mitigating these types of process emissions. But DOE's CCUS program is situated in the Clean Coal program office, and focuses primarily on carbon capture from coal-fired power plants. Congress should direct DOE to establish a single carbon capture research and development (R&D) program—outside the coal program office—that includes emissions sources across all sectors, including power plants, cement, iron and steel, ethanol, ammonia, and other large sectors. And Congress should establish a carbon capture demonstration program that funds first-of-a-kind demonstration projects in each of these sectors.[19]

Recommendation 13b: Expand RD&D into the use of carbon-neutral fuels—including hydrogen—to provide high-temperature heat for industrial processes. Carbon-neutral fuels (CNFs), such as electrolytic hydrogen produced from renewable electricity, are a promising substitute for unabated fossil fuels in the provision of high-temperature heat. DOE's current Hydrogen and Fuel Cells Technologies Office (FCTO) focuses primarily on production of hydrogen for applications in transportation systems. DOE's program should be broadened to include industrial applications of CNFs, including combustion to provide high-temperature heat for industrial processes, and should also be expanded beyond hydrogen to include other carbon-neutral fuels such as ammonia and synthetic hydrocarbons.[20]

Recommendation 13c: Expand RD&D into industrial applications for nuclear energy, such as providing process heat or producing carbon-neutral fuels. The use of nuclear energy to provide other energy services (than electricity), such as industrial process heat, hydrogen production, or water desalination will require additional innovation and tighter integration with energy end uses.[21]

Recommendation 14: Congress should explore expanding DOE's authority to set innovation-inducing energy efficiency standards for industrial processes. An ITIF assessment of environmental regulations finds that energy efficiency standards that are consistent and credible, performance-based (rather than technology-prescriptive), and become increasingly stringent over time induce greater innovation in the regulated industry.[22] Congress first required DOE to set minimum energy conservation standards in the Energy Policy and Conservation Act of 1975, and this legislation has been updated several times, most recently in 2007, as the number and type of energy-consuming products and processes has evolved.[23] However, industrial processes comprise a large gap in DOE's ability to improve energy conservation, as DOE currently sets standards that account for only 30 percent of industrial energy use.[24] The National Academies of Sciences, Engineering, and Medicine (NASEM) is currently reviewing DOE's efficiency standards program.[25] As part of its review, NASEM should examine the 70 percent of industrial energy consumption that is outside the scope of DOE's existing standards program, and make recommendations to Congress to expand DOE's authority over industrial processes.

d. Buildings

Recommendation 15: Expand investment in building technologies RD&D to improve the efficiency and reduce the energy costs of the nation's residential and commercial buildings and energy-consuming products and services. Residential and commercial buildings are the single largest energy-consuming sector in the U.S. economy, accounting for roughly 75 percent of the nation's electricity use and 40 percent of its total energy demand.[26] But in FY 2019, Congress invested only $176 million in RD&D to reduce energy consumption and carbon emissions from the buildings sector through the DOE Building Technologies Office (BTO), about 4 percent of the total applied energy RD&D budget.[27] Despite this small appropriation, BTO has set aggressive targets to improve efficiencies in lighting, space conditioning and refrigeration, water heating, appliances, and building envelopes, and is also at the forefront of building-grid integration. Achieving BTO's targets—which are premised on maintaining current funding levels—would decrease total energy use by 5 percent, cut carbon emissions by 450 million metric tons, and save consumers over $100 billion annually in energy costs.[28] Greater investment in RD&D grid-interactive buildings would enable BTO to set more ambitious targets.

Recommendation 16: Use a policy sequence of R&D funding, tax incentives, and codes and standards to continual ratchet up energy-efficiency and clean energy innovation in buildings and major appliances. Commercial and residential buildings directly account for 12 percent of U.S. greenhouse gas emissions and are indirectly responsible for an additional 19 percent of emissions as the largest consumer of electricity. Innovation that would transform this sector to radically reduce emissions is plagued by a diverse set of barriers including information asymmetry (where the buyer knows little about the product's performance), short time horizons, and split incentives (where the person paying the energy bill is not the person buying the equipment). Federal policy should seek to generate new options through the support of R&D in the public and private sector, allow users to identify the most promising options and scale them up to reduce costs by providing targeted tax incentives, and make them ubiquitous with federal appliance standards and technical support for state and local building codes. Repeating these policies as each generation of technology matures will generate a steady stream of emissions-reducing improvements.[29]

2. What policies should Congress adopt to ensure that the United States is a leader in innovative manufacturing clean technologies; creating new, family-sustaining jobs in these sectors; and supporting workers during the decarbonization transition?

Recommendation 17: Sustain and expand the Manufacturing USA network of institutes that support innovation in clean energy manufacturing. Manufacturing USA is a multi-agency effort to engage academia, industry, and the states to accelerate innovation in key areas of advanced manufacturing. DOE has established five Manufacturing USA institutes, in power electronics, advanced composites, smart manufacturing, process intensification, and reducing embodied emissions, and has announced funding to create a cybersecurity institute. These institutes are a promising beginning to tackle an important, complex, and difficult challenge with diverse stakeholders. They have the potential to evolve into a national innovation resource for advanced manufacturing that is on a par with the National Institutes of Health's role in biomedicine. The existing institutes, like their counterparts abroad such as Germany's Fraunhofer Institutes, should receive a level of core institutional funding on an ongoing basis, subject to regular review. Congress should insist that DOE triple the number of institutes that it supports through an industry-led process and with private, state, and academic support.[30]

Recommendation 18: Develop and implement a sophisticated National Strategic Plan for Advanced Manufacturing. A healthy advanced manufacturing sector is essential not only to meet the industrial decarbonization challenge, but also to sustain public support for energy and climate policy. The strength of the U.S. economy depends in part on its manufacturing prowess, and unless the economy remains strong, Americans may not perceive the value of transforming the way energy is extracted and used. Federal leadership is vital to bring together the diverse stakeholders of the manufacturing sector, including labor, small and medium businesses, and state and local governments along with federal agencies, academic institutions and leading companies, around a common vision. Key components of a sophisticated plan should include tax, trade, technology, and talent policies. The plan should be the result of a stakeholder engagement and be updated regularly.[31]

Recommendation 19: Expand technology-specific clean manufacturing R&D programs in DOE's applied energy programs. Some of DOE's applied energy technology programs have subprograms focused on addressing manufacturing challenges and advancing innovations in manufacturing that are particular to that technology. For example, the Solar Energy Technologies Office has an "Innovations in Manufacturing Competitiveness" subprogram that funds the development and demonstration of innovative solar manufacturing technologies, and helps companies with promising solar technologies survive the funding gaps that often emerge in the development cycle of new technologies.[32] But many technology R&D programs do not have comparable subprograms focused on industry-specific manufacturing challenges. Congress should expand the mandate of DOE's applied energy R&D programs to include manufacturing of clean technologies, with a central office to coordinate manufacturing programs across DOE to ensure no duplication or gaps.

Recommendation 20: Reform the Small Business Innovation Research (SBIR) program at the Department of Energy to better support small businesses' efforts to commercialize federally funded research in clean energy and clean manufacturing. Small businesses can play a critical role in driving innovation by developing and commercializing high-risk, high-reward technologies. In FY 2018, DOE funded small business research with $278 million through the SBIR program. To enhance the commercial outputs of SBIR-awarded small businesses, Congress should reform SBIR funding to allow DOE more autonomy; allow small businesses to use a portion of SBIR awards for commercialization activities; require DOE to increase the weight of projects' commercialization potential in funding decisions; and prioritize new, growth-focused companies that have received few previous SBIR awards.[33]

Recommendation 21. Charge the U.S. Trade Representative with producing a biennial report to document clean energy mercantilist practices, along with steps to counter these. "Green mercantilism"—the adoption of policies that give countries an unfair advantage to boost exports and limit imports of clean energy technologies—is a major departure from rules-based clean technology trade. Examples include lax IP enforcement, forced technology transfer, export subsidies, discriminatory standards, barriers to imports, and preferential treatment of domestic firms by their parent governments. Such policies not only distort clean energy production but also significantly reduce the incentives and ability of firms to invest in innovating better clean energy technologies.[34] ITIF has produced the Global Mercantilist Index which ranks nations on their distortive trade policies which have innovation-dampening impacts. Congress should direct the U.S. Trade Representative to track other nations' mercantilist policies and identify steps to counter them.[35]

Recommendation 22: The United States should push back against recent UN Conference on Trade and Development (UNCTAD) proposals supporting clean energy technology transfer to developing nations. Many developing nations and organizations that support them have advocated that any global climate policy should include special benefits for developing nations, including forced transfer of clean technologies and related intellectual property. While policies such as weakened intellectual property (IP) protection or forced technology transfer might help these nations modestly reduce emissions in the short-term, by reducing the economic returns from clean innovation in developed nations they would slow needed clean energy innovation and slow efforts to limit climate change.

CROSS-CUTTING POLICIES

4. **Carbon Pricing: What role should carbon pricing play in any national climate action plan to meet or exceed net zero by mid-century, while also minimizing impacts to low- and middle-income families, creating family-sustaining jobs, and advancing environmental justice? Where possible, please provide analytical support to show that the recommended policies achieve these goals. How could sectoral-specific policies, outlined in questions 1-3, complement a carbon pricing program?**

Recommendation 23: Use carbon pricing in combination with other policy tools that will bring the price of clean energy close enough to the price of dirty energy that a carbon price will not be disruptive or provoke backlash. Some advocates argue that a carbon price is, to quote Nobel prize-winning economist William Nordhaus, "a necessary and sufficient step for tackling global warming." This position neglects a wide variety of other market and system failures that inhibit clean energy innovation and lock in incumbent dirty energy technologies. While carbon prices incentivize behavioral changes and incremental innovation, they will not spark transformation. For instance, fuel taxes that made gasoline prices twice as high in Europe as in the United States encouraged Europeans to buy smaller and more efficient cars than Americans, but it did not lead to the commercialization of zero-emission vehicles. Policymakers should utilize a diverse toolkit, including public RD&D funding, regulatory reform, infrastructure financing, and tax incentives, along with carbon pricing, to achieve deep emissions reductions.[36]

Recommendation 24: Use a portion of the revenue generated by a carbon price to support clean energy innovation.[37] Federal RD&D investment and other "technology-push" policies complement the "market-pull" provided by a carbon price, driving greater emissions reductions than either policy in isolation. Additionally, RD&D can "soften the blow" of carbon pricing and other regulatory options by lowering the cost of clean energy and opening up avenues of climate policies that would otherwise be prohibitively expensive or politically untenable. For example, DOE's 2017 *Quadrennial Energy Review* found that a carbon price of $10/t$CO_2$, increasing at 5 percent annually, would reduce emissions by 11 percent by 2040, while also raising energy bills by 7 percent. But combining a carbon price with a doubling of funding for clean energy RD&D would reduce emissions by 45 percent in 2040, while also reducing energy bills by 30 percent.[38] This is not a new idea, and the two carbon-pricing policies already in existence in the United States—California's cap-and-trade program, and the Regional Greenhouse Gas Initiative—do this to some extent.[39] And even a small set-aside from a carbon tax could provide a stable, dedicated source of funding for clean energy RD&D. For instance, a carbon fee of just $2.85/t$CO_2$—equivalent to 2.5 cents per gallon of gasoline—would raise $15 billion annually, more than twice what the federal government currently invests in clean energy RD&D.[40]

5. Innovation: Where should Congress focus an innovation agenda for climate solutions? Please identify specific areas for federal investment and, where possible, recommend the scale of investment needed to achieve results in research, development, and deployment. How can Congress incentivize more public-private partnerships and encourage more private investment in clean energy innovation?

Recommendation 25: Congress should at least double federal investment in clean energy RD&D over the next five years. DOE was created in 1978 in response to the energy shortage crises of the 1970s. At the time, Congress invested nearly $10 billion (in 2017 dollars) in energy RD&D, or 0.14 percent of domestic GDP, with the purpose of increasing domestic energy resources and improving energy efficiency in order to enhance America's energy security and resilience to foreign supply shocks. The threat posed by climate change is more urgent and severe today than the energy supply shortages of the 1970s, but funding for energy RD&D has fallen to only $7 billion, or 0.03 percent of GDP.[41] ITIF recommends that the United States at least meet its original pledge as part of the international Mission Innovation agreement to double clean energy RD&D over a five year period, from $6.4 billion in 2016 to $12.8 billion in 2021.[42] Doing so—even in the absence of additional innovation policy—is projected to reduce carbon emissions by 30 percent and residential energy bills by 34 percent in 2040, as compared to a business-as-usual scenario.[43]

Recommendation 26: Create new RD&D programs to address harder-to-abate sources of emissions, including firm electricity, aviation, shipping, long-distance transport, and heavy industry such as cement, steel, and chemicals.[44] These "harder-to-decarbonize" sectors are either not well represented in the federal energy research portfolio or are funded at levels that are insufficient to address the challenge of decarbonizing these sectors. A recent study published in *Science* finds that these sources accounted for 9.2 GtCO_2 in 2014, or 27 percent of global carbon emissions.[45] ITIF recommends that Congress establish six new science and technology missions in clean energy to address these harder-to-decarbonize sectors. These recommendations are summarized here in Recommendations #8 (on hard-to-electrify transportation), #9 (on firm electricity), #13 (on industrial heat and process emissions).

Recommendation 27: Expand investment in the use-inspired basic energy research that will support next-generation energy technologies. Each of the technology missions in Recommendation #24 requires fundamental advances in basic energy sciences. Better catalysts can lower the energy requirements for hydrogen and ammonia production. New solvents and membranes could make carbon capture—whether from industrial sources or directly from the atmosphere—cheaper and more efficient. New battery chemistries will be needed to improve the energy density and storage duration of batteries. Quantum computing and machine learning can dramatically accelerate new materials discovery for clean energy applications. But while advances in foundational energy science are needed to address decarbonization challenges, disconnected, curiosity-driven research alone is likely insufficient to meet these challenges. The federal government should do more to connect basic science research with technology priorities. Congress should significantly expand NSF funding for energy-related research that advances the science underpinning clean energy technology breakthroughs. And DOE should double the number of Energy Frontier Research Centers (EFRCs) and align their focus with technology missions addressing harder-to-abate sectors.[46]

Recommendation 28: Expand investment in clean energy demonstration projects. Demonstration is an important, and often essential, stage in the evolution of energy technologies. This phase of the innovation process allows developers to overcome practical challenges that face complex systems, including those arising from integration and operation. Demonstration can also reduce the economic and institutional risks of new technologies, so that potential adopters gain confidence that new technologies will work as intended. According to the International Energy Agency, demonstration projects often contain "an element of risk that is too large for the private sector to assume," requiring public investment in clean energy demonstration projects to complement private-sector investment.[47] The demonstration phase is particularly important for capital-intensive technologies, because of the greater risk investment that these technologies pose. ITIF analysis has identified public demonstration of capital-intensive clean energy technologies as a major weakness in the U.S. and global energy innovation systems.[48]

Recommendation 29: Authorize DOE to establish an office focused on clean energy technology demonstration. This office could support a robust portfolio of clean energy demonstration projects, especially for complex, capital-intensive technologies such as carbon capture and storage, advanced nuclear reactor designs, and utility-scale storage. The demonstration activities of this office would address the "valley of death" many clean energy technologies face before they are deployable at scale. A single office of demonstration with its own appropriation could offer projects more funding stability, while also shielding projects from political pressures that may influence which projects are selected and when they are terminated. Furthermore, the office could follow best practices in notoriously difficult demonstration project management, which include the following: selecting projects at the appropriate stage of maturity for large-scale demonstration, co-investing with the private sector; allowing for flexible cost-sharing agreements between public and private partners to account for varying risks and benefits to both sectors; encouraging private sector partners to take leadership roles in managing projects to facilitate knowledge transfer; and facilitating information sharing among all potential technology users.[49]

Recommendation 30: Establish a test bed and simulation network to connect new clean energy technologies with relevant testing capabilities and simulation resources from DOE, the National Laboratories, universities, and private industry. A test bed and simulation network can enable developers of clean energy technology to efficiently match with appropriate partners and resources for technology validation, and allow an R&D community to better leverage shared resources.[50]

Recommendation 31: Improve efficiency and reduce regulatory burdens for clean energy technology transfer to attract private sector investment in later-stage R&D, commercialization, and advanced manufacturing.[51] In some instances, publicly supported institutions that could contribute to greater levels of clean innovation and commercialization are underutilized. One way to increase technology transfer activity from the national labs, and to facilitate their deeper involvement with regional economies, would be by implementing performance-based, rather than rules-based, management approaches. In particular, the administration should allow DOE labs to engage in non-federal funding partnerships that do not require DOE headquarters approval (i.e., the so-called $1 million signature authority). Further, Congress should allow national labs to repurpose a small portion of existing funds (up to 5 percent) to fund timely regional collaborations.

Recommendation 32: Make technology transfer, including of clean energy technologies, more of a priority in federally funded entities such as the national laboratories.[52] DOE's national energy laboratories are insufficiently incentivized to invest time, energy, and resources in facilitating technology transfer, in large part because technology transfer is not one of the eight main criteria in the Performance Evaluation and Management Plan (PEMP), an annual report card for the federal labs. Rather, PEMP treats successful transfers of technology to market as an afterthought. Elevating this important function to its own category would have significant impacts on the management of the labs. Adding a ninth category to the PEMP for "Technology Impact" would create a mechanism to evaluate the economic impact of lab-developed technology, creating a stronger incentive for lab managers to focus on market adoption of government intellectual property assets and technical capabilities.

Recommendation 33: Establish an automatic set-aside program that takes a modest percentage of federal energy research budgets and allocates this money to clean technology commercialization activities.[53] ITIF has recommended that Congress allocate 0.15 percent of agency research budgets (about $110 million per year) to fund university, federal laboratory, and state government technology commercialization and innovation efforts. Such funds could be used to provide "commercialization capacity-building grants" to organizations pursuing specific, innovative initiatives to improve an institution's capacity to commercialize faculty research as well as "commercialization accelerator grants" to support institutions of higher education pursing initiatives that allow faculty to directly commercialize research. Additionally, Congress and the administration should broaden—beyond universities and labs—the type of institutions that are eligible for commercialization funds, to include state entities, such as the Maryland Technology Development Corporation (TEDCO) for example, that support technology transfer activities.

Recommendation 34: Establish a "DOE Foundation" to accelerate the commercialization of federally-funded clean energy R&D. The federal government invests approximately $7 billion annually in R&D to support the energy mission of the Department of Energy. While this investment produces valuable scientific and engineering knowledge, it does not lead to the commercialization of low-carbon technologies on a commensurate scale. Building on precedents at the National Institutes of Health and other federal agencies, a DOE Foundation would leverage follow-on investment from the private sector and strengthen hands-on collaboration between private-sector innovators and federally-funded experts at the DOE national labs and elsewhere.[54]

Recommendation 35: Leverage the Department of Defense's (DOD) needs and strengths as an innovator into DOE's strategies and roadmaps for its fundamental and applied research, development, and demonstration (RD&D) so as to capture DOE-DOD synergies.[55] DOD invests about $1.6 billion in energy science and technology each year, reflecting the U.S. military's pursuit of advanced technology as a force multiplier. Military and civilian customers often seek similar features in energy systems, leading to convergent avenues of research in DOD and DOE programs. For example, the dramatic increase in electrical systems onboard military platforms is driving electrification of the battlefield. That and the need to reduce the logistics footprint are creating requirements for distributed and portable power generation, smart energy networks, improved energy storage, and wireless power transmission. ITIF has identified the clean energy technologies likely to benefit most from DOD's role as an innovator and early adopter, including solar PV, microgrids, energy storage, and wide bandgap semiconductors, fuel cells, and very small modular nuclear reactors. Congress should direct the National Research Council to conduct a study to identify impediments to and opportunities for greater DOE-DOD collaboration on energy RD&D.

Recommendation 36: Expand and reform the R&D tax credit. Private R&D by companies that supply, distribute, and consumer energy will be a critical factor in achieving climate goals. Yet, companies invest less in R&D than they ought to because the benefits of this investment often spill over to their competitors and customers. The federal government and most state governments seek to address this market failure by reducing a company's tax liability by a portion of any increase in its R&D spending. Although the United States invented this policy in 1981, it has fallen far behind its competitors, ranking 26th among the 30 members of the Organization of Economic Cooperation and Development in generosity in 2018. Congress should broaden the definition of qualifying research, expand the R&D credit, and enable research-based start-ups to better use it.[56]

- Double the alternative simplified research credit (ASC) from 14 percent to 28 percent, to bring U.S. tax incentives for corporate research closer to those of its international competitors.
- Eliminate the language excluding commercially-aimed research and allow 100 percent of expenditures on research made at universities to qualify as research expenditures under the regular or ASC credits.
- Expand the tax credit for collaborative energy research from 20 to 40 percent.
- Modify the research credit so that clean energy startups, which often have little taxable revenue, can fully avail themselves of the credit, for example by allowing small firms to take the R&D credit against their payroll taxes.

Recommendation 37: Replace the current first year expensing provisions for capital investment with an American Investment Tax Credit that provides a tax credit for investing in R&D and capital equipment. Business investment in R&D and new equipment and software drive productivity, innovation, and competitiveness. But the United States has fallen behind other nations in investment in these key building blocks, including in clean energy R&D and investment. Without such incentives it will be harder for the United States to compete globally in clean energy. As such, Congress should create a comprehensive tax credit for business investments in R&D and capital equipment and software. ITIF recommends a tax credit of 45 percent of business investments on R&D and a 25 percent credit on new equipment and software.[57] Doing this would provide a strong incentive for businesses in the United States to invest more in the building blocks of productivity, innovation, and competitiveness.

AGRICULTURE

6. What policies should Congress adopt to reduce carbon pollution and other greenhouse gas emissions and maximize carbon storage in agriculture?

e. Soil Carbon Storage

Recommendation 38: Expand RD&D programs in soil carbon storage, biochar, and agricultural practices that increase soil carbon absorption.[58] Soils have an enormous capacity to hold carbon within the top few meters of soil, currently hosting three times more carbon than is in the atmosphere.[59] However, heavily-cultivated agricultural soils can lose 50 to 70 percent of their original organic carbon.[60] The National Academies found that improved agricultural practices and technology-enhanced natural processes have the potential to sequester 3 $GtCO_2$/yr.[61] These improvements in soil function also translate into economic benefits. According to the USDA Natural Resources Conservation Service, every 1 percent increase in soil organic matter can provide $29 per acre in the U.S. Midwest through improved nutrient and water availability.[62] Current RD&D programs aimed at increasing soil carbon absorption include the ARPA-E ROOTS program at DOE and various biochar and soil carbon farming programs at USDA. However, current programs are limited in scope and fail to investigate the full suite of options at the necessary scales. Congress should implement the recommendations from NASEM and EFI reports related to soil carbon absorption.

f. Low-Carbon Ammonia Fertilizer Production

Recommendation 39: Create new RD&D programs to develop new clean ammonia production pathways.[63] The second-most manufactured chemical in the world, ammonia is used primarily for fertilizer, with global production volumes of around 160 million tons in 2017.[64] The use of ammonia and ammonia-based fertilizers has been key to enabling greater food production, and ammonia consumption is project to rise as the global population grows. However, ammonia production is incredibly carbon-intensive, in the best case producing 1.9 metric tons of carbon dioxide per ton of ammonia.[65] Congress should direct DOE to establish a new innovation hub, in the model of the Joint Center for Artificial Photosynthesis (JCAP), that is focused on novel, low-cost methods of ammonia production that do not use fossil fuels as a feedstock.

Recommendation 40: Complement RD&D with demand-pull policies to expand the market for low-carbon ammonia. Low-carbon ammonia production has already been demonstrated at commercial scale, with the Enid Fertilizer facility capturing its CO_2 for use in enhanced oil recovery since 1982.[66] And ammonia and fertilizer production facilities are among the lowest-cost opportunities for near-term deployment of carbon capture, with costs in the range of $23-33/t$CO_2$.[67] But without increased market demand for low-carbon ammonia, these technologies may continue to sit on the shelf. Congress should explore policies to expand the market for low-carbon ammonia, including tax incentives, feed-in tariffs, information and voluntary programs, and emissions standards that can provide a protected market as the technology for low-carbon ammonia matures.

NON-CO2 GREENHOUSE GASES

9. What policies should Congress adopt to reduce emissions of non-CO2 greenhouse gases, including methane, nitrous oxide, and fluorinated gases?

Recommendation 41: Continue to support RD&D to reduce methane leaks and vented emissions from natural gas systems, including within ARPA-E and the Methane Emissions Quantification and Mitigation program.[68] The Methane Emissions Quantification and Mitigation program within DOE's Oil and Gas R&D program aims to develop a suite of technologies to mitigate leaks and improve public safety, including smart in-pipe methane sensing devices, advanced in-pipe coatings, and liner materials. Methane, the main component of natural gas, is itself a potent greenhouse gas. Reducing fugitive methane emissions from natural gas systems would have the dual effect of improving reducing greenhouse gas emissions while also enhancing stewardship of domestic gas resources.

Recommendation 42: Ensure that any new methane regulations are performance-based (and not technology-prescriptive) and allow for the use of emerging technologies for leak detection and repair. EPA's 2016 New Source Performance Standards (NSPS) for the oil and natural gas sector included requirements for leak detection and repair based on the dominant technology at the time, optical gas imaging. However, DOE's programs at ARPA-E (the MONITOR program) and FE are aimed at developing advanced natural gas monitoring technologies and approaches. Under the current administration, EPA is proposing to reverse the 2016 NSPS for methane emissions from the oil and gas sector, but the outcome of these efforts has not yet been determined. EPA should use this opportunity to establish new performance-based methane regulations that would allow for new technologies, including those developed through federal R&D, to be available for compliance provided they supply the same level of leak mitigation as current technologies.

CARBON REMOVAL

10. How can Congress accelerate development and deployment of carbon removal technology to help achieve negative emissions?

Recommendation 43: Establish a comprehensive research, development, and demonstration (RD&D) initiative that implements the recommendations of the National Academies report on carbon removal.[69]

Carbon removal complements conventional mitigation but is not a replacement for it—both will be needed on a massive scale. Carbon removal addresses two essential challenges for deep decarbonization that other conventional mitigation approaches cannot: It is needed to offset residual emissions—especially non-CO_2 gases—that are impossible or prohibitively expensive to completely eliminate; and it provides a hedge against a carbon budget overshoot.[70] But most carbon removal approaches are far from commercial, and RD&D will be needed to create new options for reducing carbon pollution. The new RD&D initiative should span multiple agencies and encompass the full suite of natural, technologically-enhanced natural processes, and technological carbon removal pathways identified in the NASEM report, as well as marine-based pathways that are addressed in other reports.[71] The Energy Futures Initiative (EFI) provides a set of detailed implementation plans for a comprehensive 10-year, $10.7 billion carbon removal RD&D program.[72]

Recommendation 44: The National Science and Technology Council (NSTC) should establish a new committee on carbon management to coordinate federal research and facilitate information exchange.[73] Addressing the full suite of carbon removal RD&D needs requires harnessing the technical capabilities from multiple agencies, especially DOE, EPA, DOI, USGS, and NSF. The NSTC provides a natural framework for coordinating and optimizing interagency activities.

Recommendation 45: Expand investment in carbon utilization and implement recommendations of the recent National Academies report on carbon utilization. Carbon utilization—turning carbon dioxide from a waste product into a product of value—is a key tool to expand the market for carbon dioxide and incentivize greater carbon capture. The National Science Foundation, DOE's Office of Fossil Energy, DOE's Office of Basic Energy Sciences, and several ARPA-E programs have funded projects to turn carbon dioxide into fuels or other high-value chemicals. But these levels are insufficient to address the full suite of RD&D needs identified in the NASEM report on carbon utilization.[74]

Recommendation 46: Expand investment in DOE's Carbon Storage RD&D program to include demonstrations in depleted oil and gas fields, unmineable coal seams, basalts, and other carbon-absorbing formations.[75] Carbon utilization may provide a glide-path to large-scale carbon storage, by providing market pull for carbon capture from industrial sources. But carbon utilization will likely not reach the scale necessary to support all carbon removal needs, and geologic storage will still be needed in addition to carbon utilization. For example, if all carbon used in the global annual production of plastics (311 million metric tons per year in 2014) were sourced from industrial sources, it would consume about 0.8 $GtCO_2$ per year, while climate models project the need to remove 20-60 $GtCO_2$ per year by 2100.[76] Preliminary research suggests the United States has enough subsurface capacity to permanently sequester 1.71–14.5 trillion metric tons of CO_2, equivalent to 265–2,250 years of U.S. greenhouse gas emissions at 2017 levels.[77] DOE has already demonstrated the geologic storage in underground saline formations, and has also conducted pilot carbon mineralization projects. However, detailed site-specific work is required to confirm the potential for subsurface reservoirs. And large-scale, long-term demonstration projects are necessary to ensure captured carbon dioxide is safely and permanently stored.

INTERNATIONAL

13. The climate crisis requires a global response. U.S. leadership is critical for successful global solutions. What policies should Congress adopt to support international action on the climate crisis?

Recommendation 47: The United States should recommit to Mission Innovation and make good on its commitment to double investment in clean energy research, development, and demonstration (RD&D). The United States is the world leader in clean energy RD&D, investing more on an absolute basis than the next two countries (China and Japan) combined, and more in basic energy science than all other nations combined.[78] In conjunction with the Paris Agreement, the United States led 21 other nations and the European Union to launch Mission Innovation (MI), a global initiative to double investment in clean energy RD&D and collaborate in tackling key innovation challenges.[79] Since the launch, two additional countries have joined MI. However, American leadership and participation in MI has waned in recent years, and the United States has failed to meet its commitments and set a good example for other nations to follow. U.S. investment in clean energy RD&D at the Department of Energy increased by 22 percent from 2016 to 2019, far less than the 60 percent increase necessary to be on track to double clean energy RD&D by 2021.[80] Additionally, the United States has scaled back its participation in the Mission Innovation Challenges, which have become a prominent forum for international collaboration on decarbonization technology challenges. Congress should put the United States back on a doubling trajectory and direct federal agencies, especially DOE, to take a more active role in leading international efforts to address clean energy innovation challenges.

Recommendation 48: The United States should urge more nations to establish innovation commitments that match the ambition of their Paris commitments. 194 nations and the European Union are parties or signatories to the Paris Agreement, with most pledges taking the form of emissions targets. But the UN *Emissions Gap Report 2018* identifies two major gaps to achieving the Paris goal of limiting global temperature increase to less than 2 °C: the gap between what nations have pledged and what they are actually able to achieve; and the gap between what nations have pledged and what is needed for a 2 °C (or 1.5 °C) scenario.[81] In other words, nations are not meeting their Paris pledges, but even if they were they would not be on track to limit global temperature increase to 2 °C. Innovation is needed to close these gaps and enable nations to set and meet more ambitious emissions targets. But only 24 nations and the EU have joined Mission Innovation—the other Paris agreement—and established innovation targets and pledges to increase public investment in clean energy RD&D. And most of these nations—including the United States—are failing to meet their commitments. Nine MI member nations—South Korea, France, Italy, Netherlands, Australia, Sweden, Denmark, Norway, and Finland—and the European Union invest less now in clean energy RD&D in absolute terms than they did in 2015 when MI was launched.[82] Congress and the administration should urge more nations to set clean energy RD&D targets and invest in innovation at a level commensurate with the climate challenge.

Recommendation 49: The United States should use international forums, including Mission Innovation and the International Energy Agency, to engage international partners and lead global efforts to tackle key innovation challenges, particularly with respect to harder-to-abate sectors, long-duration energy storage, and carbon dioxide removal. Since its inception, MI has launched eight Innovation Challenges in key technology areas "where increased investment could make a significant impact": smart grids; off-grid access to electricity; carbon capture; sustainable biofuels; converting sunlight to fuels; clean energy materials; building heating and cooling; and clean hydrogen. These Innovation Challenges have served as useful focal points for prioritizing energy research and have provided a framework for information sharing and international collaboration. However, many harder-to-decarbonize sectors—including cement, steel, petrochemicals, and the transportation sector—are not well represented in the current set of Innovation Challenges. Similarly, ITIF and others have called for new Innovation Challenges addressing long-duration grid storage and carbon dioxide removal (CDR), two technologies that will be critical to meeting climate targets.[83]

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