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Transforming U.S. Energy Innovation

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The United States needs a revolution in energy technology innovation to meet the profound economic, environmental, and national security challenges that energy poses in the 21st century. If the U.S. government does not act now to improve the conditions for innovation in energy, even in times of budget stringency, it risks losing leadership in one of the key global industries of the future, and the world risks being unable to safely mitigate climate change and to reduce vulnerability to disruptions and conflicts—both domestic and international. Waiting is not an option.

Researchers at Harvard Kennedy School undertook a three-year project to develop actionable recommendations for transforming the U.S. energy innovation system. We surveyed over 100 experts across a broad range of energy technologies; conducted extensive economic modeling; and developed and implemented a new methodology for assessing how much research, development, demonstration (RD&D) investment is needed, and in which technologies. This work also included: interviews with a range of energy innovators and policymakers; the first survey of energy innovation in U.S. businesses; analyses of how effectively the Department of Energy (DOE) interacts with private firms; case studies of the operations and effectiveness of key energy innovation institutions; and development of new data on international energy RD&D spending and cooperation. This research has led us to five key recommendations for accelerating U.S. energy innovation.

(1) The U.S. government should dramatically expand its investment in energy RD&D, focused on a broad portfolio of different energy technologies and stages of innovation.

We recommend that current investments in energy RD&D be roughly doubled, to $10 billion per year (including about $5 billion for the seven technology areas considered in detail and the remainder for other areas, including Basic Energy Sciences). Experts in a range of energy technologies almost unanimously recommended increasing energy RD&D in their areas by 2–3 times, to seize the technological opportunities that now exist. Our economic modeling suggests that an investment of a few extra billion per year today could develop technologies that could save the economy hundreds of billions of dollars per year by 2050 in scenarios where there are stringent policies limiting how much carbon can be emitted.

Our current modeling suggests that there could be decreasing marginal returns from spending more than the $10 billion per year we recommend, but that conclusion should be regularly reassessed as technologies evolve. These investments should be targeted on a broad portfolio of technologies, to maximize the chances of achieving major breakthroughs. The largest percentage increases we recommend compared to 2009 funding levels are for energy storage, buildings, bioenergy, and solar photovoltaics. Despite current deficits, the United States cannot afford to forego the long-term investments that will improve its competitiveness in this multi-trillion-dollar market and its national security, while reducing both greenhouse gas emissions and other environmental hazards. These funds could be provided through channels outside the

appropriations process, as has been done successfully in the past.

(2) The U.S. federal government should implement policies that create market incentives to develop and deploy new energy technologies, including policies that have the effect of creating a substantial price on carbon emissions, and sector-specific policies to overcome other market failures.

Our modeling makes clear that *both* expanded RD&D investments and a substantial price on carbon emissions are necessary if the United States is to meet the climate change challenge and reduce dependence on imported oil at reasonable cost. Increased energy innovation investment alone, with no policies in place to drive the adoption of the resulting technologies, is very unlikely to reduce U.S. greenhouse gas emissions by more than a few percent—even with huge increases in RD&D and optimistic technology assumptions. Similarly, carbon caps or prices alone, with no increase in energy RD&D, would make the resulting energy system more costly. A clean energy standard could contribute towards the goal of reducing carbon emissions, but would be less effective than a broader carbon policy. Together, well-integrated "technology push" from increased RD&D and "demand pull" from a carbon price and sector-specific policies (such as building codes) have the potential to accomplish what neither can do alone.

(3) The U.S. government should take a strategic approach to working with the private sector on energy innovation, expanding incentives for private sector energy innovation, and focusing on the particular strategies likely to work best in each case.

The private sector has a critical role to play, as the vast majority of the energy system infrastructure in the United States is controlled by the private sector. Our research shows that private sector innovation in energy is more widespread than previously understood. Yet, today, DOE does not have an overall strategy for its interactions with the private sector. It does not collect and analyze the data necessary to learn from the experience of past projects about what mechanisms for collaboration work best and under which circumstances. We propose a new approach in which that data would be collected and analyzed, enabling learning-by-doing. Our research also shows that the demand pull policies we recommend will enhance incentives for private sector investment in energy innovation, which should also be strengthened through other policies, ranging from support for large-scale technology demonstrations to investment in training the next generation of energy technologists.

(4) The U.S. government should strengthen its energy innovation institutions, particularly the national laboratories, by giving them clear missions and direction; considerable management authority and flexibility with clear accountability for results; stable funding; a culture willing to invest in high-risk, high-payoff projects; and opportunities to lend their insights to the design of the policies and approaches they are helping to implement, including public-private partnerships.

To maximize the return on its investment in energy RD&D, the U.S. government must ensure that its energy innovation institutions are as efficient and effective as they can be. Constantly shifting funding, DOE headquarters' micromanagement, diffuse missions, risk-averse cultures, new contracting approaches that have diluted the focus on key national objectives, and insufficient ability to connect to the private sector have undermined the efficiency of U.S. energy RD&D institutions. This study recommends a range of reforms, including an increase in lab-directed funds to allow lab directors to provide seed funds for promising areas, incentives for entrepreneurialism and risk-taking for lab scientists and technicians, and a revision of contracting in the labs.

ARPA-E represents a major step in the right direction, emphasizing technical excellence, rapid adaptation, and high-risk, potentially high-payoff projects. Policymakers should provide consistent, multi-year support for ARPA-E and should not be deterred by a few failures—if there were no failures, the effort would not be pursuing the high-risk projects that have the highest potential payoffs.

(5) The U.S. government should undertake a strategic approach to energy RD&D cooperation with other countries, to leverage the knowledge, resources, and opportunities available around the world, incorporating both top-down strategic priorities and investment in new ideas arising from the bottom-up.

The energy challenges of the 21st century are global, not limited to the United States. World energy markets and energy technology development are rapidly changing as globalization progresses and new players emerge. Today, total government-controlled energy RD&D in just six emerging or transition countries (Brazil, Russia, India, China, Mexico, and South Africa), counting investments by state-owned enterprises, is as large or larger than government-sponsored energy RD&D in all of the developed countries combined. These new realities create both new competitive challenges and new opportunities, requiring the United States to ensure that high-value cooperation opportunities are not missed because of the sometimes ad-hoc and distributed nature of cooperation activities. This report recommends that a new interagency committee be established to identify additional priorities for funding and action in international cooperation in energy innovation that are not being undertaken by the agencies and that a new approach be established to collecting and analyzing the data needed to learn what approaches to RD&D cooperation work best under what circumstances. At the same time, recognizing that innovators on the ground may be most aware of new opportunities as they arise, we recommend that each of the key energy RD&D programs at DOE and each of the agencies involved in cooperation in energy innovation set aside a small portion of its funds to support international energy RD&D projects suggested from the bottom-up.

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