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MIT Industrial Performance Center

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Unlocking Energy Innovation: A Framework for Action

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The MIT-IPC Energy Innovation Project

This short report outlines the results of a study of the U.S. energy innovation system conducted at the MIT Industrial Performance Center (IPC). The Energy Innovation Project was carried out by an interdisciplinary team of researchers drawn from nine different MIT departments as well as several other U.S. universities, and was supported financially by the Doris Duke Charitable Foundation. A new book drawing on the findings of this study has just been published (Richard K. Lester and David M. Hart, *Unlocking Energy Innovation: How America Can Build a Low-Cost, Low-Carbon Energy System,* MIT Press, Cambridge, MA, 2012).

The MIT-IPC Energy Innovation Project was conducted over a three-year period of extraordinary volatility in the energy sector, encompassing the financial collapse of 2008–2009, the deep recession that followed, the largest offshore oil spill in U.S. history in the summer of 2010, the Fukushima nuclear disaster in March 2011, and the political upheavals that continue to sweep across the Arab world. In the background, the longer-term problem of energy and global climate change was often overshadowed by these tumultuous events. Yet the scientific evidence suggesting the need for an accelerated transition to a low-carbon energy system to avoid the worst consequences of climate change continued to accumulate during this period, and the Energy Innovation Project focused on how to meet the demands for innovation associated with that transition even while maintaining the reliability and affordability of energy on which our society depends.

Our study focused on the American energy innovation system and has little to say about innovation elsewhere. The U.S. has a tremendous stake in the success of low-carbon energy innovation in countries like China and India, and American participation in those efforts will be to mutual benefit. But each country's innovation system is unique, shaped by the particularities of its history, economy, and politics. That is certainly true of the U.S. Although we strongly endorse learning from abroad and closer international cooperation, American institutions of innovation will change mainly in response to domestic influences and along pathways that reflect this country's special characteristics.

Whatever happens elsewhere, U.S. leadership in energy innovation will be essential to the success of the world's climate change mitigation efforts. International cooperation is a complement, not a substitute, for American creativity, resourcefulness, and entrepreneurship. The Energy Innovation Project asked how to mobilize America's enormous innovation resources in the service of a decades-long, global energy transition. It is about a long game, and it is particularly about that part of the long game that will be played here at home.

A Ten-Point Framework for

Building a New American Energy Innovation System

America's energy system will not be transformed all at once, nor by a single "magic bullet" solution. Instead, the coming energy transition will unfold in three successive waves of innovation. Each wave will gather momentum at a different rate, and each will sweep over the energy sector at a different time. But all must be pursued in parallel, all must be accelerated, and in all cases work must begin right away:

I. The first wave, ramping up in this decade and continuing beyond, must focus mainly on energy efficiency gains in all sectors including transportation, but especially in the building sector, which currently accounts for about 40% of total energy use and 70% of electricity use. Although some additional technological advances may be needed, many options for more efficient heating, lighting, air-conditioning, insulation, and other energy uses are already available; therefore, the primary innovations in this wave will be institutional and organizational.

II. The second wave of innovation will overlap with the first, which must continue, but it will have its largest impact between 2020 and 2050. The second wave will focus on the large-scale deployment of *known* low-carbon technologies for electricity generation, transmission, distribution, and end-use, such as nuclear, solar and wind power, carbon capture and sequestration (CCS), electric/hybrid transportation, as well as grid-scale storage, driving down their costs through continual innovation.

III. A possible third wave of innovation, achieving scale only in the second half of the century, may result from radical technical advances generated by fundamental research in a broad range of scientific fields. This third wave, which could include breakthrough innovations not even imagined today, should be set in motion even as the first and second waves are breaking over the energy sector, and the research to support it must be generously funded from now on.

In each of the three waves there are many candidate technologies, each with its own pros and cons and each with its own advocates. Here we do not try to predict which innovations or which companies will or should emerge as the dominant contributors to each wave. We instead focus on how to build an innovation system that will be capable of generating good answers to these questions. This requires a different kind of innovation – a rearrangement of the incentives and patterns of interaction among businesses, between business and government, within government, and between the energy industry and other sectors of the economy.

In *Unlocking Energy Innovation* we present a ten-point framework for building a larger and more dynamic energy innovation system than exists in the U.S. today — a system that will maintain the reliability and affordability of energy on which our society depends, even as it unlocks the creativity and competitive spirit of America's technical community, entrepreneurs, investors, and energy users.

I. New Innovators

At the core of the new energy innovation system will be new market entrants, both new firms and existing firms from other sectors. The American energy industry today is dominated by large, risk-averse corporations with a history of underinvestment in innovation and, often, a strong interest in preserving the status quo. The energy industry needs an infusion of new firms, new people, and new ways of doing things. Public policy can create space for new entrants and facilitate their access to resources.

II. Expanded Competition in Electric Power Markets

The central front in the low-carbon energy transition will be the transformation of the electric power sector. Expanding the domain of market competition, promoting an open industry architecture, and encouraging the entry of new competitors into newly-opened segments of the electric power industry will all be powerful drivers of innovation. The most important spaces for competition and entry lie at the edges of the power grid. Independent power producers will experiment with innovative generation technologies at one end of the grid. At the other end, specialist energy service companies, demand response providers, and distributed generators will explore new business models, new organizational configurations, and new kinds of services for end users. To promote competition, the process of vertical disintegration of the electric utilities which began in the 1990s must be completed. The main objective at that time was lower electricity prices. Today accelerating innovation is the strongest argument for shrinking the footprint of the utilities. Expanded competition and new entrants to the power sector are the keys to all three waves of America's low-carbon energy transition.

III. Smart Integrators

"Smart integrator" transmission and distribution utilities, working closely with a national network of regional transmission organizations and independent system operators (RTO/ISOs) and with state and federal regulators, will manage the operations and development of the electric power system. While no longer controlling the power system from end to end, the utilities that run the grid will remain the system's linchpins. They will manage the interaction of independent power producers, distributed generators, energy management service providers, customers, and many other players. Their responsibility will be to ensure that the diverse innovations arising at the edges of the grid work together to achieve the system's key objectives of lower carbon dioxide emissions, improved reliability, and greater affordability. Government regulation will still be necessary in order to prevent the grid's owners from exercising their monopoly power. But regulators, too, must become "smarter", in tandem with the firms they are regulating. The regional-level transmission organizations (RTOs and ISOs) are an essential part of this institutional complex. They provide a transparent mechanism for operating wholesale power markets and for planning new and better transmission facilities. Congress should extend the system of regional transmission organizations to the entire country and grant RTOs and ISOs greater authority to plan and site new transmission lines.

IV. An Invigorated Energy Efficiency Marketplace

By the end of this decade, a thriving marketplace will speed the widespread adoption of building energy efficiency products and services. No technological breakthroughs are necessary for the U.S. to become much more energy efficient. In this first, efficiency-driven wave of innovation, the largest target of opportunity is in the building sector. In the near term, improving building energy efficiency is the most cost-effective greenhouse gas mitigation opportunity available to the U.S. The products already exist, as do the services, but they are currently confined to relatively small customer segments. Over the next decade, the most important innovations will be institutional and organizational reforms that expand the marketplace for efficiency products and services.

For new buildings and for new appliances, regulations that ratchet up energy efficiency in a predictable fashion will be the key to making these markets work better. The federal government will play a key role, defining baseline standards and ensuring national compliance with them in collaboration with state and local governments (in the case of new buildings) and manufacturers (in the case of appliances). Federal testbeds (such as the DOE's building energy efficiency innovation hub), along with innovative private buildings, such as those certified to a high level by the U.S. Green Building Council, will serve as the proving grounds for each ensuing iteration of these standards. These buildings will be the leading symbols of the first wave of innovation.

For retrofits of existing buildings, regulatory mandates are impractical, and a combination of financial incentives, new financing institutions, new administrative structures, and new business models will be necessary. As utilities increasingly focus on the grid integration task, new opportunities to administer building retrofit programs may appear in many states. The administrators of these programs will encourage vigorous competition in the provision of products and services, facilitate the availability of energy consumption data to third party service providers, and sustain public information and education efforts that aim at shaping behavior. Better and more accessible information, such as an MPG-type label for all buildings, will support the deepening of efficiency product and service markets. The business model innovations of energy efficiency service providers, supported by public RD&D and information provision programs, will allow the U.S. to begin to close the energy efficiency gap with Europe and Japan.

V. Regional Innovation Investment Boards

A new group of institutions, centered on Regional Innovation Investment Boards (RIIBs), will unlock a second wave of innovations that will enable low-carbon electricity to supplant other energy sources. The success of the second wave will depend on scaling up and cutting the unit costs of electricity-related services provided by low-carbon central station power plants, distributed generation technologies, and the smart grid. Financing for demonstration and early deployment of these innovations will be mobilized and allocated in new ways. The RIIBs, membership organizations comprised of firms drawn from all segments of the electric power sector, will allocate funding to first-of-a-kind large-scale demonstration projects, 'next few' post-demonstration projects, and early deployment programs. Teams proposing projects and programs will seek RIIB funding not as their sole source of finance but rather to augment their own investments and to lower their risks. In this way, RIIB investments will leverage larger amounts of private-sector funding. The RIIBs will choose among competing projects based on the strength of the proposing team, the quality of its management, and the potential of the proposal to achieve energy innovation goals, as well as the extent of self-funding. The RIIBs will compete with one another to build strong project portfolios in order to attract financial support from state-level trustee organizations. Over time each RIIB may specialize in areas of innovation of particular interest to its region.

VI. State Energy Innovation Trustees

Trustees set up by each state will allocate funds to the RIIBs, using the proceeds of an innovation surcharge on all retail sales of electricity within the state. The trustees will be free to allocate their funds to RIIBs in any region. The allocation will be based on the trustee's assessment of which RIIB portfolio of demonstration and post-demonstration projects and early adoption programs most closely matches its needs. The trustee organizations will be more broadly representative of stakeholders in the electricity system than the RIIBs themselves. Their members might include a variety of business sectors, government organizations and officials, environmental and labor groups, and technical experts. All proceeds from the surcharge will have to be allocated by the trustees to the RIIBs within a year of receipt.

VII. A Federal "Gatekeeper"

A federal "gatekeeper" organization will certify that projects and programs presented to the RIIBs for funding have the potential to lead to significant reductions in carbon emissions at a declining unit cost over time. To receive certification, proposals will be required to create pressure on innovators to exploit learning to reduce costs. Public subsidies for projects and programs will decline steadily on a unit basis as experience with the innovation is gained. Certification will be granted for a limited period only, and may be withdrawn if progress proves too slow. The gatekeeper will be responsible for monitoring progress. The gatekeeper will also track projects and programs targeting the same innovations to guard against duplication and overlap. However, it will take into consideration the value of pursuing several different approaches in parallel as circumstances warrant.

VIII. Dynamic Pricing

Some form of dynamic pricing (in which prices change during the course of the day) will make it possible for customers to make choices that stimulate innovation. Dynamic pricing will reduce peak loads, and it will also incentivize central station and small-scale generators as well as providers of storage and other grid services to respond to supply and demand conditions on the grid in the most effective way. Customer decision-making will also be informed by more extensive information about historical benchmarks, on-bill comparisons with neighbors, and conservation tips. A federally sanctioned labeling program will validate the quality of meters and other equipment and help customers gain confidence that offers made by smart-grid service providers are trustworthy.

IX. Open Grid Architecture and Customer Control

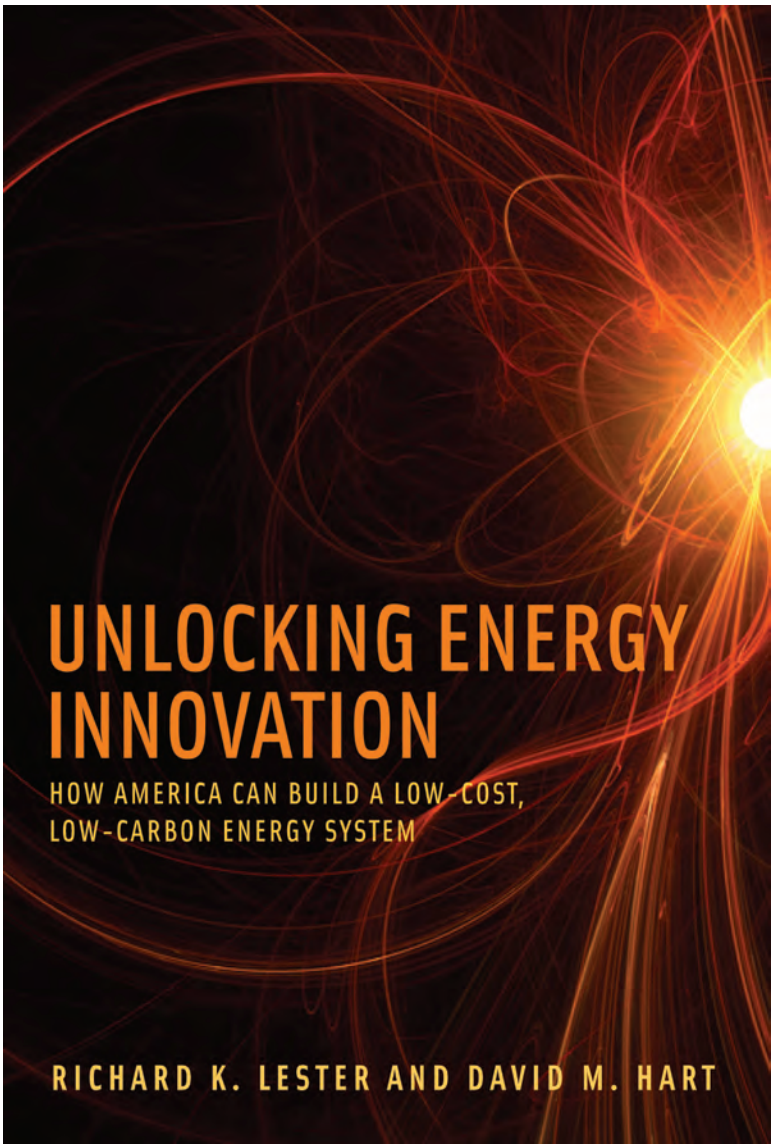
An open architecture for distributed generation and smart grid technologies, supported by dynamic pricing, will promote innovation "behind the meter" and in the rest of the power system. Investments in distributed generation, grid-scale storage, and smart grid technologies will help to make the power system more reliable, less wasteful, and more responsive to customer choice. In the future power grid, many entities will compete to provide many different kinds of services to the smart integrator and to customers. They will be able to "plug" into the grid and "play" their roles with minimal difficulty. Regulators and standard-setting bodies will ensure that the interfaces between service providers, users, and the grid remain open and that pricing is fully transparent. On the customer side of the meter, the architecture of the smart grid will be customer-controlled rather than utility-controlled. Customer-controlled architecture will give customers and third-party service providers greater freedom to experiment with devices and behaviors and provide motivation to develop innovative business models.

X. Breakthrough Innovations

A federal energy research structure, pluralistic in its styles, informed by user input, and larger and more diverse than today's system, will focus on the creation of new options for energy supply, delivery and use with the potential to contribute on a large scale in the second half of the century. The Department of Energy and its large laboratories will be an important part of the system, but other government agencies, including the Department of Defense, will play a larger role than today. Coordination of the federal research effort will be led by the Executive Office of the President. The federal long-term energy research structure will foster the open exchange of ideas, both domestically and internationally, and will be linked to the downstream stages of the innovation system.

This ten-point framework is the first draft of a program for building a new American energy innovation system. The U.S. is a long way from having such a system in place today. But we are convinced that the existing system can be renewed and greatly improved to meet the demands of the coming decades. It is important to get started soon. There is no time to lose.

For a fuller assessment of America's recent performance in energy innovation and more details on this ten-point framework for building a new U.S. energy innovation system, see Richard K. Lester and David M. Hart, *Unlocking Energy Innovation: How America Can Build a Low-Cost, Low-Carbon Energy System,* MIT Press, Cambridge, MA, 2012.



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