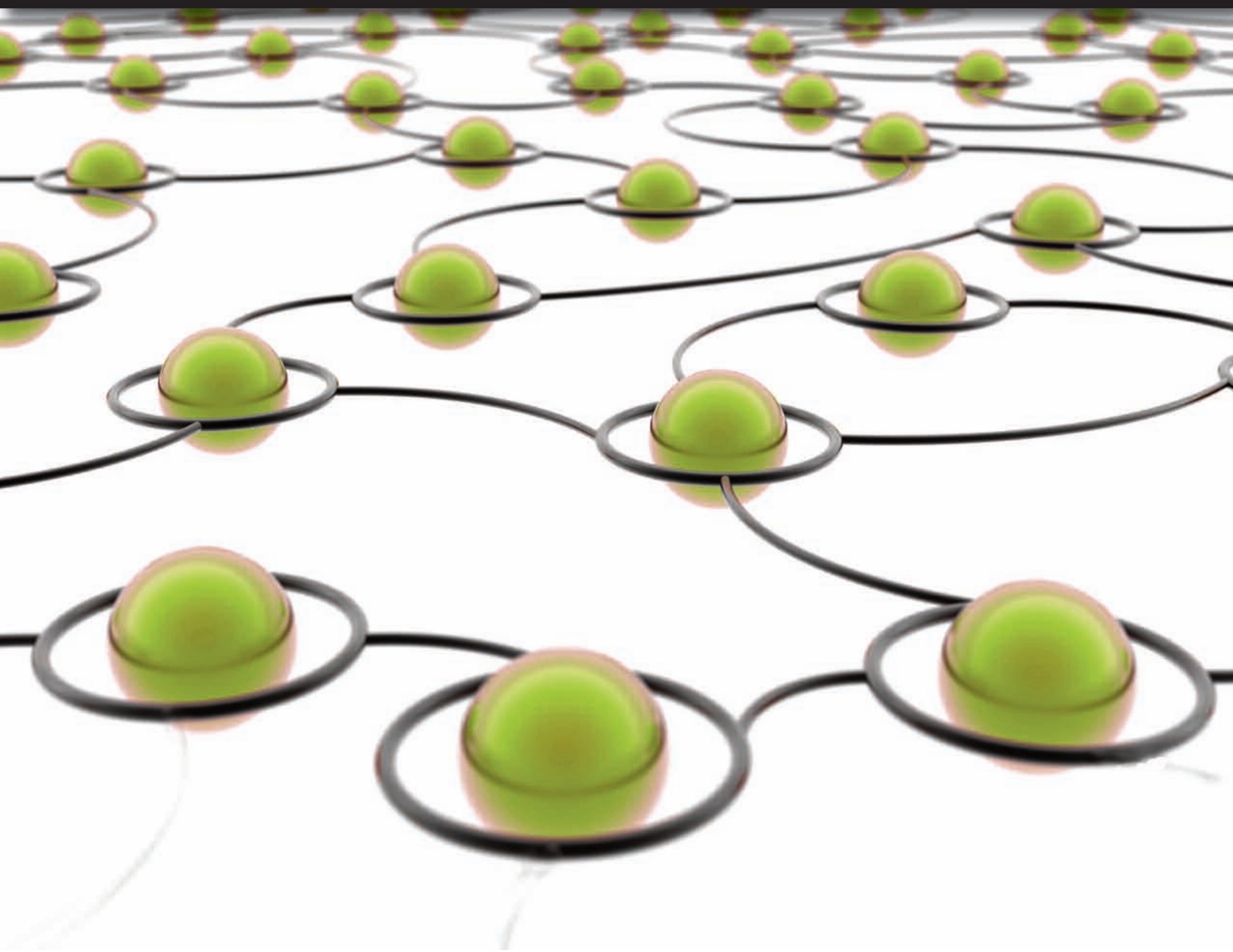
November 2009

Accelerated Climate Technology Innovation Initiative (ACT II):

A New Distributed Strategy to Reform the U.S. Energy Innovation System



CleanEnergyGroup
Innovation in Finance, Technology & Policy

Meridian Institute
Connecting People to Solve Problems

Acknowledgements

The design phase of the **Accelerated Climate Technology Innovation Initiative (ACT II)** is funded by the National Commission on Energy Policy, a project of the Bipartisan Policy Center in Washington, DC, (www.energycommission.org), and is led by Clean Energy Group (www.cleanegroup.org) and Meridian Institute (www.merid.org).

This paper is the result of extensive consultations with companies, governments, NGOs, academics and other individuals over the past several years. Meetings have been held in Berlin, London, Paris and Washington, DC, with experts in clean energy technologies, climate change, innovation, finance, intellectual property rights, information technology, agriculture, health and other fields. Clean Energy Group and Meridian Institute are thankful to the governments of Germany and the United Kingdom as well as to the Oak Foundation and the Rockefeller Brothers Fund for supporting the early, foundational work upon which this paper is built. We are especially grateful to the National Commission on Energy Policy for supporting the development of this paper and the associated design charrette, which focused on developing a detailed distributed innovation structure and strategy for clean energy technologies in the United States.

About Clean Energy Group and Meridian Institute

Clean Energy Group (CEG), a national U.S. nonprofit organization, promotes effective clean energy policies, develops low-carbon technology innovation strategies and works on new financial tools to stabilize greenhouse gas emissions. CEG concentrates on climate and clean energy issues at the state, national and international levels, as it works with diverse stakeholders from governments as well as the private and nonprofit sectors.

CEG assists states to create and implement innovative practices and public funding programs to advance clean energy markets and project deployment; creates networks of U.S. and international policy makers to address climate stabilization; advances effective, 21st century distributed innovation theories for climate technology; develops new finance and commercialization tools; and works to attract new investors to move clean energy technologies to the market more quickly. CEG's work is designed to greatly accelerate the commercialization of breakthrough low-carbon technologies and to massively scale up existing clean energy technologies as rapidly as possible to strengthen the economy and stabilize climate change emissions. CEG is supported by major foundations, state governments and federal agencies.

Founded in 1998, CEG is headquartered in Montpelier, Vermont, with additional staff based in Washington, DC, and Chicago. In 2002, CEG created and now manages a separate, national nonprofit alliance of 20 state-based, U.S. public clean energy funds and programs — Clean Energy States Alliance or CESA.

Meridian Institute helps decision makers and diverse stakeholders solve some of society's most contentious public policy issues. Meridian's professional mediators offer expert process design and facilitation, understanding of and experience with policy development and implementation, ongoing working relationships with diverse stakeholders, and in-depth substantive understanding of issues associated with the integration of environmental, economic and social priorities.

For over 20 years, Meridian Institute professionals have brought objectivity, process expertise, substantive knowledge, trust and patience to our projects. As neutral third parties, we design problem-solving processes, applying proven strategies and techniques to highly controversial public policy issues. We also aid parties in settling site- and issue-specific disputes. Our practical approach often results in unlikely parties forging new partnerships and unique alliances. In our projects, we work with all involved parties to create the right conditions for creative, practical solutions and mutually beneficial agreements that can be effectively implemented.

Above all, Meridian stands for impartiality, integrity, inclusiveness and respect for differences. We bring these values to processes that connect people to solve problems and make informed decisions in three major areas: Multi-Party Problem Solving, Strategy Assessment and Planning, and Leadership in the Theory and Practice of Collaboration.

We will devote more than 3 percent of our GDP to research and development.... This represents the largest commitment to scientific research and innovation in American history. Just think what this will allow us to accomplish: solar cells as cheap as paint....

U.S. President Barack Obama, 2009[1]

Another myth is [that] we have all the technologies we need to solve the energy challenge. It's only a matter of political will.... I think political will is absolutely necessary...but we need new technologies to transform the energy landscape.

U.S. Secretary of Energy Steven Chu, 2008[2]

The lesson I learned is that you don't even have to be brilliant if you are the first to look at something with a new tool.... If you use an old tool to tackle a problem, you've got to be really smarter than the rest of the folks because everybody has this tool. If you are the first to look with something new it's like starting a new world. You just look around and everything you see is going to be new.

U.S. Secretary of Energy Steven Chu, 2004[3]

We are in danger of learning the wrong lessons about innovation. As a result, we risk neglecting those capabilities that are the real well-springs of creativity...the capacity to integrate across organizational, intellectual, and cultural boundaries, the capacity to experiment, and the habits of thought that allow us to make sense of radically ambiguous situations and move forward in the face of uncertainty.

MIT Professors Richard Lester and Michael Piore, 2004[4]

Strategy too often neglects the question of how to get there. Yet, especially when innovation matters, the strategy is the organization.

Stanford University Professor Kathleen Eisenhardt, 2003[5]

Table of Contents

DISCLAIMER

The development of the Accelerated Climate Technology Innovation Initiative report was funded by The National Commission on Energy Policy (NCEP), a national nonprofit group. The presentation of the material in this publication does not imply the expression of any opinion or endorsement whatsoever on the part of NCEP or the Bipartisan Policy Center. The responsibility for the content of this report lies solely with the authors.

Executive Summary

For years, scientists and environmental advocates have been ringing alarm bells about the issue of climate change. Recently, the issue has begun to gain traction with the public and policy makers. At the same time, however, it has become clear that the scale and urgency of the problem are far more serious than even many climate policy advocates acknowledge. A recent *Nature* article suggests, for example, that the scale of the "technology challenge" required to help resolve the problem has been "seriously underestimated" by the Intergovernmental Panel on Climate Change.[6]

The fact is, solving the climate problem will require the fundamental transformation of the world's entire energy technology base over the next 50 years. And because our need for energy continues to grow, we must develop a carbon-free energy infrastructure in 50 years that is twice as large as our current energy infrastructure. To meet this massive challenge, we must not only accelerate the deployment of existing technologies, we must radically speed up the process of clean energy technological breakthroughs.[7]

The current research, development and deployment (RD&D) system[8] in the energy sector has produced many important and useful technologies over the years. However, this system is simply not adequate to the task of the massive scale-up and technology innovation needed at the required speed to address climate change. The system's failings have been well documented in recent reports by the Center for American Progress and the Brookings Institution,[9] as well as in a forthcoming report by the National Commission on Energy Policy. These reports argue, for example, that the current system is underfunded, fragmented, lacking coordination and collaboration, disconnected from the market and lacking a strategy for addressing intellectual property rights (IPR) and finance issues, among other problems.

With these pressing concerns in mind, Clean Energy Group and Meridian Institute came together in 2006 to seek effective and efficient ways to accelerate climate-related technology innovation. After extensive consultations with companies, government agencies, nongovernmental organizations and academics, we jointly developed a concept we call the *Accelerated Climate Technology Innovation Initiative*, or ACT II.

Distributed Innovation: A New Strategy for Technology Breakthroughs and Scale-Up

We do not propose displacing the existing energy-related RD&D system. Instead, the ACT II proposal suggests leveraging and more efficiently coordinating existing physical and intellectual resources using a set of strategies and tools collectively known as distributed innovation, or DI. ACT II complements a number of recent energy technology innovation proposals, including ARPA-E, DOE's Energy Hubs and Brookings' e-DII centers. ACT II can serve as a next-generation institutional "operating system" for these and other innovation strategies. It can begin to answer the question of "how" these new institutions would operate day to day to optimize the pace and the prospects for successfully advancing a carbon-free energy base with proven distributed innovation strategies.

Distributed innovation refers to the process of linking together numerous people with disparate expertise working in different institutions and countries, but united together in a single effort focused on product development and deployment. The business literature defines DI as "the process of managing innovation both within and across networks of organizations that have come together to co-design, co-produce and co-service the needs of customers."[10] The driving objective for distributed innovation

> From the perspective of a venture capital (VC) investor in clean energy, distributed innovation has many potential benefits. Right now the system of bringing new clean energy ideas from lab to commercial market is one filled with gaps, frictions and other problems. It is largely uncoordinated, making efficient and smarter investment difficult. The current process significantly increases investor risk. With a more coordinated approach through DI, VC investors could work more upstream in the value chain, see earlier investment opportunities and help accelerate product development, thus reducing investment risk. At least that is my hope, and why I think DI is worth trying for many low-carbon technologies.
>
> — Nancy Floyd, Founder and Managing Director, Nth Power

> We need many new breakthrough low-carbon technologies to address the climate change problem. To do so, we must accelerate the lab-to-market process, creating more commercially ready technologies in much shorter time frames. From the perspective of an active researcher in clean energy, I see potential value in distributed innovation if it brings in intellectual property rights and finance experts to work more directly and earlier with technology researchers, and opens up promising research areas to more productive ideas. This DI process could help anticipate and overcome technical barriers in both finance and IPR, and possibly move lab research more quickly into the product marketplace. We need many new models of technology innovation to address climate, and DI — along with others — is certainly one worth exploring in the field of low-carbon technology.
>
> — Nathan Lewis, George L. Argyros Professor and Professor of Chemistry, Division of Chemistry and Chemical Engineering, California Institute of Technology

is to accelerate the deployment of a specific technology by attacking the problem from multiple intervention points along the value chain, from upstream research to downstream deployment. It involves addressing the technical, market, financial, policy, regulatory and legal issues that arise along this entire chain. Distributed innovation uses creative approaches for reducing risks through targeted funding and finance strategies, and managing intellectual property rights in a manner that that enables collaboration and preserves the power of the market and competition.

DI is a new term in energy but one well known in other private and public sectors, from pharmaceuticals to consumer and agricultural products. In fact, DI strategies have been used to develop products, services and scientific breakthroughs as diverse as the iPod, the Linux operating system, the Human Genome Project, automobiles, pharmaceuticals and drought-resistant crops in the developing world.

Distributed innovation has proven to increase the speed of innovation and commercialization. It removes barriers between experts in specific disciplines that have typically been in "silos." It also bridges the public and private sectors. A review of existing projects using DI strategies concluded that well-structured distributed innovation processes result in reduced transaction costs and more efficient use of resources, among other benefits.[11]

Applying Distributed Innovation to Energy Research, Development and Deployment

Distributed innovation strategies have not yet been systematically applied to clean energy, despite the fact that this sector has many of the same characteristics as sectors that have benefited from DI. DI could provide a powerful approach to speed up clean energy innovation.

ACT II envisions applying distributed innovation concepts to low-carbon technology development, to advance technology breakthroughs and accelerate existing technologies to the scale needed to address the climate challenge. ACT II's distributed innovation strategy has three primary elements: (1) the use of internet-based open innovation tools, (2) coordinated funding and finance strategies and (3) intellectual property rights services. Each element is discussed briefly below.

The Use of Open Innovation Tools

ACT II would more effectively connect people who are encountering specific clean energy technology development challenges with "solution providers" who can help address those problems. Those posing the development challenges may be, for instance, engineers within small or large technology companies, government researchers or academics. The solution providers might include those same kinds of individuals as well as a range of other scientists and technical experts working at different organizations, including institutions outside of the energy sector.

The open innovation platforms and other tools used to enable such collaboration are often called "matchmaking infrastructure." Such an infrastructure would enable potentially tens of thousands of people to review critical challenges and propose innovative solutions. A range of incentives would be employed, including financial rewards to solution providers and cash rewards or a negotiated value for intellectual property rights. More conventional tools, such as commissioned and competitive research projects, could also be utilized.

Such an information technology infrastructure would facilitate effective, real-time collaboration among geographically dispersed players along the RD&D continuum. It would provide consumer-oriented market information to researchers working in laboratory settings, and provide product pipeline information back to the market makers. It would also breach institutional barriers and disciplinary silos.

Coordinated Funding and Finance Strategies

The second key element of ACT II's distributed innovation strategy is its focus on coordinating needed resources for funding (i.e., public money not seeking a return on investment) and finance (i.e., private capital seeking such a return) early on in the product development process. Today, federal funding tends to focus on upstream research efforts and does not generally support diversified financing products to move technologies into the marketplace. That financing is often provided through the private sector. However, promising technologies that do not meet high venture capital goals for return on investment may be "orphaned" and never receive the financial support they need to achieve market penetration. In addition, there is currently little coordination between funders and financers, creating two major potential financial gaps in the RD&D continuum. The first gap is the lack of resources for translating innovative research concepts into market-ready products; the second is the lack of resources to move these products to large-scale, full-market deployment.

> NREL is all about developing breakthroughs in clean energy technology, and we have had many successes in that regard. Over the years, though, we have realized that just developing exciting new technologies is not enough. If we are to meet the climate challenge, we must also commercialize and disseminate those new ideas rapidly and widely. The DI concept mirrors much of our own thinking at NREL. The expanded network approach could have real value in shortening the "discovery to commercialization at scale" time cycle.
>
> — Doug Arent, Director, Strategic Energy Analysis and Applications Center, National Renewable Energy Laboratory (NREL)

ACT II envisions providing or facilitating an integrated, flexible and responsive set of funding and financing mechanisms, so there is continuous financial support at appropriate levels for technology projects throughout all the stages of the development process, from early upstream research all the way through technology development and deployment. ACT II would focus on filling the aforementioned financial gaps by coordinating flows of available resources between interested funders and financers, and supplementing the process with critical financial resources where necessary.

Two key components of ACT II's finance strategy will be to reduce transaction costs along the RD&D continuum, and to mitigate risk for investors so that private capital can take an earlier "stake" in technologies identified. This approach will both lower financial barriers to entry that currently deter some investors and increase the number of stakeholders pushing the technology forward to full deployment. Both early-stage (venture capital) and later-stage (project finance) professionals have attested to the importance of such a coordinated funding approach to accelerate their successful investment decision making and increase the volume of funding they can commit to innovative clean energy technologies. Creating effective incentives for this early involvement by financial players will require both creative financing approaches and innovative IPR strategies.

Intellectual Property Rights Services

Several key reports have underscored how a failure to resolve IPR issues could undermine the innovation and diffusion of clean energy technologies.[12] We envision ACT II to have IPR staff and financial resources that enable it to use IPR as a tool for encouraging innovation, supporting collaboration between the public and private sector and navigating IPR challenges that may arise. In general, ACT II would use IPR to leverage early investment upstream in the product development process. It would also apply analytical tools to develop patent landscapes that enable it to navigate "patent tickets" or blocking patents that may hinder accelerated product development.

Specifically, ACT II would seek to create and leverage more financial incentives up the value chain, at the earlier research stages, so that companies will be more willing to consider creative IPR paths to gain greater financial advantage downstream. ACT II would also provide support for putting in place the licenses, R&D collaborations and other agreements necessary to form strong partnerships to move clean energy technologies more rapidly to market.

This IPR strategy should reduce transaction costs by supporting partnerships and consortia among multiple public- and private-sector organizations. It should also result in high-quality IPR information and analysis early in the research stage. Having IPR issues fully identified and systematically addressed early on can leverage additional investment from the private sector.

Proposed ACT II Institutional Framework

We envision ACT II being implemented via an independent institution managed by a small Executive Leadership Team (ELT) comprised of 6-8 individuals and overseen by a small Board of Directors. This new ACT II institution would link to, but be as independent as possible from, existing clean energy structures and institutions. Such independence would encourage creativity, agility, market sense and innovation, the hallmarks of this new distributed innovation strategy. ACT II's distributed and disaggregated approach and its clear mandate for technology innovation and deployment calls for a flexible, innovative structure — a collaborative, distributed and non-bureaucratic institutional model.

ACT II would prototype its DI approach with one technology area (or "node"), such as advanced photovoltaic (PV) technologies, with the intention to eventually develop a full portfolio of low-carbon technology nodes (e.g., for wind, batteries and storage technology, advanced biofuels, etc.). This would lead to a "hub and spoke" structure, with a central ELT overseeing staff and activities at multiple nodes.

We anticipate that ACT II's initial setup and pilot technology node would need on the order of $30-$50 million per year of funding to reach its accelerated innovation goals. Each additional node would require roughly $25-$30 million per year, depending on the capital intensity of the particular technology, for a range of several years depending on needs. This investment in public funding will likely be multiplied many times by leveraging additional private capital. This funding may be uneven over the project period. In particular, more money may be needed as activities move toward the demonstration and deployment of new technologies.

As much as 90 percent of this funding would be dedicated directly to RD&D. Management and overhead of ACT II, ELT staff salaries, IT systems, central office expenses and travel would be small — approximately 10 percent of the funding. Some remaining portion could also be dedicated to DI capacity building in other institutions.

> As a leading investor in renewable energy projects, Wells Fargo understands the important role that new advancements in clean energy technologies will play in the necessary transition to a low-carbon economy. However, the challenges associated with financing energy projects that use new technologies with a limited deployment history are significant. An approach like ACT II, with its emphasis on the development and deployment challenges facing the introduction of new technologies, could provide a needed boost to the speed and scale of the expansion of the clean energy sector.
>
> — Ryan Levinson, Vice President, Environmental Finance, Wells Fargo

The full ACT II concept paper sets forth detailed next steps for establishing the ACT II institution and beginning work on the first technology node.

> For clean energy, there is a driving need to move technologies from the lab to the market quickly, and with the potential for large-scale delivery. Depending on the current landscape of IPR services means risking that the potential impact of investment in a technology may be diminished due to IPR issues. A distributed innovation initiative, which has the goal of helping universities, small and large companies, national laboratories and other researchers successfully deliver technologies to market, will need the capacity to provide IPR analysis, assistance in creating IPR strategies, and the ability to help structure agreements among multiple parties to ensure the strategy is implemented.
>
> PIPRA is a not-for-profit organization whose mission is to enable innovations in the public sector to have the largest possible impact and public benefit. By combining technical, business and legal expertise, PIPRA delivers technology-specific IPR and commercialization strategy services across the fields of agriculture, health and energy. PIPRA will work with ACT II to provide IPR services that help accelerate the speed of clean energy commercialization.
>
> — Sara Boettiger, Director, Strategic Planning and Development,
> Public Intellectual Property Resource for Agriculture (PIPRA), University of California

Section 1 | The Climate Challenge

For years, scientists and environmental advocates have been ringing alarm bells about the issue of climate change. Recently, the issue has begun to gain traction with the public. At the same time, it has become clear that the scale and urgency of the climate emissions problem are far more serious than even many climate advocates admit.

The G8 leading industrialized nations recently set a goal to limit global warming to 2°C above pre-industrial levels, which will require stopping carbon dioxide (CO_2) emissions growth in the next decade and then beginning a rapid emissions decline. The G8 nations also set a goal to reduce their emissions by 80 percent by 2050 compared to 1990.

Meanwhile, global energy demand is projected to more than double by 2050, and to more than triple by the end of the century.[13]

Today's technologies are not sufficient to meet these growing energy needs while reducing emissions as required, as Figure 1 makes clear. Caltech professor Dr. Nathan Lewis writes: "Incremental improvements in existing energy networks will not be adequate to supply this demand in a sustainable way."[14] And in a recent *Nature* article, scientists suggest that the scale of the "technology challenge" to resolve the climate change problem while meeting growing energy needs has been "seriously underestimated" by the Intergovernmental Panel on Climate Change."[15]

Figure 1 | Carbon Emissions Trajectories

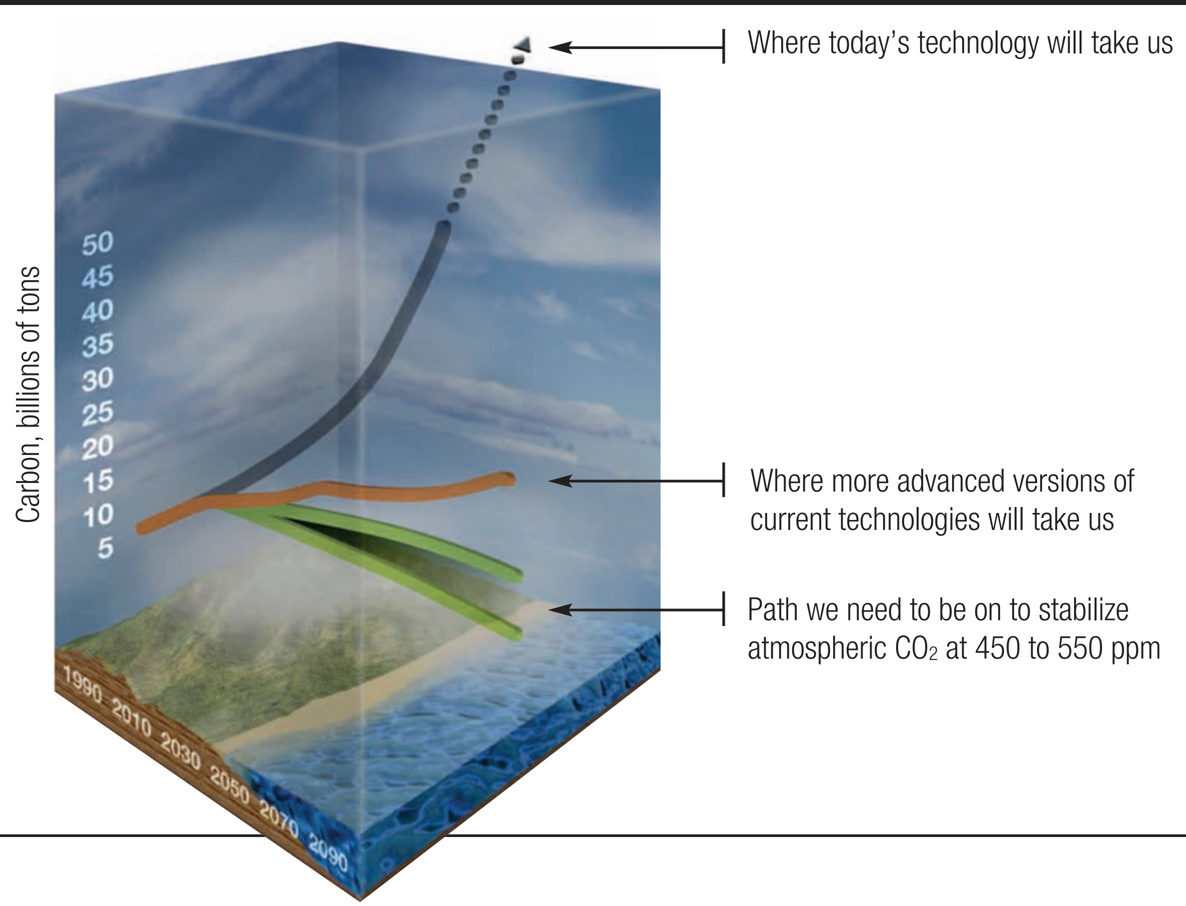
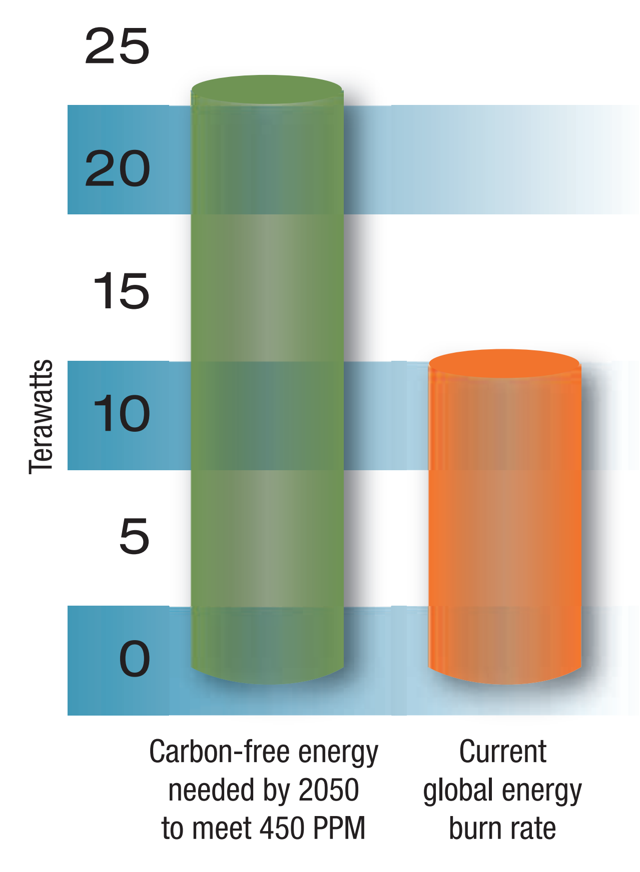


Figure 2 | Carbon-Free Energy by 2050 [16]



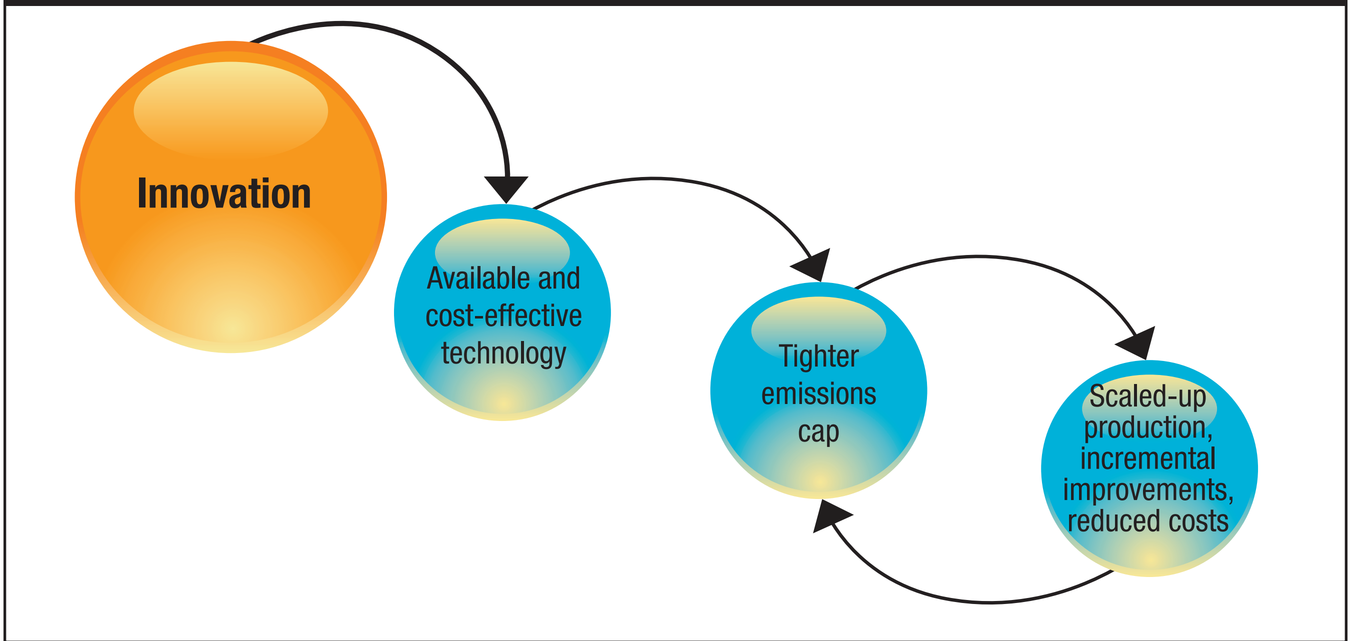
Source: Martin I. Hoffert, et al., "Energy Implications of Future Stabilization of Atmospheric CO_2 Content," *Nature* 395 (1998): 881-884.

To achieve stabilization levels of 450 to 550 ppm, new carbon-free energy in the range of 22-25 terawatts (TW) is needed. By comparison, the planet currently uses around 13 TW of total energy. (See Figure 2.) We thus must develop a carbon-free energy infrastructure in 50 years that is twice as large as our current energy infrastructure, which includes all power plants, vehicles, industries and buildings on the planet today.

In short, then, solving the climate problem will require the fundamental transformation of the world's energy technology base over the next 50 years. To meet this massive challenge, we must not only accelerate the deployment of existing technologies, we must radically speed up the achievement of technological breakthroughs. Clearly, new, powerful and rapidly scalable technologies are needed in the next decade that fundamentally "change the game" in the realm of energy generation.

It's important to note that carbon price incentives — one climate solution much discussed of late — will not on their own produce breakthrough technologies nor lead to the deployment of such technologies on the necessary scale.[17] In fact, carbon pricing, such as cap-and-trade systems, typically encourages the deployment of the cheapest existing low-carbon technologies and energy-efficiency measures (often called "no regrets" policies). Such systems do not create incentives for investment in expensive breakthrough technologies. That's because governments

Figure 3 | Technology Innovation Supports Cap-and-Trade



will generally only agree to caps that can be achieved with currently available technologies at reasonable projected costs. Also, any caps established are usually insufficient to drive deep and radical innovation; instead, they tend to drive incremental technical improvements and marginal cost reductions.

By contrast, as illustrated in Figure 3, specific technology innovation[18] measures can drive down the current cost of more expensive technologies, which could make it possible to adopt tougher emissions policies in the future. There is thus virtual consensus that, in addition to emissions caps, the challenge of climate recovery demands a complementary process that drives technology research, development and deployment (RD&D).

Noted experts support a dual track because it is likely to be the most cost-effective approach. One climate policy expert writes:

> To promote [induced technological change] and reduce [greenhouse gas] emissions most cost-effectively, two types of policies are required: policies to reduce emissions and incentives for technological innovation…. Technology incentives can deal with the market failure created by firms' inabilities to capture all the returns on their RD&D investments. Direct emissions policies (such as carbon caps or carbon taxes) can deal with the market failure created by climate-related externalities. Attempting to address the climate change problem with only one of these policy approaches cannot fully correct both market failures. As a result, adopting one approach is likely to involve higher costs than utilizing the two approaches in tandem.[19]

Ironically, because it does not reduce technology costs, pursuing only cap-and-trade in its current form may make it harder to adopt tougher emissions policies in the future. Another expert explains:

> …even though "no regrets" might be attractive as a short-term response, restricting actions to such low-cost alternatives alone may entrench existing technologies and constrain the development of new technologies needed to reduce the costs of future abatement actions. This may in effect also reduce the opportunity for the global community to define more ambitious emission reduction targets for future commitment periods.[20]

Despite this consensus on what needs to be done — both cap-and-trade and technology innovation — remarkably little attention has been paid to how to accomplish the latter. We believe that new strategies — collectively termed *distributed innovation* — offer tremendous promise. We discuss these strategies in Sections 3 through 5 of this paper, after first looking at the limits of the existing technology innovation system in Section 2.

Section 2 | Limits of the Current U.S. Research, Development and Deployment System

The major organizational players in the current energy-related research, development and deployment system include the U.S. Department of Energy (DOE), the U.S. national laboratories, state governments, public and private universities, private-sector technology companies (established and startup), utilities, venture capital firms and financial institutions, among others. The players in this system have produced some important and useful technologies, including most energy-efficient lighting and initial Integrated Gas Combined Cycle power systems. In addition, there are a small but growing number of innovation and collaborative research success stories.

One positive example of collaborative research, for example, is the Energy Biosciences Institute (www.energybiosciencesinstitute.org), a partnership between BP; the University of California, Berkeley; the Lawrence Berkeley National Laboratory; and the University of Illinois. This partnership is seeking breakthroughs in sustainable biofuels production. In addition, Battelle, which manages four DOE labs, has recently increased its focus on improving the process of commercializing technologies developed by the national labs. The National Renewable Energy Laboratory (NREL) has also demonstrated its commitment to broader outreach, through the direct involvement of venture investors under its Entrepreneur-in-Residence Program and enhanced commercial collaborations under its Solar America Initiative. These new efforts are beginning to demonstrate the potential for a more systematic approach to integrating the country's clean energy research agenda.

Despite this progress, the current energy RD&D system is simply not adequate to the task of the technology innovation and massive scale-up needed at the required speed to address the climate problem. There are many failings all along the technology development value chain — from basic research through full-scale technology deployment — that have been well documented in two recent reports by the Center for American Progress and the Brookings Institution, as well as in a forthcoming report by the National Commission on Energy Policy.[21]

The U.S. Secretary of Energy's Advisory Board itself concluded that, "The Department of Energy has a historically poor reputation as being badly managed, excessively fragmented, and politically unresponsive. The current organization of the Department is not appropriate to the magnitude and centrality of the scientific advanced technological research required by our energy challenges."[22]

The aforementioned reports suggest that the current RD&D system for clean energy:

- **Lacks adequate funding:** Both public funding and private investment are insufficient for the scale of the technology innovation effort needed. The RD&D regime does not provide an integrated capital mobilization stream that supports technology development from the funding for basic research through the financing required for large-scale deployment and diffusion of a technology.[23] Current annual investments in clean energy RD&D fall far below the $20 billion that some experts believe is necessary.[24] The Center for American Progress report argues that federal RD&D funding should be substantially increased.[25] The current system also does not address the multiple market failures that limit private investment in RD&D.[26]

- **Is fragmented:** The RD&D system is made up of hundreds of disconnected departments, agencies and laboratories across the U.S. Many of these labs and departments are siloed, working separately on energy-related research. Such siloing was encouraged during the Cold War but no longer serves national interests for rapid innovation.

- **Lacks coordination and collaboration among actors:** The current system does not sufficiently promote collaboration across institutions (e.g., among universities, national laboratories and the private sector), nor does the system adequately engage state governments with federal technology policies.[27]

- **Is based on an obsolete research paradigm:** The federal approach to RD&D today is linear, sequential and based in an early 20th century mentality, rather than being circular, dynamic and attuned to 21st century theories of innovation strategy.[28] One result is that federal labs are too focused on their existing portfolios to support transformational research into truly breakthrough technologies.

- **Is disconnected from the market:** Current public RD&D is too far removed from the marketplace. DOE's product development practices differ dramatically from commercial practices. Any product orientation the DOE does have is focused on near-term technologies. Moreover, public RD&D institutions have little effective engagement or interface with private industry.

- **Is ineffective at commercializing innovative low-carbon technologies:** Today, federal funding tends to focus on upstream research efforts and does not generally support diversified financing products to move technologies into the marketplace. That financing is often provided through the private sector. However, promising technologies that do not meet high venture capital goals for return on investment may be "orphaned" and never receive the financial support they need to achieve market penetration. In addition, there is currently little coordination between funders and financers, creating two major potential financial gaps in the RD&D continuum. The first gap is the lack of resources for translating innovative research concepts into market-ready products; the second is the lack of resources to move these products to large-scale, full-market deployment.[29]

- **Lacks federal support for deployment:** There has been limited federal support for the deployment of clean energy technologies. Instead, that role has been played almost exclusively by states, through mechanisms such as state clean energy funds.[30] As noted in the Brookings paper, "State governments are central players in energy policy due to their responsibilities for regulating energy providers and for implementing federal environmental regulations."[31] However, there is no effective deployment partnership between the federal and state governments on energy and climate.

- **Is slow and inefficient:** The time required to move a breakthrough technology from the lab to clean energy markets is inadequate to the urgent need. Also, the ratio of commercial products "out" to federal dollars "in" is simply too low.

In short, a successful technology innovation policy will require a fundamentally different paradigm than the current research, development and deployment system in the U.S. As the Center for American Progress report notes: "If the United States simply continues to pursue energy innovation as it has in the past, then the path to a low-carbon economy will be much longer and costlier than necessary."[32]

To ensure that does not happen, we propose leveraging and more efficiently coordinating existing physical and intellectual resources by prototyping new innovation strategies and tools, as discussed in the following sections.

Section 3 | The Use of Distributed Innovation for Technology Breakthrough and Scale-Up

To address and mitigate the shortcomings noted in the previous section, we propose creating an Accelerated Climate Technology Innovation Initiative, or ACT II. As we envision it, ACT II would form the foundation for a new energy innovation policy in the United States that leverages modern-day innovation strategies to accelerate the development and full deployment of "disruptive" clean-energy technologies.

Any new, successful technology innovation policy will require scaled-up funding for RD&D, but also a new way of directing that funding. In other words, more is not good enough; we need a different strategy altogether. We need a new system that encourages innovation and accelerates the time frame from lab to full market deployment by more effectively linking players along the value chain and accessing creative solutions from dispersed organizations and individuals. The DOE's own review emphasized, "The federal government alone cannot meet the nation's energy-related RD&D needs. The Department of Energy must collaborate with universities, industry and other federal agencies. It should…form partnerships with industry and academia to drive innovation."[33] We believe the ACT II proposal will effectively enable this to take place.

This section describes the current context or landscape in which ACT II will be implemented. It then introduces the major concept behind ACT II — *distributed innovation*.

The Current Landscape

In designing a new innovation architecture for energy, the changing realties of our 21st century world must be considered. The following are the primarily characteristics of the current energy innovation landscape:

- **Knowledge management:** Organizations today are finding themselves in an era of rapid knowledge creation and continuous scientific and technological change. Advances in science and technology-driven research have yielded dramatic increases in the volume of scientific knowledge. This volume of information makes it increasingly difficult for most organizations to stay current with significant new trends. Ultimately, their inability to stay apprised of new knowledge and their limiting of research to in-house resources has reduced efficiency and competitiveness.

- **Connectedness and collaboration:** Many organizations are realizing that, although they may have hired the best and brightest people in their fields, people in related industries or with related areas of expertise are necessary for maintaining product relevance and ongoing competitive advantage. Current energy RD&D strategies keep individual researchers and experts cut off from new solutions by institution, geography and their position along the technology value chain. Opportunities for collaboration among organizations across the globe have vastly expanded because of improvements in information and communication technologies — most notably the Internet and web. These technologies can quickly and easily combine the knowledge of thousands of individuals in ways that were impossible a decade ago.

- **Intellectual property rights (IPR):** IPR strategies have changed significantly and, if not appropriately managed, can potentially slow the development and diffusion of clean energy technologies. Creative new strategies can address IPR barriers and manage IPR to provide incentives for product development from diverse sectors. These strategies can be successfully applied to clean energy innovation.

- **Funding and finance:** A final characteristic of the new clean energy innovation landscape is the high likelihood of increased federal investment in clean energy technology and, in comparison to other sectors, a strong interest among the venture capital and private equity communities.

Distributed Innovation

New business strategies and tools — collectively called *distributed innovation* (DI) — have evolved to address this changing innovation landscape. The term distributed innovation refers to global, collaborative product development initiatives that link together numerous people working in different institutions and countries with disparate expertise, but united together under a single project focused on product development and deployment.[34] The business literature defines DI as "the process of managing innovation both within and across networks of organizations that have come together to co-design, co-produce and co-service the needs of customers."[35] DI uses the latest information technology, collaboration tools and "open innovation" approaches to supplement in-house research and development capacity.

As two experts on distributed networks write: "The innovation process has taken on a more integrated and networked model."[36] This "networked model" is not a conventional information-sharing network, however, but rather an entirely new approach that goes beyond linking existing institutions. It makes those institutions work together in new collaborative ways.

Distributed innovation accelerates the deployment of a specific technology by attacking the problem from multiple intervention points along the value chain, from upstream research to downstream deployment. The issues addressed along this chain may include, but are not necessarily limited to: technical; market and financial; policy; regulatory; and legal (including IPR) issues.

Distributed innovation strategies ensure that a broad institutional infrastructure is in place that supports the judicious use of resources by efficiently transforming upstream research into new technologies that penetrate the market. This type of collaboration builds linkages all along the value chain (from upstream RD&D to downstream deployment) and across dozens, hundreds and sometimes thousands of people throughout the world. This borderless environment fosters meaningful collaboration among an array of institutions, but more importantly, it removes barriers between experts in specific disciplines that have typically been in silos. It also bridges the public and private sectors.

Distributed Innovation in Other Sectors

Distributed innovation is a new term in energy but one that is well known in other private and public sectors, from pharmaceuticals to consumer goods to agricultural products. In fact, distributed innovation strategies have been used to develop products as diverse as the iPod, the Linux operating system, the Human Genome Project, Boeing airplanes, automobiles,[37] pharmaceutical products and drought-resistant crops in the developing world. DI thus has a proven track record of success. Though the innovation challenges faced by the energy sector are substantial, relevant lessons can be learned from innovation processes in these other sectors.

In these other fields, DI has overcome some of the same barriers facing energy innovation: lack of connection between laboratories and the marketplace; failure to connect all the elements of the value chain; lack of focus on rapid product development; failure to connect across disparate disciplines; difficult IPR hurdles; and established, insular cultures.

Companies and institutions using DI recognize that:

- There are more smart people outside of their organizations than inside. As Bill Joy, founder of Sun Microsystems, famously said (in what has become known as Joy's Law), "Most of the smart people in the world don't work for your company."[38]

- Successful innovation requires creatively combining internal and external knowledge in new ways and often involves connecting existing but dispersed pieces of knowledge rather than generating new knowledge.

- Collaboration improves innovation, accelerates it and reduces the cost of it. Innovation can arise from the free exchange of ideas between scientists with different backgrounds. The cross-fertilization of ideas, scientific disciplines, experiences and minds enables scientists to tap creativity on a scale that is beyond the reach of any individual or small group working in academia, government or industry alone.

- Solutions to problems often come from unexpected places. The origin, quantity and diversity of solutions, and the breadth of expertise available to develop those solutions, continues to surprise organizations that have employed these methodologies.

Examples of Successful Distributed Innovation

The following examples show how distributed innovation methodologies have been used effectively in other sectors.

The Generation Challenge Programme (GCP, www.generationcp.org) is a global project involving well over 100 scientists in more than 30 countries who are collaborating to develop improved rice, maize and other crop varieties. The GCP was created to better link upstream research activities with downstream product development, testing and deployment activities. It brings together major agricultural centers to focus on product development in shorter time frames.

The GCP grew out of a reform agenda for the Consultative Group on International Agricultural Research (CGIAR). The CGIAR is a global partnership of governments, research institutes and private foundations working to improve agricultural science and food security for the poor. It was established in the 1970s as a network of individual research centers in the developing world and is widely recognized as being a key player in the "Green Revolution."[39] Despite its early success, the CGIAR's accomplishments have slowed in the past few decades because of "increasingly fragmented and restricted project- and Center-based programming and funding."[40] The traditional loosely networked "centers of excellence" approach was not capable of solving the complex agricultural challenges facing the developing world today.

The GCP recognizes that no single institution could command the breadth of expertise and resources necessary to achieve these objectives. Thus, it employs a distributed innovation strategy that leverages intellectual and physical resources — funds, skills, equipment, knowledge and social capital — from many institutions and initiatives, public and private. This structure provides the agility needed to capture emerging opportunities, promote innovative partnerships and develop appropriate product delivery schemes.

InnoCentive (www.innocentive.com) is an example of an innovation platform that has emerged to support distributed innovation. InnoCentive hosts an internet-based platform that posts scientific problems from its clients (the "seekers") to a global network of more than 170,000 registered "solvers" from more than 175 countries. The seekers include pharmaceutical, biotechnology, consumer goods and specialty chemicals companies such as Eli Lilly, Procter & Gamble, Avery Dennison and Janssen, as well as The Rockefeller Foundation. Solvers offer solutions to each problem for a pre-specified money award; all IP is transferred to the seeker. Since 2001, more than 800 problems that could not be solved by the RD&D laboratories of some 50 clients have been posted. About 50 percent of the posted problems have been solved, with almost $4 million paid out to successful solvers.[41]

One example of success from InnoCentive comes from the Ocean Spill Recovery Institute, which in 2007 was seeking a way to separate frozen oil from water in oil recovery barges. This challenge was solved by a chemist from the concrete business with no experience in the oil industry. He successfully adapted a tool from the cement industry that was designed to vibrate cement to keep it in liquid form.

In InnoCentive's original business model, the solvers work independently and do not share their knowledge or solutions with each other. Recognizing the limitations of this format and learning from the experience of their solvers, last year InnoCentive launched a new initiative to support and encourage teams of innovators to work together on challenges through shared workspaces and new IP governance structures.

The Benefits of Distributed Innovation

Companies engage in distributed innovation not only because it speeds the process of innovation and commercialization, but also because there are significant cost- and risk-sharing benefits. When IBM, for example, adopted the open-source Linux operating system and tapped into the skills of the global Linux community, the company was able to cut their investment costs to upgrade all their product lines at one-fifth the normal investment required to upgrade a single product. And, the resulting products were "better tested, more robust and market-ready more immediately."[42] Similarly, Proctor & Gamble, which has pursued an aggressive distributed innovation model, has increased R&D productivity by nearly 60 percent, doubled their innovation success rate and reduced the cost of innovation significantly.[43]

Here, two DI experts expound on the benefits of the concept:

> Organizations undertake distributed innovation with suitable partner organizations to allow shared risk, reduced costs and access to readily available skilled staff. The benefits of collaborating can be viewed in terms of knowledge creation, dissemination, exploitation and learning. . . . Another reason why organizations engage in distributed innovation is to acquire scarce competencies or technology that they do not possess themselves. Given the complexity of modern products and the degree of regulation required, the innovation process requires significant specialist resources to support the development stages of a new product. . . .
>
> Thus, through the amalgamation of the core competencies of a number organizations, the capacity of the innovation process of a distributed network can be considerably larger and better resourced than that of an internally focused one.
>
> No one organization has the internal capacity to scan all areas of innovative opportunity within the sector. By engaging within a distributed network, the exchange of knowledge between network nodes concerning breakthroughs and interesting leads grows exponentially.[44]

A review of existing projects using DI strategies concluded that well-structured distributed innovation processes result in reduced transaction costs; more efficient use of resources; high trust among collaborators; self-organizing teams of collaborators; and dense, clustered networks of collaborators who are similarly qualified and motivated.[45]

To address the climate crisis at the speed and scale necessary, we need new, modern low-carbon innovation strategies. Instead of dividing responsibility among many government and private agencies for different elements of the innovation chain, we envision a new approach to link those efforts toward accelerated commercial goals. Current government policy is based on the outdated and divided linear model. Our ACT II proposal presents a more integrated, dynamic model that is based on distributed innovation and that links all elements of the innovation chain through a networked process. Our proposal is discussed in depth in the next section.

Section 4 | The Application of Distributed Innovation to Energy RD&D via ACT II

Distributed innovation is a powerful approach that would significantly speed up clean energy innovation. Our proposal — the Accelerated Climate Technology Innovation Initiative — will apply DI innovation strategies to low-carbon technology development, to advance technology breakthroughs and accelerate existing technologies to the scale needed to address the climate challenge.

We do not propose displacing the existing energy-related RD&D system. Instead, the ACT II proposal suggests leveraging and more efficiently coordinating existing physical and intellectual resources using a set of strategies and tools collectively known as distributed innovation. While ACT II is envisioned as an independent initiative that effectively harnesses and coordinates existing expertise and resources, the strategies at the core of the ACT II proposal can serve as a next-generation institutional "operating system" for a number of recent energy technology innovation proposals, including ARPA-E, DOE's Energy Hubs and Brookings' e-DII centers.[46] It can begin to answer the question of "how" these new institutions would operate day to day to optimize the pace and the prospects for successfully advancing a carbon-free energy base with proven distributed innovation strategies.

Given the extraordinary complexity of the climate and energy problem, different strategies are needed to accelerate multiple clean energy technologies. Solutions will vary from technology to technology based on the technical, institutional, financial and other constraints that limit or inhibit scale-up or advances. Distributed innovation, with its decentralized and bottom-up approach, seems the perfect fit to apply to these challenges.

ACT II's distributed innovation strategy has three primary elements:

1. Supporting research, development and deployment with **open innovation tools** (widely used in some sectors, but underutilized in the energy sector), in addition to more conventional tools (e.g., commissioned and competitive projects);

2. Establishing **funding and finance strategies** that drive innovation along the RD&D continuum by increasing coordination and reducing risk and transaction costs for key players in each phase of RD&D; and

3. Providing **intellectual property rights services** that enable ACT II to use IP as a resource for engaging participants and financing, while also solving IP challenges (e.g., patent "thickets" and blocking patents).

We will look at each of these elements in detail in a moment. First, it bears noting what the ACT II strategy is capable of achieving. ACT II will:

- **Support the accelerated development and deployment of *breakthrough* clean energy technologies and the scale-up of existing technologies.** ACT II is focused on goals that can fundamentally change the game in energy and climate. Achieving those goals will yield useful outputs and products along the way, including breakthroughs in the laboratory and the accelerated development and deployment of new *and* existing technologies.

- **Be product-focused**, to rapidly drive upstream research to downstream product development and deployment within defined timeframes.

- **Build linkages among all relevant actors** early in the RD&D process, including academic researchers, national laboratories, government agencies, private companies, financiers, utilities, installers and state deployment funds. It will incentivize their engagement and financing at earlier stages in the RD&D process. This will result in new cross-functional teams that will link the upstream RD&D community with the downstream commercialization, finance and deployment community in an innovative, synergistic manner.

- **Address the whole technology value chain**, from applied research through deployment. ACT II will identify friction points in the RD&D continuum, clear bottlenecks and fill gaps that impede rapid product development.

- **Utilize existing physical and intellectual capital** from public-sector institutions, companies and individuals (through various DI tools) throughout the United States and around the world, including at universities, national laboratories, companies and venture capital firms.

- **Efficiently utilize public funding and private financing** by coordinating key players from the funding and finance communities early in the RD&D process and by shifting funding away from siloed research projects and toward product-focused projects. DI tools can also incentivize private capital to finance technology earlier in the technology development continuum.

- **Produce a replicable model** using one or two individual technologies, for application to a broad suite of low-carbon technologies that could benefit from the distributed innovation process.

- **Develop a truly diverse portfolio of technology options on different time scales** — from short-term solutions to reduce emissions almost immediately to mid-range commercial opportunities in the next 5-10 years, to longer-term, disruptive innovations not yet imagined for energy. All of these options will be designed to create the framework for a long-term, 50-year transitional plan to stabilize greenhouse gas emissions.

Innovation Toolkit

ACT II will rely on information technology (IT) tools and distributed innovation tools, as well as conventional RD&D strategies such as competitive solicitations and commissioned projects.

IT tools will facilitate effective real-time collaboration networks that link geographically dispersed individuals and institutions along the clean energy RD&D continuum. These tools will provide consumer-focused market information to those working in lab settings, and provide product pipeline information back to the market makers. In short, an IT infrastructure will create linkages among all core members of the ACT II community and enable ongoing collaboration.

As discussed in Section 3, new DI tools such as "innovation platforms" are being used in other sectors to solve problems and to accelerate innovation and product deployment. ACT II would use these tools to connect "seekers" who are encountering specific clean energy technology development challenges with "solvers" who can help address these problems. The solvers could include, for example, other companies or academics, including individuals and institutions outside of the energy sector.

These distributed innovation tools, which are often called "matchmaking infrastructure," would enable potentially tens of thousands of people to review clean energy challenges and propose solutions. A range of financial incentives will be employed, including financial rewards to solvers and cash rewards or a negotiated value for intellectual property rights.

Many new companies have been established for just this purpose — to create innovation platforms for use in DI. These include InnoCentive (discussed previously), YourEncore, NineSigma, Innovation Exchange, Oakland Innovation and Science24Seven. These companies differ widely in their breadth, topical focus, business model and value proposition.[47] These are just the kinds of companies that would be an important part of ACT II.

Funding and Finance

ACT II will provide an integrated, flexible and responsive set of funding mechanisms designed to overcome shortfalls and gaps in the current clean energy financing system.

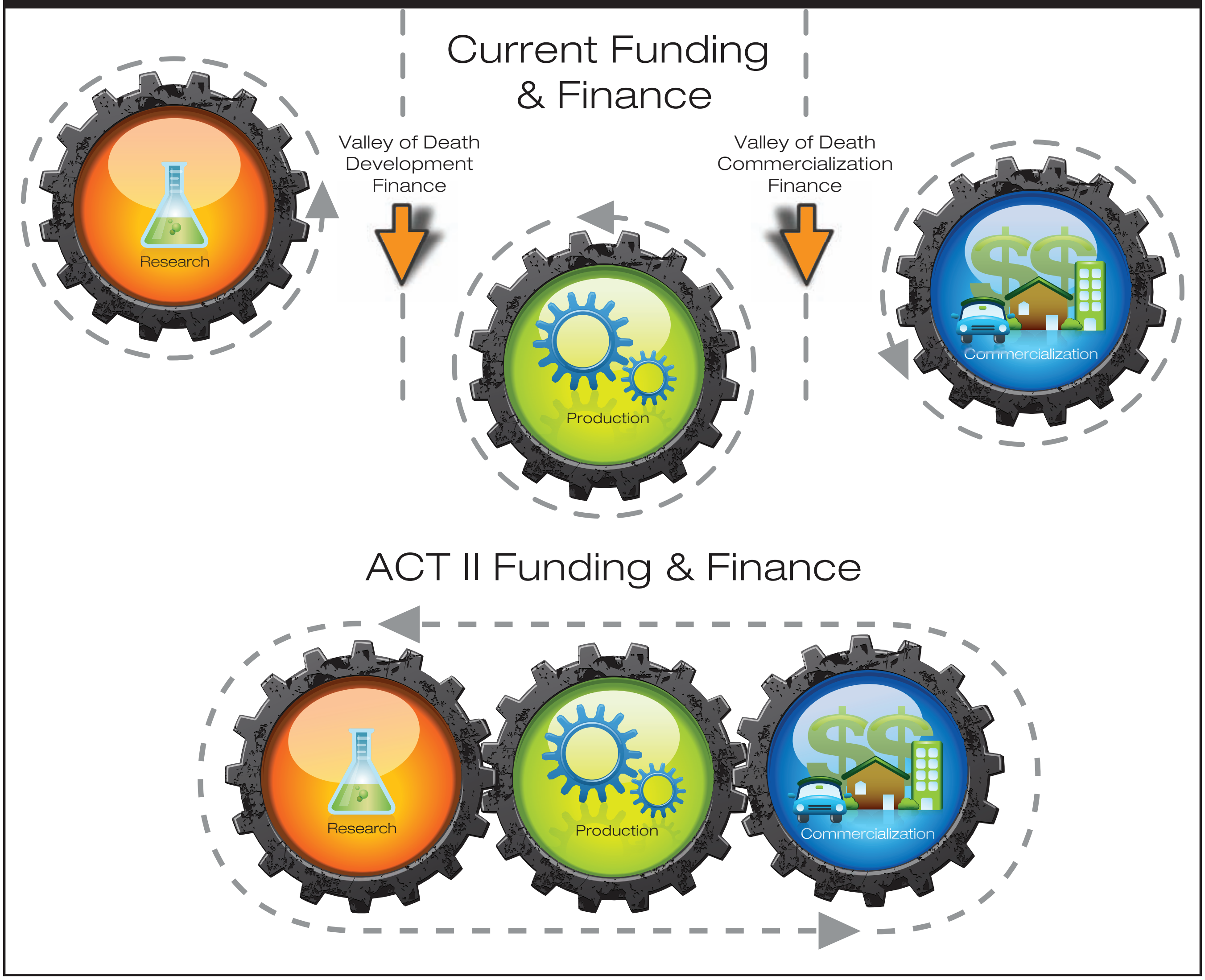
Current financial support for clean energy-related RD&D falls woefully short of what will be needed to spur a massive scale-up of breakthrough technologies. ACT II will reduce transaction costs along the RD&D continuum, thus maximizing the efficiency of existing funding. ACT II will also mitigate risk for private investment, so that private capital can take an earlier stake in technology development (i.e., "get skin in the game"). This will further reduce transaction costs and increase the number of stakeholders pushing a technology forward to full deployment. Creating incentives for this early involvement will require creative IP and financing strategies.

Current funding for clean energy does not support the stages of the RD&D cycle in an integrated way, resulting in the two infamous financing "valleys of death." (See Figure 4.)

- **Development finance gap:** Federal funding supports upstream research efforts, but does not provide the types of diversified financing products needed to support the broad-scale deployment and diffusion of technologies into the marketplace. The first "valley of death" is thus the lack of finance for translating innovative research concepts into market-ready products.
- **Commercialization finance gap:** Promising technologies that do not meet high venture capital goals for return on investment may never receive the level of financial support they need to achieve significant market penetration. The second "valley of death" is thus the lack of finance to move products to large-scale, full-market deployment.

Given its limited resources, ACT II will focus its strategic investments and DI tools on filling these gaps along the RD&D continuum and easing the friction points, in order to provide continuous support for technology projects through all stages of the development process.

Figure 4 | Clean Energy Funding & Finance



ACT II will also address the lack of coordination between funding and finance. On the funding side (i.e., dollars provided without expectation of a financial return on investment), there are only a limited number of actors, including the federal government, some private donors and increasingly state and local governments. On the financing side (i.e., private capital that seeks a return on investment), there are a multitude of participants, including corporations, venture capital firms, private and public equity investors, utilities and state and local governments, to name only a few. But under the current RD&D paradigm, these unrelated parties are likely to act in an uncoordinated fashion, potentially leaving gaps in the needed financing chain. This lack of coordination of the funding and finance cycle increases transaction costs and risks for all participants.

ACT II will focus on coordinating funding and finance early in every product development process. It will aim to increase the overlap and communication between dispersed public and private organizations involved in the currently siloed stages of RD&D, whether they are researchers doing research, startups developing products, large companies going to scale or states deploying technologies broadly. This approach will lower the financial barriers to entry that currently deter some investors and increase the number of stakeholders pushing the technology forward to full deployment. Both early-stage (venture capital) and later-stage (project finance) professionals have attested to the importance of such a coordinated funding approach to accelerate their successful investment decision-making and increase the volume of funding they can commit to innovative clean energy technologies. Creating effective incentives for this early involvement by financial players will require both creative financing approaches and innovative IP strategies.

Intellectual Property Rights

Private companies typically employ in-house or external legal counsel to advise on intellectual property rights issues. But there is currently no institution in the clean energy sector that provides such services to public institutions or academia. A recent report has underscored how a failure to resolve IPR issues could undermine the innovation and diffusion of clean energy technologies.[48] The third key element of ACT II is thus its dedicated focus to solve IPR problems all along the value chain. Indeed, ACT II's success will require that it leverage the power of IPR while also overcoming IPR barriers, real and perceived.

In general, ACT II's IPR strategy will involve, first, using IPR to leverage early investment upstream in the product development process, and second, applying analytical tools to develop patent landscapes that enable ACT II to navigate patent tickets or blocking patents that may hinder accelerated product development. These two steps are critically important, and will affirmatively help players up and down the value chain to think and act in a forward fashion and overcome IPR barriers systematically.

In particular, ACT II's IPR function will:

- Use a proactive IPR strategy as a tool to create new financial opportunities and solutions, thereby encouraging innovation.
- Create and leverage more financial incentives up the value chain, at the earlier research stages, so that companies will be more willing to compromise IPR issues to gain greater financial advantage downstream.
- Identify the friction points in the value chain where IPR issues can be expected to stymie accelerated product development.
- Lubricate those friction points by helping participants, for example, navigate patent thickets or engage key patent holders in licensing arrangements.
- Provide support for putting in place the licenses, R&D agreements and other arrangements necessary to form strong partnerships to move clean energy technologies more rapidly to market.

A successful ACT II IPR strategy should help to reduce transaction costs by supporting partnerships and consortia. The success of ACT II depends on its ability to identify, create and support working relationships among diverse organizations. Differences in organizational cultures (e.g., between public- and private-sector organizations) need to be overcome. ACT II will need to be able to navigate amidst a variety of existing IPR policies, whether arising from the source of funding (federal, state, etc.), universities' institutional IPR policies, or elsewhere.

This strategy should also create high-quality information and analysis. ACT II will have the capacity to develop high-quality patent information and analysis for selected low-carbon technologies. Early-stage assessments of the patent landscape surrounding an innovation can give critical insight into decisions about whether to invest further and the potential for legal risks associated with the investment. Having the IPR issues fully known and systematically addressed at the earliest research stage can leverage additional investment from the private sector.

Precedent for These Types of IPR Services

The nonprofit Public Intellectual Property Resource for Agriculture (PIPRA, www.pipra.org), which was founded with support from The Rockefeller Foundation, addresses many of the same IPR issues facing the clean energy sector. The technical focus of PIPRA is market failures in the development and deployment of poverty-reducing agricultural technologies for developing countries. But the innovative approach and structure of PIPRA could be successfully applied to current failings in the clean energy technology sector. In agriculture, as in clean energy, there exists uncertainty about IPR thickets, difficulties at the interface between the public and private sectors, and in many areas a lack of cohesive, informed IPR management strategies. PIPRA is now funded by some of the same government and private donors that are concerned about climate. PIPRA is a unique IPR solutions organization in the "public goods" sector.

PIPRA's staff engages in three types of activities that are needed in clean energy commercialization. First, they apply an in-depth understanding of IPR law and science to address innovation problems in a practical setting. Second, they offer project-specific services, such as analyzing the IPR issues around a specific technology, advising whether there are alternative technical strategies that could avoid IPR hurdles, discussing the costs and benefits of patenting/licensing the invention, and exploring which companies are likely to be interested in product development and deployment. And third, they support the negotiation and drafting of agreements necessary to move technologies from the lab into the marketplace. These services have proved useful to public-sector institutions, consortia and public-private partnerships in developing and implementing IPR management strategies in the agricultural arena.

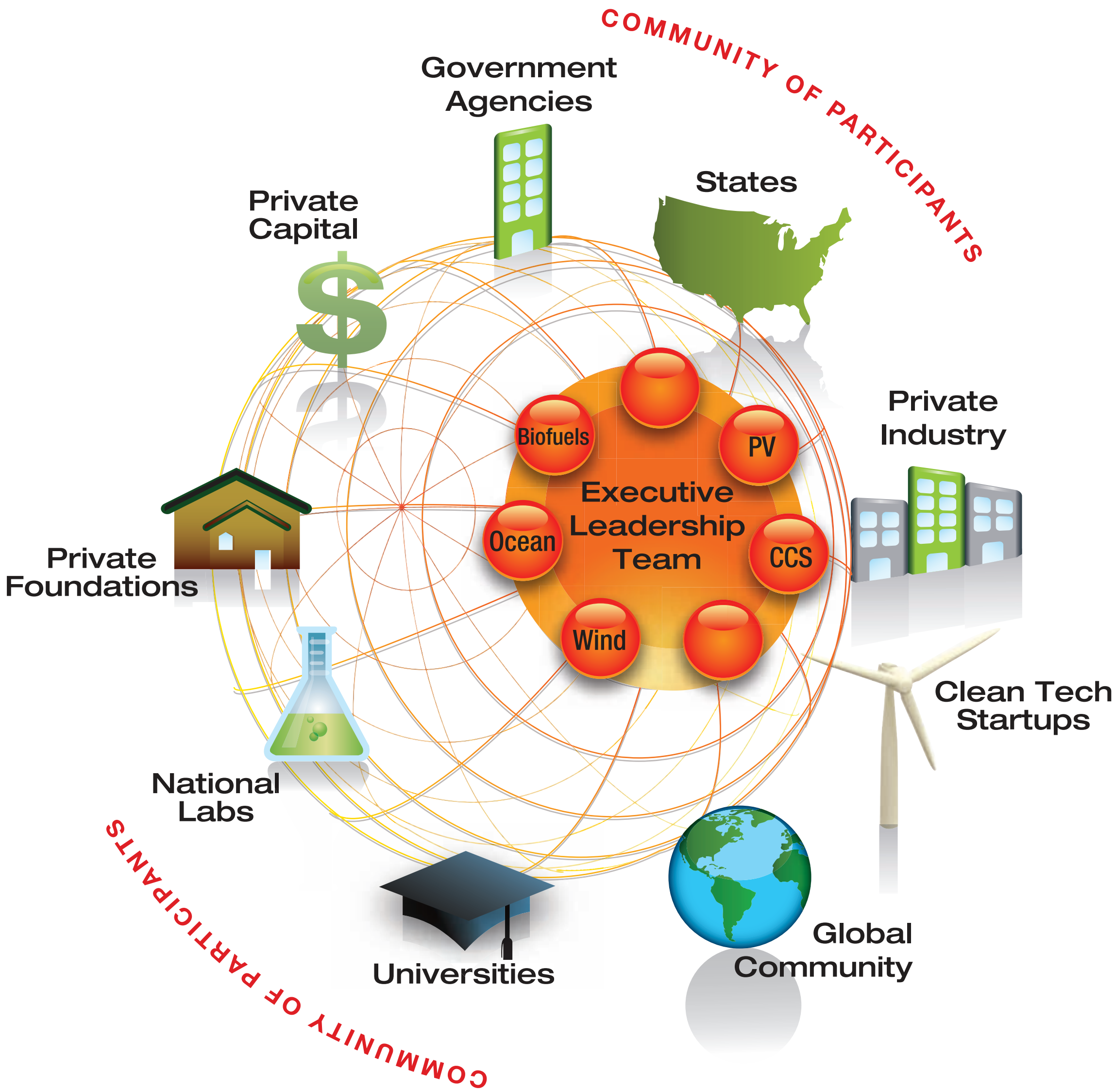
In the clean energy field, the IPR capacity of a PIPRA-like organization does not exist anywhere in the world, at either the national or international levels. This is a major gap in any serious effort to accelerate clean energy product development and deployment — a gap that ACT II could fill.

Section 5 | The ACT II Institutional Framework

As we envision it, ACT II would be an independent institution managed by a small Executive Leadership Team (ELT) comprised of approximately 6-8 individuals and overseen by a small Board of Directors. The largely virtual entity would link to existing energy-related federal and state institutions, universities and the private sector. ACT II would be a complement to existing RD&D initiatives and generally utilize existing institutional and intellectual resources. Again, ACT II's innovation strategies could be integrated with recent energy technology innovation proposals, including ARPA-E, DOE's Energy Hubs and Brookings' e-DII centers, which all call for new independent institutions for energy innovation.

ACT II would prototype its DI approach within one technology area, such as advanced photovoltaic (PV) technologies, with the intention to develop a full portfolio of low-carbon technologies (e.g., advanced PV, wind, batteries and storage technology, advanced biofuels, etc.). This would eventually lead to a "hub-and-spoke" structure, with the central Executive Leadership Team overseeing multiple technology nodes. (A *node* is a technology area such as advanced PV or wind; each node would include work on multiple specific technologies.) Figures 5 and 6 illustrate ACT II's proposed institutional structure.

Figure 5 | ACT II R&D Structure



A New Independent Institution

A key operating principle for ACT II should be its independence. The institutional structure should be as independent as possible from existing, traditional energy-related structures and institutions. This may be difficult for established and incumbent institutions to accept. But there are clear benefits to such independence. Independence encourages creativity, agility, market sense and innovation, the hallmarks of this new distributed innovation strategy. Indeed, innovation works most successfully when managed by independent institutions.[49] And, a more distributed and disaggregated approach to technology innovation and deployment calls for a loose, innovative structure — a collaborative, distributed and nonbureaucratic institutional model.[50]

Of course, cooperation with existing institutions is key; the goal is independent strategic direction connected with cooperation and complementary implementation. Linkages should be made with the DOE, the National Science Foundation, state energy agencies and clean energy funds, universities and the private sector. ACT II would bring together the best talent from these institutions within the context of a distributed innovation framework.

ACT II could also effectively function as an independent "skunk works"[51] for federal agencies interested in prototyping distributed innovation strategies within a few low-carbon energy technology nodes, in an effort to integrate these strategies within the DOE and other federal agencies. This approach would help better link federal research with key private-sector players and others — including states, which are critical for deployment.

A first step could be for the new Secretary of Energy, using existing authorities and resources, to provide funding to an independently established ACT II organization. ACT II would then also seek other sources of public and private funding.

Executive Leadership Team Responsibilities

During the initial prototyping phase, which would focus on a single technology area, the Executive Leadership Team would have two basic functions: (1) managing the technology node using the distributed innovation strategy described previously, and (2) supporting institutions that are not actively engaged in the collaborative research supported by ACT II, but that want to use DI tools to complement their existing R&D capacity.

Assuming the initial prototype is successful and ACT II expands into the hub-and-spoke model envisioned, the ELT would likely shift its focus to high-level strategy and making connections among multiple technology nodes (e.g., to determine if research in a biofuels technology node has relevance for research in an advanced solar node).

During the prototyping phase, the ELT would be composed of a Chief Executive Officer, an IPR Director, an Innovation Director, a Funding and Finance Director, one or two Technology Directors (e.g., advanced PV experts, to begin) and a Communications Manager. The core responsibilities for each role are described below. Much more detailed terms of reference for each position would need to be developed before hiring staff and launching the initiative. Of course, significant coordination and communication would be required among ELT members, and the core responsibilities listed for one position are likely to bridge across several positions.

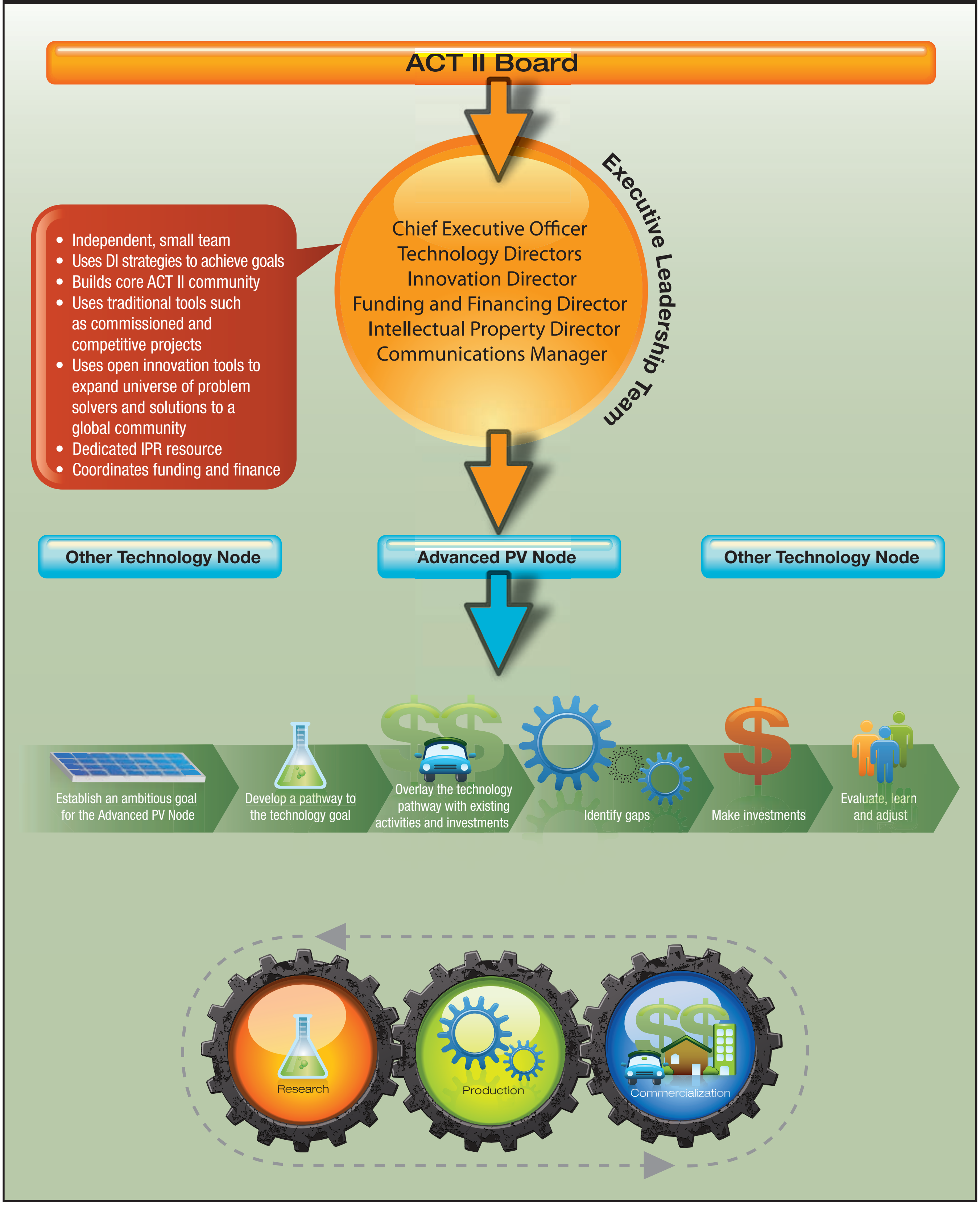
1. The Chief Executive Officer would develop and implement an evolving strategy for ACT II; provide day-to-day management of ACT II; secure funding; and work with key policy makers.

2. The Technology Directors would identify research priorities; disaggregate the initiative's goal into manageable pieces of work that are amenable to conventional and distributed innovation tools; and provide oversight of research being conducted with ACT II resources.

3. The Innovation Director would identify work appropriate for posting to various innovation platforms; select an appropriate platform to solve each problem; and monitor the process, from initial posting to the selection of the "winner."

4. The Funding and Financing Director would promote cooperation at the beginning of each project among the key players in the funding and finance continuum — e.g., federal agencies, private investors, companies and states — to ensure an efficient flow of resources, from conception to deployment and diffusion.

Figure 6 | ACT II Institutional Structure



5. The Intellectual Property Director would provide IP services as described previously, with a focus on structuring partnerships and research agreements in a manner that drives innovation and technology deployment, as well as helping people navigate IP challenges.

6. The Communications Manager would manage the IT infrastructure, develop an outreach and communications strategy and manage external communications with outside organizations.

A critical early step for all members of the ELT will be establishing accountability measures, to ensure that research is brought to the marketplace within established timelines. These accountability measures and processes will be critical to provide confidence to investors. To ensure that accountability measures and processes are perceived as fair and objective, an outside advisory group should be convened to assist with this process.

The ACT II Budget

ACT II's initial setup and pilot technology node would need on the order of $30-50 million per year of funding. Each additional node would cost roughly $25-30 million per year, depending on the capital intensity of the particular technology, for a range of several years depending on needs. This investment in public funding will likely be multiplied many times by leveraging additional private capital.

These numbers are not static; they may be uneven over the first 10-year period. In particular, more money may be needed as activities move toward the demonstration and deployment of new technologies.

One of the principal benefits of the "virtual" organization we envision is its low overhead and high ratio of funds distributed for research and development. As much as 90 percent of the funding sought would be dedicated directly to RD&D, through distributed innovation strategies as well as traditional commissioned and competitive grants. The remaining 10 percent would cover management, overhead, staff salaries, IT systems, central office expenses and travel. Some remaining portion of the funding could also be dedicated to building DI capacity in other institutions.

These numbers have some basis in other DI projects that are managed by small groups relying on other institutions. For example, the Generation Challenge Programme discussed previously, which is a global program but involves less-capital-intensive technologies, has a $15 million annual budget. Of that amount, 75 percent is dedicated to research, 15 percent to training and capacity building and 10 percent to program management.

Section 6 | Conclusion

ACT II is designed to establish a new direction for the innovation of low-carbon technologies in the United States. It is only a beginning — an effort to use innovation strategies that have not been widely applied in the energy sector. But these strategies have been used by governments, private companies and donors for both private commercial products and “public goods” problems.

The current energy RD&D system’s insularity and resistance to learning from other disciplines, fields and people has crippled innovation in the energy sector for the past few decades. So it’s perhaps ironic that the solution to reforming the energy innovation system comes, in fact, from outside that system.

Clearly, the climate and energy problems we face today are too serious and severe to rely on the same old thinking. To solve these problems in our lifetime, we must try a new approach. As described in this paper, distributed innovation will effectively connect the many smart people working in energy and tap the global brainpower of experts in other disciplines to help solve the climate technology problems we face.

The use of distributed innovation will be a prototyping exercise — an experiment to try a novel approach. But it’s novel only to energy, not to scientists and businesspeople in other fields. It is a small leap, actually, to apply what most business journals are calling the next-generation, 21st century innovation approach that many companies will use for years to come.[52]

Also, it is a relatively inexpensive experiment. About $30-50 million per year could fund a prototype of potentially revolutionary solar technology strategies. A small, agile team, operating independent of but linked to the DOE and other critical players in the energy RD&D continuum, could be working in a matter of months.

Moreover, distributed innovation as a strategy is inclusive and collaborative. We do not propose displacing the existing energy-related RD&D system. As described above, the ACT II proposal suggests coordinating existing physical and intellectual resources using DI strategies and tools. While ACT II is envisioned as an independent initiative, the core strategic elements in ACT II could be thought of as a next-generation institutional “operating system” for ARPA-E, DOE’s Energy Hubs and Brookings’ e-DII centers. It can begin to answer the question of “how” these new institutions would operate day to day to optimize the pace and the prospects for successfully advancing a carbon-free energy base with proven distributed innovation strategies.

The energy officials of this new Administration have an historic opportunity to launch a new era of clean energy technology innovation. ACT II is an approach that should be considered and funded, to demonstrate how modern innovation strategies can help meet the 21st century energy challenges faced by the United States and the global community.

Appendix A | Specific Next Steps for an Advanced Photovoltaic Technology Node

This appendix is based on a two-day design meeting held in California in March 2009. At that meeting, we met with 25 individuals working in the solar PV field, including representatives from university labs, the DOE, national laboratories, venture capital firms, startup companies, project finance companies and utilities, as well as individuals with distributed innovation expertise and experience from other sectors. This group was asked to respond to the ACT II concept and to propose steps for moving the initiative forward.

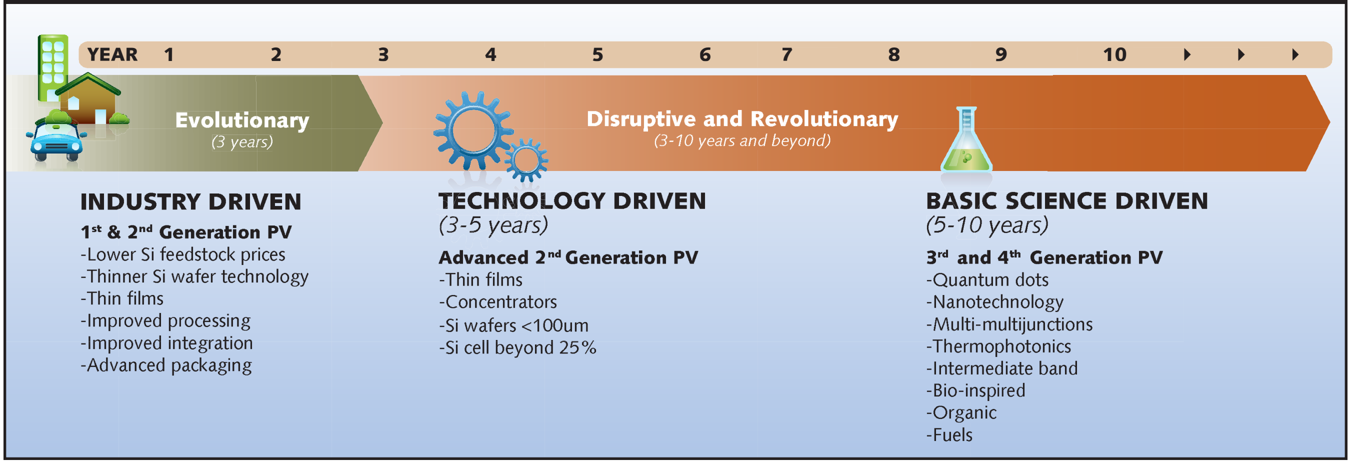
The ideas regarding institutional structure developed at the meeting were included in Section 5 of this paper. Specific next steps for implementing ACT II's first technology node — for advanced photovoltaic technologies — are included in this appendix.

Meeting participants agreed that ACT II should, for each technology node, establish a transformative goal that can fundamentally change the game in energy and climate. However, achieving those goals should also yield useful outputs and products along that pathway, including breakthroughs in the laboratory and accelerated development and deployment of technologies that play a role in achieving the transformative goal. Thus ACT II will have long- and mid-term goals (e.g., for 2020-2030), but also many nearer-term products and outputs that support the mid-term goals.

Given the focus on breakthrough technologies, ACT II's advanced PV node would focus on third- and fourth-generation PV technologies. (See Figure 7.) Third-generation PV technologies, which are not yet commercially available, aim to achieve higher energy conversion efficiency while further reducing materials and manufacturing costs. They are quite different from earlier designs in that they employ a variety of technical approaches to increase their ability to generate electric power from a given amount of light.[53] Their efficiencies are low at present, but their designs hold out the promise of exceeding the theoretical efficiency limits of current PV cells by 30-50 percent within the next decade. A number of these technologies should be characterized by very low processing and capital costs, along with the potential for large-scale manufacturing volumes. This combination should give third-generation PV cells a strong cost-competitive position over time.

Fourth-generation PV technologies are defined by some researchers as those with the potential to directly produce hydrogen or liquid fuels, potentially without the intervening step (and associated efficiency losses) of first generating electricity. In some cases, the same core technology can be utilized for either power production or fuel generation. Any PV technology capable of efficiently generating fuels has the potential to not only address the inherent storage challenges of intermittent renewables like sunlight, but also to tackle the American transport system's current dependence on imported fossil fuels. New research into nanoscale materials suggests that it may be possible to achieve these goals before the end of the next decade.[54]

Figure 7 | ACT II Accelerated RD&D Timeframe for Advanced PV Technologies



Meeting participants felt the ACT II Executive Leadership Team should convene a meeting of experts to establish an overall goal for the advanced PV node. The operation of the node would begin with a careful analysis of all potentially eligible early-stage PV technologies, by a specialized evaluation team selected by the Board and the ELT. From this universe of potential technology opportunities, a number of the most promising ideas would be chosen for full ACT II support.

As a starting point, participants drafted a potential goal for an ACT II advanced PV technology node, as follows:

- Produce electricity from solar energy sources at $.05/kWh or less, including the cost of storage for at least 24 hours
- Deploy 1 TW (on average) of electricity from these solar energy sources by 2025 (8 trillion kWh/yr, or 5 percent of global energy demand)
- All solutions must be sustainable relative to the provision of water and food resources
- This goal assumes four years for invention, three years for product development and ten years for deployment

This goal is in keeping with the one set by President Obama in his April 27, 2009, speech to the National Academy of Sciences, in which he called for many scientific advances including “solar cells as cheap as paint.”[55] This goal was first proposed by Professor Nathan Lewis of Caltech, an adviser to this project.[56]

Participants felt ACT II should then develop a pathway to the technology goal, based on the advice of a group of well-regarded experts (most likely convened for one or more meetings). This will require disaggregating the overall goal into manageable elements and identifying near-term, mid-term and longer-term activities. In pursuing ambitious technology breakthrough goals, ACT II will need to disaggregate challenges into manageable elements. Some ACT II successes may be major breakthroughs, while others may be smaller achievements that enable larger successes. This approach will support breakthrough technology development, while also yielding important near- and mid-term innovations and products. Ultimately, both are needed to achieve our common goal. ACT II’s success should be judged by both near-term and longer-term outputs.

Meeting participants then outlined the following next steps:

- **Overlay the technology pathway with existing activities and investments** to identify gaps and bottlenecks, which can help guide ACT II's investments.

- **Make investments** to address the gaps and bottlenecks identified above. These investments will be made within the context of ACT II's distributed innovation strategy, which includes: tools for supporting research (commissioned and competitive research projects; distributed innovation tools and platforms); IP services; and funding and finance strategies for reducing risk along the RD&D continuum.

- **Evaluate, learn and adjust.** Accomplishing the overall goal will require long-term commitment, focus and flexibility. ACT II will build robust mechanisms for assessing progress, learning from successes and failure and adjusting future investment decisions to reflect these lessons learned.

If the Advanced PV Node is deemed successful, ACT II will establish additional technology nodes, with their own management teams. Thus the ELT's role would expand to include coordinating multiple technology nodes. Outside experts would be convened to help establish the criteria for selecting additional technology nodes.

About the Authors

Lewis Milford is President and founder of Clean Energy Group and the Clean Energy States Alliance, two nonprofit organizations that work with state, federal and international organizations to promote clean energy technologies. He also works with many public agencies (including public pension funds) in the United States and Europe that invest in clean energy. Mr. Milford is frequently asked to appear as an expert panelist at energy conferences throughout the United States and Europe. His articles promoting clean energy have appeared in the *New York Times, Boston Globe, Electricity Journal* and *Solar Today*. Prior to founding CEG in 1998, Mr. Milford was a vice president of the Conservation Law Foundation, where he conducted litigation and advocacy relating to a variety of energy and environmental issues and testified before numerous legislative and regulatory agencies. Previously, Mr. Milford was a New York Assistant Attorney General representing the State of New York in the Love Canal hazardous waste case, and a law professor and director of the public interest law clinic at American University in Washington, D.C., where in federal court and before Congress he represented Vietnam War veterans harmed by Agent Orange. Mr. Milford is the co-author of *Wages of War*, a social history of American war veterans, published by Simon and Schuster in 1989. He has a J.D. from Georgetown University Law Center and is a Phi Beta Kappa graduate of Rutgers College.

Todd Barker is a Partner at Meridian Institute. For more than 15 years, Mr. Barker has served as a respected and trusted facilitator and mediator of numerous dialogues, public processes and negotiations. These projects have addressed a wide array of issues related to the environment, agriculture, health, science and technology, and security. In recent years, Mr. Barker has worked extensively on policy and innovation issues related to energy, climate change, agriculture, food security and emerging technologies such as nanotechnology. He has been involved with the creation of new institutions, such as the African Agricultural Technology Foundation, and is working with other organizations, such as the Public Intellectual Property Resource for Agriculture and the Generation Challenge Programme, that were created to help accelerate product development in the agriculture sector. Also, Mr. Barker helped organize and facilitate a meeting for The Rockefeller Foundation that examined open-source models of innovation in the agriculture and health fields. Prior to joining Meridian, Mr. Barker worked for The Keystone Center as a mediator. Mr. Barker received a Master of Science from the University of Michigan, where his studies focused on environmental policy and dispute resolution.

Jessica Morey is a Project Director with Clean Energy Group. She works primarily on CEG's International Climate Change Technology Innovation Initiative, as well as assisting CEG's Clean Energy States Alliance (CESA), a multi-state coalition of state programs working together to support clean energy technologies and markets. Ms. Morey manages the state-federal partnership-building project and directs CESA's DOE Hydrogen Education project. In addition, she acts as CEG's liaison to the Sustainable Energy Finance Initiative (SEFI) of the United Nations Environment Programme (UNEP). She works with the Basel Agency for Sustainable Energy to manage the UNEP-SEFI Public Finance Alliance, an international consortium of publicly backed funding agencies dedicated to building sustainable energy markets. Before joining CEG, Ms. Morey worked as a clean energy analyst in the World Bank's central energy unit. Her projects included mainstreaming low-carbon analysis into Bank energy projects and improving coordination and knowledge-sharing across the Bank's energy practice and international development partners. She has also consulted with the Natural Resources Defense Council on the Carbon Neutral Costa Rica campaign and worked as the International Fellow at the Pew Center for Global Climate Change. Ms. Morey received her Bachelor's in Environmental Engineering from Dartmouth College, a Masters in International Affairs from American University and a Masters in Sustainable Development from the UN University for Peace in Costa Rica.

Kenneth Locklin is a senior investment executive with a 20-year commitment to clean energy investment, development, management and finance. He serves as the Director of Finance and Investment with Clean Energy Group. Through CEG, Mr. Locklin works with Ceres to advise the Investor Network on Climate Risk on low-carbon investment strategies. He also advises early-stage clean energy technology companies on their development and planning. Mr. Locklin is a founding Co-Chair of the Finance Committee of the American Council on Renewable Energy, the leading U.S. renewable energy umbrella organization. He is a graduate of Yale University.

Kevin Bryan is a Mediator at Meridian Institute, where he works with other professionals to design, convene and facilitate multi-party problem solving interactions to resolve public policy problems of mutual interest. Mr. Bryan helps parties identify critical issues, build relationships and trust, construct innovative solutions and implement the results. His project expertise spans several areas of interest, including homeland security, international development and infrastructure provision, local and regional governance systems and community-based collaboration, and climate change and energy policy. Mr. Bryan earned a Bachelor of Science in Civil Engineering from Howard University.

Sara Boettiger, Ph.D. is Director of Strategic Planning and Development at the Public Intellectual Property Resource for Agriculture. She is an agricultural economist with a background in intellectual property law, and a consultant for the Bill & Melinda Gates Foundation. She publishes in the field of IP law and policy and serves on the Board of Trustees of CIMMYT (the International Maize and Wheat Improvement Centre) and the Board of Directors for the Institute of Forest Biotechnology. Ms. Boettiger's professional interests are focused on the design and implementation of practical services to support innovation and improve livelihoods in developing countries. Her research interests are in the law and economics of: IP rights and developing countries; collaborative innovation systems; open source in copyright and patents; university technology transfer systems; and the strategic use of all forms of intellectual property to serve the interests of developing countries. Ms. Boettiger holds a B.A., University of Arizona; M.S., University of California, Berkeley, and Ph.D., Agricultural and Resource Economics, University of California, Berkeley.

Jill Panetta, Ph.D., is the founder of, and was the Chief Scientific Officer for, InnoCentive, a web-based international community that matches scientists to relevant research and development challenges. Ms. Panetta was also a manager at Eli Lilly and Company, with more than 16 years of experience in drug discovery research. Her research has led to the discovery of potential products to treat asthma and inflammatory bowel diseases. Ms. Panetta received her doctorate in organic chemistry from Dartmouth College, followed by a postdoctoral fellowship at the University of California.

Endnotes

1 Barack Obama, Speech to the National Academy of Sciences, April 27, 2009. Available at http://www.thedailygreen.com/environmental-news/latest/obama-science-speech-47042703?src=nl&mag=tdg&list=dgr&kw=ist.
2 Steven Chu, Speech to the 2008 National Clean Energy Summit, August 18, 2009. Available at http://www.cleanenergysummit.org/video/video.html.
3 Steven Chu, Conversations with History: Conversation with Steven Chu, UC Berkeley, February 13, 2004. Available at http://www.youtube.com/watch?v=y-7gWsoXtUw.
4 Richard K. Lester and Michael J. Piore, *Innovation: The Missing Dimension* (Cambridge, MA: Harvard University Press, 2004).
5 Quoted in: Andrew Hargadon, *How Breakthroughs Happen: The Surprising Truth about How Companies Innovate* (Boston, MA: Harvard Business School Press, 2003).
6 Roger Pielke, Tom Weigly and Christopher Green, "Dangerous Assumptions," *Nature* 425 (2008): 531-532.
7 Note that cap-and-trade incentive systems — one climate solution much discussed of late — will not on their own produce breakthrough technologies. In fact, these systems typically encourage the deployment of the cheapest existing low-carbon technologies without creating incentives for investment in expensive breakthrough technologies. There is virtual consensus that the challenge of climate recovery demands both emissions caps and a complementary process that drives technology innovation.
8 The major organizational players in this system include the U.S. Department of Energy (DOE), the U.S. national laboratories, public and private universities, private-sector technology companies (established and startup), utilities, venture capital firms and financial institutions, among others.
9 Brookings Institution, *Energy Discovery-Innovation Institutes: A Step toward Energy Sustainability* (meeting summary) (Washington, DC: Metropolitan Policy Program at Brookings Institution, 2009).
Available at http://www.brookings.edu/~/media/Files/events/2009/0209_energy_innovation/20090209_edii.pdf;
Peter Ogden, John Podesta and John Deutch, *A New Strategy to Spur Energy Innovation* (Washington, DC: Center for American Progress, 2008).
Available at http://www.americanprogress.org/issues/2008/01/pdf/energy_innovation.pdf.
10 Lawrence Dooley and David O'Sullivan, "Managing within Distributed Networks," *International Journal of Innovation Management* 11, no. 3 (2007): 397.
11 Meridian Institute, *Open Source Models of Collaboration in the Life Sciences: 2005 Bellagio Meeting* (Dillon, CO: Meridian Institute, 2005).
Available at http://www.merid.org/OS/bellagioOSreport.pdf.
12 Shane Tomlinson, Pelin Zorlu and Claire Langley, *Innovation and Technology Transfer: Framework for a Global Climate Deal* (London: E3G and Chatham House, 2008): 84. Available at http://www.e3g.org/images/uploads/E3G_Innovation_and_Technology_Transfer_Full_Report.pdf.
13 Nathan S. Lewis, et al., *Basic Research Needs for Solar Energy Utilization: Report of the Basic Energy Sciences Workshop on Solar Energy Utilization* (Argonne, IL: Argonne National Laboratory, September 2005). Available at http://www.sc.doe.gov/bes/reports/files/SEU_rpt.pdf.
14 Ibid., ix.
15 Pielke, et al., "Dangerous Assumptions."
16 Current total energy use has increased to 13TW since this 1998 total, but the amount of carbon-free energy needed in 2050 remains in the range of 22-25TW.
17 There is a growing body of academic literature to support this position. See, for example, Knut A. Alfsen and Gunnar S. Eskeland, *A Broader Palette: The Role of Technology in Climate Policy* (Stockholm: Swedish Ministry of Finance, 2007).
Available at http://www.sweden.gov.se/content/1/c6/07/89/07/788128bb.pdf;
Climate Dialogue at Pocantico, *International Climate Efforts Beyond 2012* (Arlington, VA: Pew Center on Global Climate Change, 2005).
Available at http://www.pewclimate.org/docUploads/PEW_Pocantico_Report05.pdf; Lewis Milford, *From Here to Stabilization: A Call for Massive Climate Technology Innovation* (Montpelier, VT: Clean Energy Group, 2006). Available at http://www.cleanegroup.org/Reports/ceg_stabilization.pdf.
18 For purposes of this paper, the term *innovation* means: "putting ideas into commercial use" including "creation of new products and services, the use of new production technologies and techniques and the implementation of new ways to organize work and business processes." Robert Atkinson and Howard Wial, *Boosting Productivity, Innovation, and Growth through a National Innovation Foundation* (Washington, DC: Information Technology and Innovation Foundation and Metropolitan Policy Program of the Brookings Institution, 2008): 5.
Available at http://www.itif.org/files/NIF.pdf.
19 Lawrence Goulder, *Induced Technological Change and Climate Policy* (Arlington, VA: Pew Center on Global Climate Change, 2004): iv.
20 Atle C. Christiansen, *Technology Change and the Role of Public Policy: An Analytical Framework for Dynamic Efficiency Assessments* (Lysaker, Norway: Fridtjof Nasnsen Institute, 2001): 817. Available at http://www.fni.no/doc&pdf/FNI-R0401.pdf.
21 Brookings Institution, *Energy Discovery-Innovation Institutes*; Ogden et al., *A New Strategy*.
22 Brookings Institution, *Energy Discovery-Innovation Institutes*, 23.
23 Ibid., 21-23.
24 Ibid., 4.
25 Ogden, et al., *A New Strategy*, 11-13.
26 Brookings Institution, *Energy Discovery-Innovation Institutes*, 14-18.
27 Ogden, et al., *A New Strategy*, 2.
28 Milford, *From Here to Stabilization*, 4.
29 Ogden, et al., *A New Strategy*, 3.
30 See the Clean Energy States Alliance website for a summary of state activities (www.cleanenergystates.org).
31 Brookings Institution, *Energy Discovery-Innovation Institutes*, 20.

32 Ogden, et al., *A New Strategy*.
33 Brookings Institution, *Energy Discovery-Innovation Institutes*, 25.
34 For background information on distributed innovation, see:
- Lewis Milford and Daniel Dutcher, *Climate Choreography: How Distributed and Open Innovation Could Accelerate Technology Development and Deployment* (Montpelier, VT: Clean Energy Group, 2008). Available at www.cleanegroup.org/Reports/Climate_Choreography_July08.pdf.
- Thomas Malone and Mark Klein, "Harnessing Collective Intelligence to Address Climate Change," *Innovations* 2, no. 3 (2007): 15-26.
- Diego Rodriguez and Doug Solomon, "Leadership and Innovation in a Networked World," *Innovations* 2, no. 3 (2007): 3-13.
- Philip Evans and Bob Wolf, "Collaboration Rules," *Harvard Business Review* 83, no. 7 (2005): 96-104.
- Clayton Christensen, Heiner Baumann, Rudy Ruggles and Thomas Sadtler, "Disruptive Innovation for Social Change," *Harvard Business Review* (2006): 94-101.
- Alan MacCormack, Theodore Forbath, Peter Brooks and Patrick Kalaher, "Innovation through Global Collaboration: A New Source of Competitive Advantage," *Harvard Business Review* (2007).
- Karim R. Lakhani and Jill A. Panetta, "The Principles of Distributed Innovation," *Innovations* 2, no. 3 (2007): 97-112.
- Steven Eppinger, "Innovation at the Speed of Information," *Harvard Business Review* 79, no. 1 (2001): 149-158.
- Larry Huston and Nabil Sakkab, "Connect and Develop: Inside Proctor and Gamble's New Model for Innovation," *Harvard Business Review* 83, no. 3 (2006): 53-66.
- William Taylor, "Here's an Idea: Let Everyone Have Ideas," *New York Times*, March 26, 2006.
- Meridian Institute, *Open Source Models*.

35 Dooley and O'Sullivan, "Managing within Distributed Networks," 397.
36 Ibid., 398.
37 Hirotaka Takeuchi, Emi Osono and Norihiko Shimizu, "The Contradictions that Drive Toyota's Success," *Harvard Business Review* (2008).
38 Lakhani and Panetta, "The Principles of Distributed Innovation."
39 The CGIAR partnership now includes 25 developing countries, 22 industrialized countries, 4 private foundations and 13 regional and international organizations. See http://www.cgiar.org/who/members/index.html.
40 CGIAR, *A Revitalized CGIAR — A New Way Forward: The Integrated Reform Proposal* (Washington, DC: CGIAR Change Steering Team, 2008): 4.
41 John Hagel and John Seely Brown, "The Next Wave of Open Innovation: How InnoCentive Aims to Exploit Sophisticated Technology and Networking Capabilities to Connect Problems with Their Potential Solvers," BusinessWeek.com, April 8, 2009.
Available at http://www.businessweek.com/innovate/content/apr2009/id2009048_360417.htm.
42 Satish Nambisan and Mohanbir Sawney, *The Global Brain: Your Roadmap for Innovating Faster and Smarter in a Networked World* (Upper Saddle River, NJ: Wharton School Publishing, 2008): xxi.
43 Ibid., 25.
44 Dooley and O'Sullivan, "Managing within Distributed Networks," 399-400.
45 Meridian Institute, *Open Source Models*, 14.
46 ARPA-E stands for the Advanced Research Projects Agency-Energy. For information on the agency see http://arpa-e.energy.gov/ and this report by Clean Air-Cool Planet: http://www.cleanair-coolplanet.org/cpc/documents/ARPA-E_AnEnergyFutureTransformed.pdf.
DOE's Energy Hubs refers to a proposal by Steven Chu, Secretary of Energy, to build a network of eight small Energy Innovation Hubs to focus on new breakthrough clean energy technologies, though the future of this proposal is in question because of budget cuts from Congress. See http://www.wired.com/wiredscience/2009/07/doelablet/.
For more on Brookings' e-DII technology innovation centers proposal see: Brookings Institution, *Energy Discovery-Innovation Institutes*.
47 See InnoCentive http://www.innocentive.com; YourEncore http://www.yourencore.com; NineSigma http://www.ninesigma.com; Science24Seven http://www.science24seven.com; Oakland Innovation http://www.oakland.co.uk; and Innovation Exchange http://www.innovationexchange.com.
48 Tomlinson, et al., *Innovation and Technology Transfer*.
49 One of the world's leading theorists of technology innovation, Harvard Business School Professor Clayton Christensen, notes that managing for disruptive change in the private sector, which has strong parallels to public institutions, usually requires new and independent institutions. He writes:

> "Companies that have tried to develop new capabilities within established organizational units also have a spotty track record, unfortunately. Assembling a beefed up set of resources as a means of changing what an existing organization can do is relatively straightforward. People with new skills can be hired, technology can be licensed, capital can be raised, and product lines, brands and information can be acquired. Too often, however, resources such as these are then plugged into fundamentally unchanged processes — and little change results.... When disruptive change appears on the horizon, managers need to assemble the capabilities to confront the change before it has affected the mainstream business. In other words, they need an organization that is geared toward the new challenge before the old one, whose processes are tuned to the existing business model, has reached a crisis that demands fundamental change." (Clayton Christensen, *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail* (New York: HarperBusiness, 2000): 174-175.)

That innovation institutions should be independent entities is an established view in the business literature. One author shares several reasons for this conclusion:

> "A firm that invests in augmenting its current capabilities and maintaining its current focus might perform rather poorly in generating ideas that are outside its core capabilities.... To stimulate radical innovations, researchers are often isolated from the influence of the rest of the organization. This has become known as the 'skunk works model' of innovation. The skunk works model was the organizational design followed by IBM to nurture the by then revolutionary PC, and it is employed by many large innovative firms, such as Intel, HP and Apple, to develop potential breakthroughs.... [I]t gives researchers the necessary autonomy, independence and freedom to escape the established lines of thought and produce novel ideas.... [I]t can also help to overcome the resistance that radical innovations meet inside the organization."

(Andrea Fosfuri and Thomas Ronde, *Leveraging Resistance to Change and the Skunk Works Model of Innovation*, Center for Industrial Economics Discussion Papers (Copenhagen, Denmark: University of Copenhagen, 2007-10): 9, 11.)

50 In other words, to be successful at innovation, form follows function — structure follows strategy. "Years of academic research suggest that, beyond some fairly low threshold, successful innovators are not really more gifted or creative than the rest of us. Rather, they simply better exploit the networked structure of ideas within unique organizational frameworks. [S]trategy too often neglects the question of how to get there. Yet, especially when innovation matters, the strategy is the organization." (Prof. Kathleen Eisenhardt, Foreword to Hargadon, *How Breakthroughs Happen*, viii.)

51 The term *skunk works* comes from the name of the windowless facility built by the Lockheed Corporation in California during the Cold War to develop secret military projects separate and apart from the established business operations.

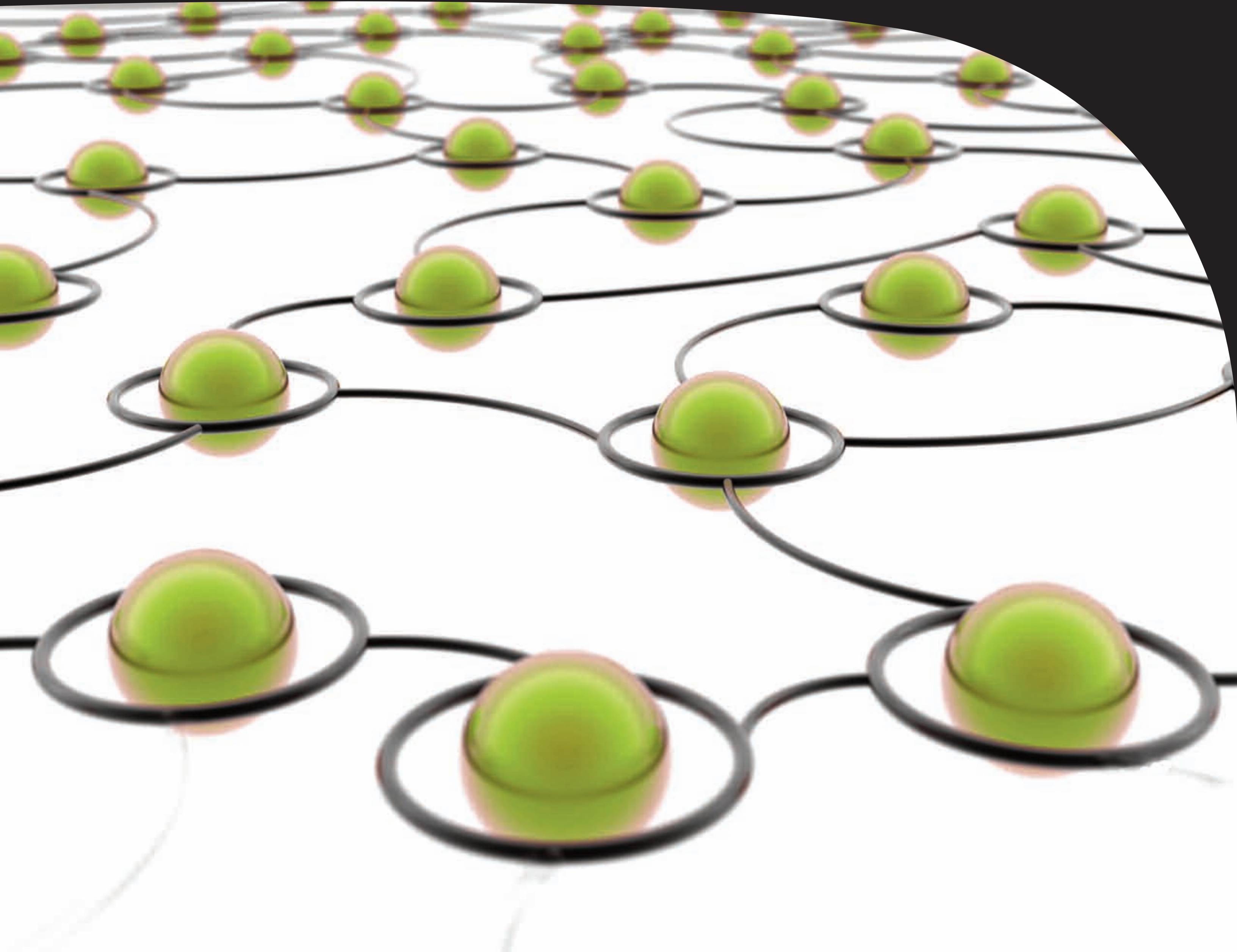
52 Milford, *From Here to Stabilization*.

53 Representative third-generation technologies include: photoelectrochemical cells; organic or plastic-based Gräetzel cells; dye-sensitized solar cells; nanocrystal solar cells; multi-junction cells; and multi-exciton generation solar cells based on quantum dots, nanorods, nanowires, etc.

54 R.A. Grimme, C.E. Lubner, D.A. Bryant and J.H. Golbeck, "Photosystem I/Molecular Wire/Metal Nanoparticle Bioconjugates for the Photocatalytic Production of H2," *Journal of the American Chemical Society* 130 (2008): 6308-6309.

55 Obama, Speech to the National Academy of Sciences.

56 Professor Lewis was quoted as saying, "Nanotechnology offers us a way, in principle, to make very cheap materials — like the paint you buy at Home Depot — act as solar cells and batteries." "Nanotech Could Make Solar Energy as Easy and Cheap as Growing Grass," nanotechwire.com, September 17, 2007. Available at http://nanotechwire.com/news.asp?nid=5039.



Clean Energy Group
Innovation in Finance, Technology & Policy

50 State Street, Suite 1
Montpelier, Vermont 05602
(802) 223.2554
www.cleanegroup.org

Meridian Institute
Connecting People to Solve Problems

1920 L Street, NW, Suite 500
Washington, DC 20036
(202) 354.6440
www.merid.org