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“OUR GENERATION’S SPUTNIK MOMENT”: REGULATING ENERGY INNOVATION

Joseph P. Tomain*

I. INTRODUCTION

In his 2011 State of the Union Address, President Obama stressed the necessity of innovation as the key to unlocking our economic future. More pointedly, he stated that now is “our generation’s Sputnik moment.”¹ Just as the United States responded to national security threats posed by a cold war Russia, today we must respond to threats to our economy and our environment, as well as to our national security, posed by an oil addiction that we have not been able to break for over half a century.

The intertwined needs to provide sufficient energy, environmental protection, and a vibrant economy in a more secure world will depend, to a significant extent, on technological innovations in the clean energy sector of our economy. That sector has been neglected by government for too long, dominated by a fossil fuel policy that has outlived its useful life, and offers great promise on a number of alternative fronts. The promise of a clean energy future, however, will only be effectively realized through a smart and systemic innovation policy that goes beyond traditional research and development (R&D), and aims at changing systems and at radically transforming the energy economy.² Additionally, an innovation policy that targets commercialization has the power to attract private investment,³ thus creating new clean energy markets.⁴ An energy innovation

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¹ President Barack Obama, State of the Union Address (Jan. 25, 2011), *available at* http://abcnews.go.com/Politics/State_of_the_Union/state-of-the-union-2011-full-transcript/story?id=12759395 [hereinafter 2011 State of the Union].

² CLEAN AIR TASK FORCE & CONSORTIUM FOR SCI., POL’Y & OUTCOMES, FOUR POLICY PRINCIPLES FOR ENERGY INNOVATION & CLIMATE CHANGE: A SYNTHESIS (2010), *available at* <http://www.catf.us/resources/publications/files/Synthesis.pdf> [hereinafter CLEAN AIR TASK FORCE].

³ *See, e.g.*, Daniel R. Cahoy & Leland Glenna, *Private Ordering and Public Energy Innovation Policy*, 36 FLA. ST. U. L. REV. 415 (2009).

⁴ Stuart Benjamin & Arti K. Rai, *Fixing Innovation Policy: A Structural Perspective*, 77 GEO. WASH. L. REV. 1 (2008).

policy, of course, is not itself sufficient and must complement anti-trust, competition, intellectual property, and technology transfer policies among others.⁵

The scale and magnitude of shifting from a traditional fossil fuel policy to a clean energy economy cannot be underestimated. Over the last fifty years, for example, we have been talking about our dependence on foreign oil and the need to wean ourselves from the Middle East, yet our oil imports only increase. Similarly, for the same period of time our use of renewable energy resources has stayed flat.⁶ Perhaps more alarming is the cost involved with such a transformation. If, for example, we sought to supply only 25 percent of our energy mix from low carbon nuclear power, then we would have to build 1,000 one-gigawatt nuclear reactors by 2050 at an estimated cost of \$6–\$7 billion per reactor.⁷ Today, only two nuclear power units are in the pipeline.⁸ To power an electric car and truck fleet to replace our current gas and ethanol-fueled vehicles would require 500 new nuclear power plants.⁹ As a final example, the Obama administration has set a target of an 80 percent drop in greenhouse gas omissions by 2050.¹⁰ To meet that target, either alternative energy supplies will have to go from supplying nearly zero percent to 100 percent of all of our energy needs, or large-scale carbon capture and storage must capture all of the carbon dioxide

⁵ See MICHAEL A. LEVI ET AL., COUNCIL ON FOREIGN REL., ENERGY INNOVATION: DRIVING TECHNOLOGY COMPETITION AND COOPERATION AMONG THE U.S., CHINA, INDIA, AND BRAZIL (2010), available at http://i.cfr.org/content/publications/attachments/Energy_Innovation_Report.pdf.

⁶ See ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, ANNUAL ENERGY REVIEW 2009, at xx, Report No. DOE/EIA-0384 (2010), available at <http://www.eia.doe.gov/aer/pdf/aer.pdf> [hereinafter 2009 ENERGY REVIEW].

⁷ See ARJUN MAKHIJANI, INST. FOR ENERGY AND ENVTL. RES., ASSESSING NUCLEAR PLANT CAPITAL COSTS FOR THE TWO PROPOSED NRG REACTORS AT THE SOUTH TEXAS PROJECT SITE (Sept. 26, 2008), available at <http://www.ieer.org/reports/nuclearcosts.pdf>; THIRD WAY, THE FUTURE OF NUCLEAR ENERGY: A WHITE PAPER 7 (Jan. 2011), available at http://content.thirdway.org/publications/370/Third_Way-INL_-_The_Future_of_Nuclear_Energy_A_White_Paper.pdf. For several estimates, see JOHN M. DEUTCH ET AL., UPDATE OF THE MIT 2003 FUTURE OF NUCLEAR POWER (2009).

⁸ See *New Nuclear Plant Status*, NUCLEAR ENERGY INST., <http://www.nei.org/resourcesandstats/documentlibrary/newplants/graphicsandcharts/newnuclearplantstatus/> (last visited Mar. 25, 2011) (reporting that thirty nuclear units are in some stage of planning; however, at this writing, only two units are moving forward); see also Matthew L. Wald, *U.S. Pushed, but Reactors are Lagging*, N.Y. TIMES, Jan. 31, 2011, at B1.

⁹ David Biello, *Green Energy's Big Challenge: The Daunting Tasks of Scaling Up*, YALE ENV'T 360 (Jan. 20, 2011), http://e360.yale.edu/feature/green_energys_big_challenge_the_daunting_task_of_scaling_up_/2362/.

¹⁰ Office of the Press Secretary, *President to Attend Copenhagen Talks*, WHITE HOUSE (Nov. 25, 2009), <http://www.whitehouse.gov/the-press-office/president-attend-copenhagen-climate-talks>.

emitted by all cars.¹¹ These are not easy tasks. In fact, to remove one gigaton of carbon from the atmosphere, now containing about 770 gigatons, would require 273 coal-fired power plants to implement carbon capture and storage systems.¹² Construction costs are estimated at \$1 billion to nearly \$3 billion¹³ for each unit and carbon capture and storage will add considerable costs to new plants.¹⁴

Traditional energy policy has outlived its useful life. Today, the United States' energy mix, as we well know, is constituted by 85 percent fossil fuels and negligible, but growing, amounts of renewable and clean energy resources.¹⁵ Because our current energy policy has been in place since the late nineteenth century, both private energy industries and the administrative agencies assigned to monitor them have developed a mutually supportive regulatory structure dedicated to promoting energy production. Additionally, over that period of time, trillions of dollars have been invested in the energy economy and consumers have grown dependent on relatively cheap, abundant and reliable energy that is available literally at their fingertips. Consequently, incumbent firms and regulators are not anxious to change the ways they do business, nor are consumers anxious to change their consumption habits.¹⁶ Nevertheless, there are sufficient reasons for the country to change from fossil fuels to a clean energy future. In brief, a vibrant economy, job creation, protecting the environment, continued reliable energy, and national security demand that we move away from our traditional energy policy and create a clean energy future. Energy transformation integrates these several variables into a coherent new energy policy.¹⁷

In a forthcoming book, entitled *Ending Dirty Energy Policy*,¹⁸ I argue that for over a generation we have been developing a consensus energy policy that can be called either a clean energy or a low carbon energy policy. I argue further that one can be either skeptical or agnostic about global warming or climate change and

¹¹ Biello, *supra* note 9.

¹² *Id.*

¹³ See Duke: New Coal Plant's Cost Rises to \$2.9B, INDIANAPOLIS BUS. J. (Apr. 16, 2010), <http://www.ijb.com/duke-new-coal-plants-cost-rises-to-29b/PARAMS/article/19382>; Thomas Content, *Power Plant Cost to Top \$1 Billion*, MILWAUKEE J. SENTINEL, June 14, 2008, at D1.

¹⁴ See MASS. INST. OF TECH., THE FUTURE OF COAL: OPTIONS FOR A CARBON-CONSTRAINED WORLD (2007), available at http://web.mit.edu/coal/The_Future_of_Coal.pdf.

¹⁵ See generally 2009 ENERGY REVIEW, *supra* note 6, at 3.

¹⁶ See, e.g., Jon R. Luma, *Why Does Energy Efficiency's Promise Remain Unfulfilled?*, YALE ENV'T 360 (Feb. 7, 2011), http://e360.yale.edu/feature/why_does_energy_efficiencys_promise_remain_unfulfilled/2367/ (discussing consumers' reluctance to invest in energy efficiency).

¹⁷ See, e.g., PRESIDENT'S COUNCIL OF ADVISORS ON SCI. AND TECH., EXEC. OFFICE OF THE PRESIDENT, ACCELERATING THE PACE OF CHANGE IN ENERGY TECHNOLOGIES THROUGH AN INTEGRATED FEDERAL ENERGY POLICY vii (2010).

¹⁸ JOSEPH P. TOMAIN, ENDING DIRTY ENERGY POLICY: PRELUDE TO CLIMATE CHANGE (forthcoming 2011).

still support a dramatic change in energy policy. I should add, however, that climate change skepticism or agnosticism is limited. The scientific evidence of climate change is sound and reliable and there is a high degree of reliable evidence regarding anthropogenic contributions to climate change.¹⁹ The earth is warming and we are contributing to it. Skepticism or agnosticism enters the analysis once the question is posed: What can we do about it? The topic of this Article, technological innovation in the energy sector, is a partial response to that question. In the first instance, we will not successfully address climate change without energy innovation. In the second instance, innovation in the energy sector is valuable in and of itself regardless of one's attitude about climate change. Finally, energy innovation must be seen as a necessary, but insufficient, element of our clean energy future.

Today, it is popular to decry the failure of leadership in Washington D.C. on issues of energy, the environment, and climate.²⁰ It seems unlikely that the 112th Congress will address the issue. It also seems unlikely that the current administration will propose dramatic legislation along these fronts. Nevertheless, there is an emerging nonpartisan politics supporting a smarter and cleaner energy future.²¹ In support of the emerging politics and in support of the emerging consensus energy policy, we are seeing a rapidly expanding body of empirical and policy literature promoting a clean energy future. In short, below the federal level, states and local governments, for-profit and nonprofit actors, and private capital are being directed to clean energy. At the heart of all of this momentum is energy technology innovation. Innovation, as discussed here, is distinct from traditional R&D and is seen as a network of public and private sector institutions whose

¹⁹ See INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT (2007) [hereinafter IPCC SYNTHESIS REPORT]; Adam Voiland, 2009: *Second Warmest Year on Record; End of Warmest Decade*, NASA (Jan. 21, 2010), <http://www.nasa.gov/topics/earth/features/temp-analysis-2009.html>. Regardless of the high level of consensus on the human contribution to global warming, political arguments continue to attack the science. For a rebuttal to skeptics, see *Scientific Consensus on Global Warming*, UNION OF CONCERNED SCIENTISTS <http://www.ucsusa.org/ssi/climate-change/scientific-consensus-on.html> (last visited Mar. 25, 2011) and SKEPTICAL SCIENCE, <http://www.skepticalscience.com/> (last visited Mar. 25, 2011).

²⁰ See, e.g., LEWIS MILFORD & JESSICA MOREY, CLEAN ENERGY GROUP, INNOVATION TO INFRASTRUCTURE: CLEAN ENERGY WITHOUT CAP AND TRADE (2010), available at http://www.cleanenergy.org/Reports/Innovation_to_Infrastructure_CEG_Paper_11.10.10_final.pdf.

²¹ See, e.g., RACHEL GOLD & STEVEN NADEL, ASSESSING THE HARVEST: IMPLEMENTATION OF THE ENERGY EFFICIENCY PROVISION IN THE ENERGY POLICY ACT OF 2005 (2011), available at <http://www.aceee.org/sites/default/files/publications/research-reports/E113.pdf> (discussing the nonpartisan nature of implementing EPA Act 2005).

activities initiate, develop, and diffuse new technologies²² for the purpose of creating a market-scale clean-energy economy.²³

This Article will discuss the reasons for public investment in energy innovation, by describing some of the existing barriers to adequate investment, and will then explain existing and proposed strategies for a more fully invested innovation policy.

II. WHY REGULATE?

The question “why regulate?” has been the subject of a vigorous scholarly debate over the last four decades.²⁴ If the greatest American contribution to law and political theory is our Constitution, then the second most noteworthy contribution is administrative law. To be sure, the United States has had an administrative apparatus since its founding.²⁵ The modern administrative state, though, dates to the Progressive Era in the last quarter of the nineteenth century. Legislation was passed and agencies were created to solve social and economic problems. Administrative agencies proliferated over the next several decades. Yet, it was not until the passage of the Administrative Procedure Act in 1946²⁶ that policy analysts and political thinkers attempted to construct a theory of agency behavior that applied to the wide variety of agency actions—from the regulation of securities and radio frequencies to agriculture and aviation. The great treatises of

²² Simona O. Negro, Marko P. Hekkert, & Ruud Smits, *Stimulating Renewable Energy Technologies by Innovation Policy* 3, (Innovation Studies Utrecht working paper series 08-13, 2008).

²³ See, e.g., Helge Godoe & Stian Nygaard, *System Failure, Innovation Policy and Patents: Fuel Cells and Related Hydrogen Technology in Norway 1990–2002*, 34 ENERGY POL’Y 1700 (2006).

²⁴ Regulatory theories, generally, look either to economics or to some political version of the public interest. In this Article, I am agnostic about which is the superior theory because the regulatory demands of changing energy policy or responding to global warming challenge both theories. Useful discussions of both theories can be found in George L. Priest, *The Origins of Utility Regulation and the “Theories of Regulation” Debate*, 36 J. LAW & ECON. 289 (1993); STEVEN P. CROLEY, *REGULATION AND PUBLIC INTERESTS: THE POSSIBILITY OF GOOD REGULATORY GOVERNMENT* (2008); SIDNEY A. SHAPIRO & JOSEPH P. TOMAIN, *REGULATORY LAW AND POLICY: CASES AND MATERIALS* CH. 3 (3d ed. 2003).

²⁵ See generally Jerry L. Mashaw, *Recovering American Administrative Law: Federalist Foundations, 1787–1801*, 115 YALE L.J. 1186 (2006); Jerry L. Mashaw, *Reluctant Nationalists: Federal Administration and Administrative Law in the Republican Era, 1801–1829*, 116 YALE L.J. 1636 (2007); Jerry L. Mashaw, *Administration and “The Democracy”*: *Administrative Law from Jackson to Lincoln, 1829–1861*, 117 YALE L.J. 1586 (2008); Jerry L. Mashaw, *Federal Administration and Administrative Law in the Gilded Age*, 119 YALE L.J. 1362 (2010).

²⁶ *Administrative Procedure Act*, P.L. 79-404, 60 Stat. 237 (this enactment was repealed and now has provisions in a revised title).

administrative law followed shortly thereafter.²⁷ More importantly, following the administrative law treatises came scholarly analyses of how and why government regulates at all. How can government justify its many interventions into private markets and into the lives of its citizens? These inquiries yielded valuable political insights about government.²⁸ However, political analyses did not offer a broad coherent theory of government regulation. Instead, that task was left to the field of law and economics.

The prevailing theory of regulation is firmly based on classical microeconomic analysis and can be described as a theory of market failure.²⁹ Interestingly, this theory describes a cyclical pattern that starts and ends with competitive markets. The analysis of government regulation begins by assuming that private and competitive markets are the desired form of social ordering. Private and competitive markets can help markets achieve efficiency with all of its virtues. Such markets can create wealth, stimulate innovation, and allocate resources to their most valued uses. The problem, of course, is that private markets do not always function as competitively as theory would have it. Instead, for any number of reasons—negative externalities being the most obvious example—markets expose their imperfections. Once a market imperfection is discovered, government intervenes in order to fix it. The existence of a market failure then becomes the justification for government intervention generally. Consequently, government regulation is intended to fix and stabilize ailing markets and create conditions for competition.³⁰ Government regulation, in turn, experiences failures of its own, in which case, regulatory reform or deregulation is necessary. Full deregulation is simply a return to the market thus completing the cycle.

Given this approach to market intervention by government, the pattern of regulation can be seen as linear. A problem (such as tainted meat or monopoly power) is identified, legislation is passed, a government agency is charged with fixing the problem, then the agency addresses the identified problem pursuant to its

²⁷ See, e.g., LOUIS L. JAFFE, *JUDICIAL CONTROL OF ADMINISTRATIVE ACTION* (1965); KENNETH CULP DAVIS, *ADMINISTRATIVE LAW* (1951); KENNETH CULP DAVIS, *ADMINISTRATIVE LAW AND GOVERNMENT* (1960); KENNETH CULP DAVIS, *ADMINISTRATIVE LAW TREATISE* (1958).

²⁸ See, e.g., ROBERT BALDWIN & MARTIN CAVE, *UNDERSTANDING REGULATION: THEORY STRATEGY AND PRACTICE* (1999); HERBERT HOVENKAMP, *ENTERPRISE AND AMERICAN LAW, 1836–1937* (1991); MORTON KELLER, *REGULATING A NEW ECONOMY: PUBLIC POLICY AND ECONOMIC CHANGE IN AMERICA, 1900–1933* (1990); MARVER H. BERNSTEIN, *REGULATING BUSINESS BY INDEPENDENT COMMISSION* (1977).

²⁹ See generally ALFRED E. KAHN, *THE ECONOMICS OF REGULATION: PRINCIPLES AND INSTITUTIONS* (1988); STEPHEN G. BREYER, *REGULATION AND ITS REFORM* (1982); SIDNEY A. SHAPIRO & JOSEPH P. TOMAIN, *REGULATORY LAW AND POLICY* (3d ed. 2003); see also ANTHONY OGUS, *REGULATION: LEGAL FORM AND ECONOMIC THEORY* (1994); W. KIP VISCUSI, JOHN M. VERNON & JOSEPH E. HARRINGTON, JR., *ECONOMICS OF REGULATION AND ANTITRUST* (2d ed. 1995).

³⁰ See *supra* note 29.

legislative mandate. In the case of tainted meat, the Food and Drug Administration can set standards and monitor food manufacturing processes. In the case of monopoly power, government regulators can set price and profit rules intended to set rates at hypothetically competitive market levels. In both instances, regulators are acting retrospectively fixing problems that have already occurred.

A regulatory regime which fixes broken markets is retrospective rather than anticipatory. It is also inadequate. *Ex post* regulation *may* remedy past problems, such as aggressive subprime lending or Gulf oil spills, *should they reoccur*, but the damage has been suffered. Thus, the dominant regulatory model fails to account fully for the costs suffered after harm has occurred. *Ex post* regulation inadequately anticipates future problems because it intentionally ignores them. The economic and social costs of the failure to anticipate the meltdown on Wall Street, for example, is almost beyond accounting.³¹ A sound regulatory state, therefore, requires *ex ante* rules to efficiently and effectively prevent harm before it occurs; to reduce overall transaction costs; and, to fairly and equitably distribute benefits and widely compensate the injured.

Clean energy and climate change are categorically different sorts of problems than those addressed *ex post* by traditional regulation. Neither is something that only has occurred in the past. Instead, we are currently experiencing the effects of a suboptimal energy policy and of neglected attention to climate change. More dramatically, clean energy and climate change are not single events; instead they involve a multiplicity of actors, occur over generations, and are imbued with a wide range of uncertainties and complexities of the sort regulators have not seen before. We do not know, for example, the exact relationship between increases in carbon dioxide due to burning fossil fuels and rising global temperatures. We do not know, as another example, with any reasonable certainty, the dollar cost of a transformation to an energy future without fossil fuels or the costs of mitigating or adapting to climate change. We have little to no idea on how to perform reliable cost-benefit analysis on these problems or choose an appropriate discount rate.³² It may well be the case that cost-benefit analysis is of little to no use with complex

³¹ See FIN. CRISIS INQUIRY COMM’N, THE FINANCIAL CRISIS INQUIRY REPORT, at xvii (2011), available at http://c0182732.cdn1.cloudfiles.rackspacecloud.com/fcic_final_report_full.pdf (concluding that the 2008–2010 recession was avoidable).

³² Key papers in the debate over the discount rate are: NICHOLAS HERBERT STERN, THE ECONOMICS OF CLIMATE CHANGE: THE STERN REVIEW (2007) (using a discount rate of 1.4%); William Nordhaus, *A Review of the Stern Review on the Economics of Climate Change*, 45 J. OF ECON. LITERATURE 686 (2007) (5%); Martin Weitzman, *The Stern Review of the Economics of Climate Change*, 45 J. ECON. LITERATURE 703 (2007) (6%); see also Kenneth J. Arrow, *Global Climate Change: A Challenge to Policy*, 4 ECONOMISTS’ VOICE 1 (June 2007); David A. Weisbach & Cass R. Sunstein, *Symposium on Intergenerational Equity and Discounting*, 74 U. CHI. L. REV. 1 (2007). See also Douglas A. Kysar, *Discounting . . . On Stilts*, 74 U. CHI. L. REV. 119 (2007).

problems such as climate change.³³ Scientific, technological, and financial uncertainties plague both issues. To those uncertainties, we can add socio-political complexities that are transboundary, multi-jurisdictional, and multi-generational.

The standard market imperfection model that has been relied upon to fix past problems in a linear way is not up to the task of addressing the dynamic complexities of clean energy and climate change. Instead, regulators must acknowledge the systemic and inter-related nature of our energy future and act accordingly. Indeed, transforming energy policy and addressing climate change are intimately connected. They are connected logically, scientifically, technologically, and economically. Further, and most importantly, we cannot wait until the harm is suffered, then apply an *ex post* fix. Such a wait-and-see approach may well be catastrophic.³⁴

Because clean energy and climate change present categorically different regulatory challenges, the regulatory responses must also be categorically different as well. The challenges presented by both problems must be anticipated; they must be addressed *ex ante*; and, we must proceed with great caution.³⁵

The arguments for a new energy innovation policy respond to both the dominant regulatory model of market failure and to a more precautionary approach. From the market failure perspective, there are two market failures that justify government regulation in support of energy innovation. Both market failures involve the economic concept of public goods. Quite simply, a public good, such as police or military protection, is a good that the private sector will under supply.

The first market failure is the negative externality of carbon emissions from dirty energy. For decades, our energy economy was constructed around the idea that cheap, abundant energy was the single most important input into the economy. Indeed, the country has enjoyed astounding economic expansion together with growth in energy production and consumption throughout the twentieth century. However, the adamant commitment to a belief in a direct and positive correlation between energy and the economy has produced a public good in the form of dirty energy. Dirty energy is a direct consequence of the failure to internalize the

³³ For a critical discussion of cost-benefit analysis, see FRANK ACKERMAN & LISA HEINZERLING, *PRICELESS: ON KNOWING THE PRICE OF EVERYTHING AND THE VALUE OF NOTHING* (2004); Susan Rose-Ackerman, *Putting Cost-Benefit Analysis in Its Place: Rethinking Regulatory Review*, 65 U. MIAMI L. REV. 335 (2011).

³⁴ See, e.g., RICHARD A. POSNER, *CATASTROPHE: RISK AND RESPONSE* 43–58, 123–38 (2004).

³⁵ See John Applegate, *Embracing a Precautionary Approach to Climate Change*, in *ECONOMIC THOUGHT AND U.S. CLIMATE CHANGE POLICY* 171 (David M. Driesen ed., 2010) (discussing the precautionary principle); but see CASS R. SUNSTEIN, *WORST-CASE SCENARIOS* 118–175 (2007).

externalities of pollution. In other words, it can be claimed that carbon emissions build-up is the greatest market failure the world has known.³⁶

The second market failure that justifies the regulation of energy innovation is also a public good—clean energy. The private sector under-supplies clean energy for multiple reasons including the fact that for decades fossil fuel industries have had extraordinary government regulatory support as well as substantial direct and indirect financial subsidies. Because of these subsidies the energy playing field is not level, competitive markets are lacking, incumbents thwart new entrants, and energy innovation is grossly underfunded.

From the precautionary perspective, energy innovation policy is more than R&D, pursues multiple pathways, perceives clean energy as a public good, and seeks collaboration.³⁷ Government intervention into energy innovation markets is warranted because of traditional market failures, because of the need for a precautionary approach to climate change, and because continued reliance on dirty energy is environmentally and economically unsound. Our energy future depends upon technological innovation and there are multiple arguments for public spending in this field.

A. The Argument from Science and Mathematics

The first argument comes from science and mathematics particularly the field of cybernetics. The father of cybernetics, MIT mathematician Norbert Wiener, authored a manuscript on innovation in the 1950s.³⁸ In it he remarked about the need for approaching the question of the exhaustion of natural resources as a necessary element of future planning thus anticipating current discussions about the intersection of energy and the environment.³⁹ Wiener developed the field of cybernetics, which is the interdisciplinary study of systems and particularly their feedback loops. In one sense, the relationship of energy policy and climate change exemplifies the grandest of all feedback loops encompassing both nature and the fuel cycle. An example of a negative feedback loop is the polar ice caps. As the ice caps melt because of an increase in temperature, less sunlight will be directed away from Earth, which in turn increases the Earth's surface temperature further still. Similarly as permafrost melts due to global warming, the thawing soil releases massive quantities of methane into the atmosphere thus further contributing to global warming.⁴⁰ On the positive loop side, as the earth warms and as trees grow,

³⁶ NICHOLAS STERN, A BLUEPRINT FOR A SAFER PLANET: HOW TO MANAGE CLIMATE CHANGE AND CREATE A NEW ERA OF PROGRESS AND PROSPERITY 7, 11–13, 117–18 (2009); see also ANTHONY GIDDENS, THE POLITICS OF CLIMATE CHANGE 49–50 (2009).

³⁷ CLEAN AIR TASK FORCE, *supra* note 2, at 1–3.

³⁸ NORBERT WIENER, INVENTION: THE CARE AND FEEDING OF IDEAS (1994) (published posthumously).

³⁹ *Id.* at 1.

⁴⁰ CHRIS WOLD, DAVID HUNTER & MELISSA POWERS, CLIMATE CHANGE AND THE LAW 13 (2009).

carbon sinks increase, thus absorbing CO₂. The private sector cannot afford to fund the interdisciplinary studies and the basic science research necessary to understand these complex relationships and the direction of feedback loops more generally.

Science and mathematics also play a crucial role in the study and understanding of the relationship between energy and the environment especially as it pertains to understanding climate change through scientific and economic modeling. Perhaps the most notorious computer model, known as World3, was employed by the Club of Rome in its study of the relationship between increasing world population and finite natural resources with results published in a book titled *The Limits to Growth*.⁴¹ The model was challenged, the conclusions were regarded with suspicion, and the report was generally perceived as too pessimistic.⁴² The critics, however, overreacted. Nowhere in the book, for example, do the authors argue that the world is running out of any resource as the debunkers claimed. Instead, the study has proven to be sturdy and reliable and, since its publication, its forecasts have proven to be accurate.⁴³ Perhaps the most important vindication of *The Limits to Growth*, has been the increased use of computer models to study the world and its environment.⁴⁴

B. The Argument from Business and Philanthropy

In the world of the philanthropy, the Bill and Melinda Gates Foundation is the 800-pound gorilla. Curiously, perhaps, the Foundation is not actively involved in the energy and environment space. Instead, the Foundation concentrates on global development, global health, and domestic education.⁴⁵ Nevertheless, Bill Gates has recognized that the private sector under invests in energy innovation and that public sector and foundations must play a greater role in creating new technologies

⁴¹ DONELLA H. MEADOWS ET AL., *THE LIMITS TO GROWTH: A REPORT FOR THE CLUB OF ROME'S PROJECT ON THE PREDICAMENT OF MANKIND* (1972).

⁴² See, e.g., MATTHEW R. SIMMONS, *REVISITING THE LIMITS TO GROWTH: COULD THE CLUB OF ROME HAVE BEEN CORRECT, AFTER ALL?* 11 (Oct. 2000), available at http://www.greatchange.org/ov-simmons,club_of_rome_revisted.pdf.

⁴³ See *id.*; Graham Turner, *A Comparison of the Limits to Growth with Thirty Years of Reality* 1 (Commonwealth Scientific and Indus. Research Org. Working Paper Series, Working Paper No. 1834-5638, 2008), available at <http://www.csiro.au/files/files/plje.pdf>; DONELLA MEADOWS, JORGEN RANDERS & DENNIS MEADOWS, *LIMITS TO GROWTH: THE 30-YEAR UPDATE* (2004).

⁴⁴ See, e.g., Daniel A. Farber, *Climate Models: A User's Guide* (2007), available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1030607 (follow "One-Click Download" link).

⁴⁵ See *About the Foundation: Our Approach to Giving*, BILL & MELINDA GATES FOUND., <http://www.gatesfoundation.org/about/Pages/our-approach-to-giving.aspx> (last visited Mar. 25, 2011).

for a new economy.⁴⁶ More particularly, he has joined several other CEOs, from Xerox, General Electric, Bank of America, and others to form the American Energy Innovation Council (AEIC).⁴⁷ What is notable about this organization is that its leading members, for the most part, are not involved directly with energy industries. However, they all recognize that energy innovation is essential for a vibrant economic future. The AEIC was formed because its members believe that (1) “the energy challenge is much worse than most people realize” and (2) “there is a vast, but neglected, potential to produce and spread innovation in the energy sector.”⁴⁸ The mission of the organization is quite straightforward: to “foster strong economic growth, create jobs in new industries, and reestablish America’s energy technology leadership through robust, public investment in the development of world-changing clean energy technologies.”⁴⁹

The AEIC adopts one of the market failure arguments made above to justify expanding public investment in energy innovation.⁵⁰ The organization acknowledges that private firms will under-invest in innovation when they are not in a position to capture all the benefits generated from their intellectual property ideas.⁵¹ The AEIC, though, does not admit the corollary proposition that private firms are, too often, too narrowly focused on their own short-term needs.⁵² Private firms are also likely to under-invest when profit margins are low, when competitors are not investing either so that they do not lose competitive advantage, and when costs of innovation appear staggering as they do on the energy and climate change fronts. Further, incumbency and tradition are powerful drags on energy firms.⁵³ Firms are too often “locked-in” to old ways of doing business. Similarly, firms have developed a path dependency on past investments and need to recoup a return on those investments before entering into and investing in new fields.

Lock-in occurs as a result of an organization’s continued commitment to its culture and as a result of its embedded infrastructure, the regulatory environment

⁴⁶ See Bill & Melinda Gates Found., *2010 Annual Letter from Bill Gates: Innovation*, available at <http://www.gatesfoundation.org/annual-letter/2010/Pages/investment-in-innovations.aspx> (last visited Mar. 25, 2011).

⁴⁷ See generally *Members*, AMERICAN ENERGY INNOVATION COUNCIL, <http://www.americanenergyinnovation.org/> (last visited last visited Mar. 25, 2011).

⁴⁸ AM. ENERGY INNOVATION COUNCIL, *A BUSINESS PLAN FOR AMERICA’S ENERGY FUTURE 3* (2010), available at <http://www.americanenergyinnovation.org/full-report> [hereinafter INNOVATION COUNCIL].

⁴⁹ *Id.* at Preface.

⁵⁰ *Id.* at 12.

⁵¹ See RICHARD G. NEWELL, *THE HAMILTON PROJECT*, THE BROOKINGS INST., A U.S. INNOVATION STRATEGY FOR CLIMATE CHANGE MITIGATION (2008), available at <http://fds.duke.edu/db?attachment-103--6101-view-689>.

⁵² WIENER, *supra* note 38, at xv (from the *Preface* by Steve Joshua Heims).

⁵³ See, e.g., William B. Bonvillian & Charles Weiss, *Taking Covered Wagons East: A New Innovation Theory for Energy and Other Established Technology Sectors*, 4 INNOVATIONS: TECHNOLOGY, GOVERNANCE, GLOBALIZATION 289 (2009).

in which it operates,⁵⁴ and the cache of technologies it already has in place.⁵⁵ Path dependency is the organization's continued commitment to the type of investments it has made in the past and to the ways it has made its business decisions. In both instances, past behavior is an impediment to game-changing innovation processes and products. Further, the private sector's narrow vision first focuses on mature technologies and incremental advances rather than on new and creative technologies.⁵⁶

The second economic argument for increased public spending is based upon the fact that energy innovation has received only a fraction of innovation dollars. The AEIC, following other reports, notes that the energy sector spends roughly 0.3 percent of its sales revenues on research and development compared with 18.7 percent for pharmaceuticals and 11.5 percent for aerospace and defense.⁵⁷ It has also been reported that the private sector invests \$3 billion annually in energy R&D but this is an industry with annual revenues of over a trillion dollars.⁵⁸

Economists recognize the role that innovation plays in contributing to a country's economic growth.⁵⁹ Curiously, however, only recently has innovation played a significant role in economic theory. Predominant economic theory, whether classical, neoclassical or Keynesian, has preferred to rely on markets, price signals, and government spending as the driving forces behind economic growth. The emerging discipline of innovation economics, however, provides an alternative to the traditional model of economic growth and recognizes that

⁵⁴ Jim Watson, *Setting Priorities in Energy Innovation Policy: Lessons for the UK*, BELFER CTR. FOR SCI. AND INT'L AFFAIRS 27 (2008), available at http://belfercenter.ksg.harvard.edu/files/2008_Watson_Priorities.pdf.

⁵⁵ Keith Smith, *Climate Change and Radical Energy Innovation: The Policy Issues 1, 16* (Ctr. for Tech., Innovation and Culture, Working Paper No. 20090101, 2009), available at http://www.sv.uio.no/tik/InnoWP/Smith%202009_Climate%20Change%20and%20Energy%20Innovation.pdf.

⁵⁶ CHARLES WEISS & WILLIAM B. BONVILLIAN, STRUCTURING AN ENERGY TECHNOLOGY REVOLUTION 130 (2009).

⁵⁷ INNOVATION COUNCIL, *supra* note 48, at 6; see also James Duderstadt et al., *Energy Discovery-Innovation Institutes: A Step Toward America's Energy Sustainability*, METROPOLITAN POL'Y PROGRAM, BROOKINGS INST., 15 (2009), http://www.brookings.edu/~media/Files/rc/reports/2009/0209_energy_innovation_muro/0209_energy_innovation_muro_full.pdf.

⁵⁸ See Daniel M. Kammen & Gregory F. Nemet, *Reversing the Incredible Shrinking Energy R&D Budget*, ISSUES IN SCI. AND TECH., Fall 2005, at 84, 84–85, <http://www.climate-technology.gov/stratplan/comments/Kammen-2.pdf>; Josh Freed, Avi Zevin & Jesse Jenkins, *Jumpstarting a Clean Energy Revolution with a National Institutes of Energy*, BREAKTHROUGH INST., 4–5 (Sept. 2009), http://thebreakthrough.org/blog/Jumpstarting_Clean_Energy_Sept_09.pdf.

⁵⁹ See, e.g., WILLIAM J. BAUMOL, THE FREE MARKET INNOVATION MACHINE: ANALYZING THE GROWTH MIRACLE OF CAPITALISM (2002); WILLIAM J. BAUMOL, ROBERT E. LITAN & CARL J. SCHRAMM, GOOD CAPITALISM, BAD CAPITALISM, AND THE ECONOMICS OF GROWTH AND PROSPERITY (2007).

“knowledge, technology, entrepreneurship, and innovation [are] primary factors for economic growth rather than . . . independent forces that are largely irrelevant in the prevailing doctrinal approaches”⁶⁰ In addition to emphasizing variables different from those in the traditional schools of economics, innovation economics relies on a different definition of efficiency.

According to traditional economic theory, efficiency, in short, is wealth creation—the economic pie gets bigger. Too often, though, traditional economics relies on a static model of the economy to generate efficiency gains. Innovation economics approaches efficiency differently. This alternative economic model requires actors to have the capability of reorganizing production in ways that lead to the greatest output with the fewest inputs and actors who can adapt to new situations by adopting new technologies as flexibly as possible.⁶¹ Instead of taking the market as a given factor to which private firms react, innovation economics recognizes the market-shaping and interactive role of those firms. This brand of economics is more forward-looking and more suitable to addressing complex and systemic problems such as energy policy or climate change. Our country’s dependency on fossil fuels serves as a powerful example of old style economics. Energy innovation policy captures the vision of the new economics.⁶²

Under the old model, the theory is that if price signals are changed, through a carbon tax for example, then the hypothetical market will correct itself and function properly. Maybe. Innovation economics instead posits that we must rethink our concepts of prices and markets and particularly the relationship between energy and the economy because of the complexities of each. More specifically, and more importantly, our country’s need for clean energy can only be satisfied by adaptive and proactive economic policies that look to systems change, public-private partnerships, disruptive technologies, and investments in a knowledge-based economy, even in the face of incomplete and uncertain information. Standard economic theories wait for markets to react; innovation economics intends to create new more dynamic markets.

C. The Argument from Politics

The Obama White House has adopted a set of policies and priorities which focus on technological innovation. As a general matter, the guiding principles of the president’s technology policy include: (1) innovation in the economy; (2) innovation in science; (3) innovation in public administration; and (4) developing an innovative government culture of accountability and transparency.⁶³ President

⁶⁰ Robert D. Atkinson & Darlene Hackler, *Economic Doctrines and Approaches to Climate Change Policy*, INFO. TECH. AND INNOVATION FOUNDATION, 7 (Oct. 2010), <http://www.itif.org/files/2010-econ-climate-change.pdf>.

⁶¹ *Id.*

⁶² See, e.g., ANATOLE KALETSKY, *CAPITALISM 4.0: THE BIRTH OR A NEW ECONOMY IN THE AFTERMATH OF CRISIS 190–200* (2010).

⁶³ See, e.g., *Technology: Guiding Principles*, WHITE HOUSE, <http://www.whitehouse>.

Obama has promoted innovation in both of his State of the Union addresses. In 2010, he linked investment in basic research with the creation of clean energy jobs and the need for greater energy efficiency.⁶⁴ In 2011, he returned to his theme of innovation as central to “winning the future.”⁶⁵ The president underscored the public goods nature of innovation particularly for basic science.⁶⁶ The private sector cannot afford to invest in this space and, therefore, public spending must be made.⁶⁷

In his 2011 State of the Union message, the president set out certain goals. By 2035, he challenged America to provide 80 percent of its electricity from clean energy resources. He also challenged America to have 1 million electric vehicles on the road by 2015. The guiding force behind all of the proposals is job creation as a result of leadership in research and technology.⁶⁸ The president’s 2012 budget addresses clean energy by proposing \$3.2 billion for Department of Energy’s (DOE) energy efficiency and renewable energy programs; \$237 million for electric delivery and energy reliability; and \$650 million for the Advanced Research Projects Agency, an energy innovation agency. In addition, total investments in bio-energy research, development and demonstration are slated for a 16 percent increase. In part, that public funding will come by redirecting fossil fuel subsidies to clean energy initiatives.⁶⁹

The president’s energy agenda includes the development of a clean energy standard to be applied against policies and investments in our energy future.⁷⁰ The standard sets a goal of doubling the amount of electricity generated from clean energy over the next twenty-five years.⁷¹ It defines clean energy as being generated from renewable resources and nuclear power together with clean coal and natural gas technologies.⁷² The standard also intends to protect consumers against rising energy bills while ensuring regional fairness.⁷³ Clean energy was the recipient of

gov/issues/technology (last visited Mar. 25, 2011).

⁶⁴ President Barack Obama, State of the Union Address (Jan. 27, 2010), *available at* <http://www.whitehouse.gov/the-press-office/remarks-president-state-union-address> [hereinafter 2010 State of the Union].

⁶⁵ 2011 State of the Union, *supra* note 1.

⁶⁶ *Id.*

⁶⁷ 2010 State of the Union, *supra* note 64.

⁶⁸ *See, e.g.*, Heather Zichal, *Keeping America Competitive: Innovation and Clean Energy*, WHITE HOUSE BLOG (Jan. 31, 2011, 4:01 PM), <http://www.whitehouse.gov/blog/2011/01/31/keeping-america-competitive-innovation-and-clean-energy>.

⁶⁹ *See* ENV’T & ENERGY STUDY INST., FACT SHEET: OBAMA ADMINISTRATION FY 2012 BUDGET PROPOSAL 1 (Feb. 2011), *available at* http://files.eesi.org/fy12_budget_factsheet.pdf.

⁷⁰ *Budget Fact Sheet: Winning the Future through Innovation*, WHITE HOUSE, <http://www.whitehouse.gov/omb/factsheet/winning-the-future-through-innovation> (last visited Mar. 25, 2011).

⁷¹ *Id.*

⁷² *Id.*

⁷³ *See id.*

over \$90 billion through the American Recovery and Readjustment Act, also known as the Stimulus Bill, which is credited as having generated or saved over 224,500 jobs.⁷⁴ Additionally, the president intends to propose over \$8 billion for research, development, and deployment investments in clean energy technology programs,⁷⁵ while also investing in advance manufacturing technologies,⁷⁶ electric vehicles,⁷⁷ and efficiencies in buildings.⁷⁸

D. The Argument from Policy

The policy arguments for a clean energy economy are coalescing and, as noted above, have been developing for nearly four decades. The country has enjoyed significant economic prosperity and world leadership for most of the twentieth century. However, the United States is facing a reduced share of the world economy particularly as the economies of China and India expand dramatically.⁷⁹ The United States must now compete more aggressively in a more competitive world. The 2008–2010 recession slowed our growth considerably and our economic rebound appears to be more gradual than might be desired.

Energy, of course, will continue to be a major input into our economy. Nevertheless, it does not follow that we must continue to rely on dirty resources as our predominant energy inputs. Instead, the expansion of alternative and renewable fuels, greater gains in energy efficiency, and changes in production and consumption habits will lead to a transformation in our energy portfolio that will

⁷⁴ Office of Media Affairs, *President Obama's Plan to Win the Future by Producing More Electricity through Clean Energy*, WHITE HOUSE (Feb. 3, 2011), <http://www.whitehouse.gov/the-press-office/2011/02/03/president-obama-s-plan-win-future-making-american-businesses-more-energy>. See also *Budget Fact Sheet: Winning the Future through Innovation*, WHITE HOUSE, <http://www.whitehouse.gov/omb/factsheet/winning-the-future-through-innovation> (last visited Mar. 25, 2011).

⁷⁵ The White House, *President Obama's Plan to Win the Future by Investing in Clean Energy Research and Development*, HOMELAND SECURITY DIGITAL LIBRARY, <http://www.hsdl.org/?view&doc=136826&coll=limited> (last visited March 25, 2011).

⁷⁶ The White House, *President Obama's Plan to Win the Future by Investing in Advanced Manufacturing Technologies*, HOMELAND SECURITY DIGITAL LIBRARY, <http://www.hsdl.org/?view&doc=136823&coll=limited> (last visited March 25, 2011).

⁷⁷ *Vice President Biden Announces Plan to Put One Million Advanced Technology Vehicles on the Road by 2015*, DEP'T OF ENERGY (Jan. 26, 2011), <http://www.energy.gov/10034.htm>.

⁷⁸ *President Obama's Plan to Win the Future by Making American Businesses More Energy Efficient through the "Better Buildings Initiative,"* WHITE HOUSE (Feb. 3, 2011), <http://www.whitehouse.gov/the-press-office/2011/02/03/president-obama-s-plan-win-future-making-american-businesses-more-energy>.

⁷⁹ See, e.g., The Brookings Institution, *Building a Long-Term National Strategy on Growth Through Innovation: Panel 2: The Potential of Green Energy and Technology* (Jan. 12, 2011), http://www.brookings.edu/~media/Files/events/2011/0112_gti/20110112_innovation_panel2.pdf (comments of Jeffrey Immelt, CEO of General Electric).

support a vibrant economy, a better environment, and a safer world. Again, innovation is central to achieving these policies.⁸⁰

III. INNOVATION POLICY PRINCIPLES

A smart energy innovation policy goes beyond traditional R&D. A smart policy cannot rely on a linear approach intended either to push technologies into the market by investing resources to solve a particular problem, such as the space race, or to create a demand and pull technologies into the market by setting standards such as best available technology.⁸¹ Both the push and the pull approaches are examples of creating an innovation pipeline which narrowly focuses on a particular problem or technology.⁸² While both are useful, even together, they are insufficient. Instead, a creative innovation policy must recognize that a proliferation of clean energy technologies will be successful as a result of complex and non-linear processes that will attempt to change systems, will be interactive, and will attempt to create virtuous circles that expand innovation processes and generate the next innovation cycles.⁸³

The successful policy will require a systems approach for a full array of solutions including formal and public education regarding the benefits of an innovative clean energy economy. Ideally, such an approach will create a clean energy marketplace that can “go viral” as the information and digital revolution did in the 1990s.⁸⁴ Similarly, a successful and transformative clean energy revolution will occur as a result of “multiple dynamic feedbacks between the stages of the [innovation] process.”⁸⁵ Further, success is more likely to be realized as a result of networks of innovators, collaborations among public and private actors, and coalitions of a variety of institutions.

For many of the reasons previously mention in Part II, the private sector will necessarily under-invest in energy innovation. Private investment, however, can be stimulated by federal support particularly as market signals become stronger and

⁸⁰ See generally JOSEPH E. STIGLITZ, *FREEFALL: AMERICA, FREE MARKETS, AND THE SINKING OF THE WORLD ECONOMY* (2010).

⁸¹ See, e.g., Laura Diaz Anadon & John P. Holdren, *Policy for Energy Technology Innovation*, in *ACTING IN TIME ON ENERGY POLICY*, 89–127 (Kelly Sims Gallagher ed., 2009).

⁸² See generally John Seely Brown & John Hagel III, *The Next Frontier of Innovation*, 3 *MCKINSEY Q.* 83 (2005), available at <http://www.johnseelybrown.com/pushpull.pdf>.

⁸³ Negro et al., *supra* note 23, at 9; Kelly Sims Gallagher, John P. Holdren & Ambuj D. Sagar, *Energy-Technology Innovation*, 31 *ANNUAL REV. ENV'T & RESOURCES* 193, 200 (2006).

⁸⁴ See, e.g., Negro et al., *supra* note 22.

⁸⁵ See Venkatesh Narayanamurti et al., *Institutions for Energy Innovation: A Transformational Challenge*, *BELFER CTR. FOR SCI. AND INT'L AFFAIRS* 2 (Fall 2009), <http://belfercenter.ksg.harvard.edu/files/Institutions-for-Energy-Innovation-A-Transformational-Challenge.pdf> [hereinafter *Institutions for Energy Innovation*].

investment risk reaches tolerable levels. Parenthetically, the most desirable signal that government could send to help develop clean energy economy is to set a price on carbon.⁸⁶ For the purposes of this analysis, though, this Article assumes that a carbon tax or cap-and-trade regime is unlikely to occur in the short term. Nevertheless, steps can be taken to help create the new economy.

A first, and necessary, step to sending proper signals and rationalizing risk would be to articulate, and then implement, an energy innovation policy based upon sound principles. In several papers, Harvard's Belfer Center for Science and International Affairs, has articulated a set of five principles (Belfer Principles) upon which to base a clean energy innovation policy.⁸⁷ The Belfer Principles were drawn from lessons learned from successful innovation programs at research institutions and national laboratories.⁸⁸ The Belfer Principles include mission, leadership, culture, structure, management, and funding.⁸⁹ These principles provide a sound basis for thinking about innovation policy and for redesigning energy innovation agencies. Institutional design must match mission and must create a culture where innovation is encouraged, supported, and highly valued. As sound as these principles are, however, they must be supplemented by lessons learned from philanthropy and from investment firms. Two additional principles, discussed below, should supplement the Belfer principles. New energy innovation policy should include a sell discipline as well as planning and evaluation strategies.

A. Mission

While it may appear obvious that a well-defined mission is central to any successful organization, the reality is that too often organizations spend too little time focusing on mission and, even more often, too little time revisiting and reevaluating their missions. This failure to focus on mission affects public and private sectors alike. Businesses, nonprofit organizations, and even academic units, such as law schools, attempt to define their missions and find the exercise to be more difficult than they first anticipate. Defining an organization's mission requires significant focus and concentration and a great deal of interaction and discussion among key actors or stakeholders. Often, this process is the result of a facilitated conversation led by skilled experts who are aware of the temptations to

⁸⁶ See, e.g., Robert Stavins, "Pitfalls in Public Policies": *Can the U.S. Compete with China on Green Tech?*, N.Y. TIMES (January 19, 2011, 01:18 PM), <http://www.nytimes.com/roomfordebate/2011/01/18/can-the-us-compete-with-china-on-green-tech/pitfalls-in-public-policies>.

⁸⁷ See generally Laura Anadon et al., *U.S. Public Energy Innovation Institutions and Mechanisms: Status and Deficiencies*, BELFER CTR. FOR SCI. AND INT'L AFFAIRS 2 (January 14, 2010), <http://belfercenter.ksg.harvard.edu/files/US-Public-Energy-Innovation-Institutions-and-Mechanisms.pdf> [hereinafter *U.S. Public Energy Innovations Institutions*]; see also *Institutions for Energy Innovation*, *supra* note 85.

⁸⁸ *Id.*

⁸⁹ *Id.*

cut such exercises short. Once an organization defines its mission, it cannot rest content in its accomplishment. Instead, an organization must continuously monitor and evaluate itself. The experience of the United States automobile industry and the market threats to such major corporations as IBM, Kodak, and Xerox during the technological revolution of the 1980s and 1990s are examples of firms that were slow to adjust their missions in light of changing technologies and markets. Energy regulators have a similar inattentive record. Indeed, even though we have been aware of the need for an environmentally sensitive energy policy and of our dependence on foreign oil, energy policy has been stalled for over a generation.

A clearly articulated mission defines an organization's purpose and core values, helps attract talent, serves as a measure of progress and success, and shapes internal design and management. Additionally, a clear mission will serve as the basis for evaluating and coordinating projects and structuring a budget. An energy innovation organization, several of which are discussed below, must have, as part of its mission, the intent to provide innovation as a public good, the creation of new energy markets, the promotion of a diversity of energy portfolios, technologies and products, and the encouragement of new entrants across the energy sector. Due to the heterogeneity and dynamic nature of developing a new energy economy, and the innovations needed to populate it, an innovation organization must be flexible and adaptive while simultaneously applying rigorous standards and benchmarks against which proposed projects are evaluated and which funded projects are measured.

B. Leadership

Similarly, sound leadership may appear to be an obvious and necessary component of any organization. However, finding the appropriate leader for a public-sector organization can too often become debilitated by politics. Aside from political constraints, the job description for the leader of an energy innovation organization will be challenging and might be written as:

Wanted: CEO with outstanding credentials, talents and experiences including: science/technology background; business/finance/investment acumen; managerial expertise; public and private sector knowledge and/or experience; policy analysis understanding; and, the ability to focus on for-profit markets and public goods goal. The CEO must have the capacity to deal with business leaders, national political figures, and academic institutions. The CEO will be required to run a multibillion dollar enterprise over a period of several years at a minimum. The CEO must be able to create a work environment and culture which attracts the best scientists, engineers, policy analysts and other energy experts and technicians.

This job description might just as well require that the CEO "walk on water." Still, given the challenge of leading an energy transformation, the description is not far

off. The leader of an energy innovation agency must bring with her scientific and managerial excellence, an understanding and sympathy with the organization's mission, and the ability to coordinate and integrate both internal and external activities in both the public and private sectors. Such a leader must have one eye on the public goods mission of innovation policy and another on for-profit marketability. The innovation CEO must create an environment that encourages people to develop their skills and that is adaptable to changes in markets. Further, the CEO must have the vision to move an organization forward while regularly reevaluating its articulated mission making appropriate changes when and where necessary.

C. Culture

At bottom, the energy innovation organization must create an entrepreneurial culture which stresses commitment and excellence from top to bottom. Google, for example, is notorious for having created a culture which encourages and rewards creativity and innovation for all of its employees. All employees have access to the CEOs at weekly meetings; no one is pigeon-holed into one narrow job assignment; there are offices around the world and a global employee base; and there are very few single offices; instead there are Googleplex workspaces.⁹⁰ Bicycles, scooters, and dogs are not alien to the workspaces and food bars, video games, and other entertainments are ubiquitous.⁹¹ The commitment to employees is core to Google's mission and its success.

Energy innovation staff must recognize that personal initiative and creativity are prized, that openness is central to success, and that problem-solving and commercialization are the core objectives. The culture must also value collaboration and interaction as well as experimentation. Energy innovation will require the agency to think through, as part of its policy, new rules for a new intellectual property regime. At one level, intellectual property must be open to the extent that there is little to no ownership by the public agency. However, in order to make private participation attractive, certain intellectual property rights must be made available to that sector.⁹² Nevertheless, the agency's culture must encourage the widespread dissemination of information in order to capture the synergies possible through collaboration.

Energy innovation agencies should also work to promote public education particularly in areas of science and technology.⁹³ By broadening education in

⁹⁰ See, e.g., *The Google Culture*, GOOGLE, <http://www.google.com/corporate/culture.html> (last visited Mar. 25, 2011).

⁹¹ See *id.*

⁹² See, e.g., Jonathan M. Barnett, *Property as Process: How Innovation Markets Select Innovation Regimes*, 119 YALE L. J. 384 (2009).

⁹³ See, e.g., ROBERT D. ATKINSON & MERRILEA MAYO, ITIF, REFUELING THE U.S. INNOVATION ECONOMY: FRESH APPROACHES TO SCIENCE, TECHNOLOGY, ENGINEERING

energy and technology studies, the nation can help create a culture that becomes an attractive employment opportunity and career path as well as a continuous learning environment. While an innovation culture invites the exploration of multiple approaches to problem-solving, it must remain accountable to mission and to articulated processes and protocols.

D. Management

The management structure for an energy innovation agency must break down the narrow and linear approach of current R&D policy. Walls that separate basic and applied research or that separate science and technology from economic and policy analysis into separate niches must be dismantled. Staff, project directors, and managers must be given a degree of independence so that they can react to new information as well as to scientific, technological, economic, and political developments. A critical mass of researchers for each project must be attained so that sufficient expertise and diversity of viewpoints are directed at projects. Further, senior directors must have regular access to their chief officers so that budgets and directions can be adjusted accordingly.

Consistent with mission, leadership, and culture, management must have as a principal task the development of mid-level managers who can nurture scientists, inventors, and problem solvers. They must be able to carry out meaningful performance reviews of personnel and programs and assess both against the overall mission of the organization. The intent is to create a professional staff capable of carrying out programs as well as managing and evaluating them.

E. Funding

While the Obama administration has increased R&D in the energy sector, clean energy innovation funding must be substantial. According to a National Science Foundation study, for example, federal non-defense energy R&D declined in real terms from about \$7 billion in 1980 to about \$1 billion in 2006.⁹⁴ Current budget proposals increase non-defense DOE R&D particularly in clean energy areas. Further, the budget increases funding for efficiency and renewable resources and reduces funding for fossil fuels thus starting to realign subsidies away from dirty energy to a clean economy.⁹⁵

We can look at the innovation process as being composed of various stages from fundamental research to technological development, demonstration, and then,

AND MATHEMATICS (STEM) EDUCATION, (2010), *available at* <http://www.itif.org/publications/refueling-us-innovation-economy-fresh-approaches-stem-education>.

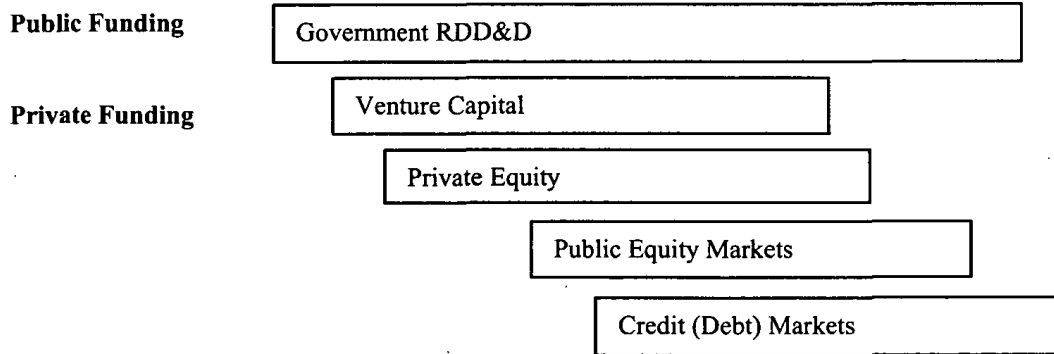
⁹⁴ PETER OGDEN, JOHN PODESTA & JOHN DEUTCH, A NEW STRATEGY TO SPUR ENERGY INNOVATION 11 (2008), *available at* http://www.americanprogress.org/issues/2008/01/pdf/energy_innovation.pdf.

⁹⁵ *See supra* notes 80–83.

ultimately, to deployment and diffusion.⁹⁶ Along that continuum, different regulatory interventions and different investment sources will be needed. The following graph provides examples of energy technologies and funding sources:

Clean Energy Technology Innovations and Funding Sources⁹⁷

Stages of Development	<i>Early R&D Proof of Concept</i>	<i>Demonstration & Scale Up</i>	<i>Commercialization & Marketability</i>	<i>Diffusion & Maturity</i>
Examples of Clean Energy Technologies	<ul style="list-style-type: none"> • Advanced battery chemistries • Algal Biofuels • Artificial Photosynthesis • Fuel Cells • Hydrogen Storage • Material Science • Next-generation Solar • Synthetic Genomics 	<ul style="list-style-type: none"> • Carbon Capture & Storage • Cellulosic Biofuels • Enhanced Geothermal • Offshore Wins • Fuel Cells • Wave/Tide power • Plug-in Electric Vehicles • Solar Thermal • Smart Grid 	<ul style="list-style-type: none"> • Coal-bed Methane • Fuel Cells • Heat Pumps • Hybrid Electric Cars • Industrial Energy Efficiency • LED Lighting • Solar Photovoltaics • Small-scale Hydro • Smart Meters 	<ul style="list-style-type: none"> • Building Insulation • Compact Fluorescent Lights • Condensing Boilers • Large-scale Hydro • Municipal Solid Waste • Onshore Wind • Public Transport • Sugar-cane Based Ethanol • Traditional Geothermal • Waste Methane Capture



⁹⁶ Gallagher, Holdren & Sagar, *supra* note 83, at 200.

⁹⁷ Adapted from WORLD ECON. FORUM, GREEN INVESTING 2010: POLICY MECHANISMS TO BRIDGE THE FINANCING GAP 35 (Jan. 2010), available at http://www3.weforum.org/docs/WEF_IV_GreenInvesting_Report_2010.pdf.

For basic scientific research in the areas of fusion or hydrogen storage, as examples, direct federal contributions are desirable. Once the technology passes the threshold at which it becomes viable, then it may be necessary to form public-private partnerships to build demonstration projects. The science and technology behind carbon capture and storage is well known and now demonstration projects are needed to market-test them. Consequently, public and private funding will be necessary. After demonstration, such things as indirect public support through the use of tax incentives, performance standards including national portfolio standards, can encourage investment in wind and solar.⁹⁸ Such measures can be used to bring those technologies to scale. Additionally, increased private funding will be used to bring those technologies to cost competitive levels. Following that stage, it will be necessary to achieve diffusion, which simply means having the technology widely available at scale and in markets, and identifying where private funding is most needed because private investors will attempt to capture gains from trade.

Stable, sufficient, and reliable long-term funding is a necessary prerequisite for successful innovation. More specifically, there must be sufficient and sustained support for early-stage and exploratory development. Similarly, senior managers and directors must be afforded a degree of discretion and flexibility over their budgets and the ability, within limits, to set funding priorities. The challenge of balancing flexibility with reliability in funding requires commitment to all of the above principles. More importantly, however, variability in funding should be driven by the success or failure of projects according to internal measures, performance reviews, and by external market forces rather than by external policies or politics. Also, along the innovation continuum, there will be a mix between public and private funding.

The relationship of the private sector to public sector innovation funding will vary across the continuum depending on the stage of technological development. To the extent that basic science and early-stage research is involved, the active involvement of the private sector may be minimal and government will, and should, shoulder the bulk of the costs. Even at the early stages, though, government should involve the private sector in policy development and in the identification of promising innovation paths. As innovation moves towards commercialization, the private sector role will increase and grow in importance. Innovation policy then becomes a dynamic public-private partnership which will require clear protocols and lines of authority.

These five principles are sound and are based, for the most part, on private organizations. They are adaptable to a public agency especially one with its eyes on commercialization. Nevertheless, because developing clean energy is intended

⁹⁸ See, e.g., Lincoln L. Davies, Commentary, *Power Forward: The Argument for a National RPS*, 42 CONN. L. REV. 1339 (2010); see also Bonvillian & Weiss, *supra* note 53, at 47; LAURA DIAZ ANADON ET AL., TACKLING U.S. ENERGY CHALLENGES AND OPPORTUNITIES, ENERGY INNOVATION TECH. GRP. 17 (2009), available at http://belfercenter.ksg.harvard.edu/files/ERD3_Energy_Report_Final.pdf; THE BROOKINGS INST., ACTING IN TIME ON ENERGY POLICY 104 (Kim Sims Gallagher ed. 2009).

to be transformational, the energy innovation organization will operate in a more dynamic environment than ordinary public or private sector entities. The energy space will be challenged by rapid technological changes, varying economies of scale, the potential for creating a variety of network effects, increased competition, the opening of new markets, and the potential for enormous profits. Energy innovation agencies will be at the center of dramatic political, economic, and social change. These agencies, then, must anticipate and manage change and must resist, as best they can, the types of lock-in and path dependency that can stymie any organization. Consequently, two additional principles should be added to the five Belfer Principles, a sell-discipline and planning and evaluation strategies.

F. Sell Disciplines

The end goal of the energy innovation agency is to put new technologies onto new markets. In short, the end goal is to turn a profit. In order to successfully operate in a dynamic market, an organization must not only anticipate change, they must be willing to abandon unpromising projects. The public-sector can learn from successful private-sector strategies and can look to money managers for insights into profit-making.

Successful professional money managers operate with two core ideas. First, they have a market niche and have a plan or model for investing in that niche. For example, a hedge fund may concentrate on emerging markets or distressed assets and they construct investment models to signal when investments in these markets should be made. To remain successful, however, they regularly and systematically test and refine their models. If the model fails to earn returns as predicted, then the model must be changed.

The second essential idea, and an integral part of the model, is a sell discipline. Investment models are purportedly designed and based on the idea that objective data indicates when investments should be made. Similarly, the model must also rely on objective indicators to determine when an asset should be sold or an investment position should be reduced. In short, money managers cannot afford to lose their objectivity regarding their investments regardless of how attractive and profitable a stock or other investment has been in the past. A crucial dimension of that objectivity is to develop a sell discipline, which is a set of protocols for divesting themselves from a particular stock or investment when the objective indicators show that the investment no longer fits their model.

The energy innovation agency must similarly adopt a sell discipline for project investments. The organization must establish benchmarks and protocols against which to measure the development, and likely success, of a particular budgeted project. When the project fails to meet those benchmarks and protocols, then funding must end. New innovation policy must look more like venture capital investments than as a source of long-term government financing. If the program does not produce, then "second round funding" will not be made. Too often, it seems, that projects or institutions are funded this year and will be funded next year because they were funded last year. While multi-year funding will be

necessary for most of the energy projects contemplated for a clean energy future, such funding cannot be held hostage to either bad ideas or to inefficient and ineffective execution of policy proposals.

G. Planning and Evaluation: Benchmarks, Assessment, and a Theory of Change

Just as energy innovation agencies can learn from private sector money managers about how to operate in a for-profit world, they have much to learn from contemporary philanthropy. Over the last two decades, forward-thinking philanthropies have dramatically changed the way they do business. Historically, foundations perceive themselves as doing good by writing checks in response to either grant requests or to perceived community needs. Too often, however, the effectiveness of check-writing and the impact of those grants have gone wanting. Because foundations were unable to measure the impact of their grants, they began to rethink their own operations and began to change their organizational cultures. Creative foundations began to transform themselves into organizations committed to having a discernible and measurable impact on their communities. Further, instead of simply making grants, foundations began to use their financial and human capital to affect change through leadership in large part by using a variety of strategies and activities to improve their communities or have an impact on their particular fields of interest.⁹⁹ As part of their organizational change, philanthropies developed and adopted a set of protocols to help them assess and measure impact.

To that end, foundations engaged in strategic thinking, treated their grant making and programming as investments rather than as charity, and began to employ continuous evaluation of programs and mission. Foundations also adopted sell disciplines and discontinued unpromising programs. Most importantly, as an aid to furthering their missions, creative foundations adopted benchmarks, assessment, and theories of change.

These last elements for a successful energy innovation organization are all aimed at internal organizational measurements. The organization must continually monitor and measure itself against its mission and against its articulated objectives. Measurement, of course, implies quantitative metrics and energy innovation metrics are neither tightly defined nor well tested. Still, they must be a necessary part of any innovation organization even though they will necessarily be supplemented with qualitative data.¹⁰⁰

⁹⁹ See, e.g., PAUL BREST & HAL HARVEY, MONEY WELL SPENT: A STRATEGIC PLAN FOR SMART PHILANTHROPY (2008); MATTHEW BISHOP, PHILANTHROCAPITALISM: HOW THE RICH CAN SAVE THE WORLD (2008); Michael Porter & Mark R. Kramer, *Philanthropy's New Agenda: Creating Value*, HARV. BUS. REV. 121 (1999). See also Dennis Hirsch, *Green Business and the Importance of Reflexive Law: What Michael Porter Didn't Say*, 62 ADMIN. L. REV. 1063 (2011); Stephanie Strom & Miguel Helft, *Google Finds It Hard to Reinvent Philanthropy*, N. Y. TIMES, Jan. 30, 2011, at BU1.

¹⁰⁰ Gallagher, Holdren & Sagar, *supra* note 83, at 210–14.

For many innovation projects, there are limited quantitative metrics that can be usefully measured. Still, there are some useful quantitative measures available. An energy innovation agency, for example, can count the number of proposals received and the number of proposals that are funded. They can monitor the amounts of funding, the areas of funding, and time periods for various proposals. In addition, the agency can track the amount of private investment that different projects attract. Similarly, human resources, such as the number of scientists and technicians, can be measured quantitatively as can the number of projects, consortia, and the like. Further, the number of scientific and scholarly papers, patents, and marketable technologies can be counted.¹⁰¹

Of course, measuring outcomes through quantitative benchmarks has a limited value, in part, because quantitative benchmarks are difficult to create and because the work of establishing and refining benchmarks falls somewhere between art and alchemy rather than between math and science. Nevertheless, quantitative markers have some value as long as the organization continues to rethink its assessment tools and its benchmarks against its mission and against the organization's theory of change. Although, it is more difficult to calculate the market penetration of successful strategies to reduce oil dependence, lower carbon emissions, or increase energy efficiency, these are the sorts of measurements that must be taken. The core problem of designing adequate metrics is the fact that the quantifiable costs of energy innovation are not commensurable with the non-quantifiable benefits of a healthier environment. Still, even quantifiable benchmarks, although they are imperfect and often cannot measure the overall purpose of funding, can provide useful data.

Here lies a crucial element for measuring success in energy innovation. It is imperative for both the public and private sectors to develop a set of common metrics to measure and assess the success of their investment dollars. Ideally, a metric should be designed to indicate how much energy is saved per dollar invested in a specific project. Similarly, a sound energy metric should also indicate how many carbon emissions (or emissions reductions) result per dollar spent as well. These metrics, then, will help shape the necessary benchmarks.

Successful investments in energy innovation should involve changes in complex energy systems across disciplines and, ultimately, in patterns of production and consumption. Quantitatively testing whether or not systems have been changed by any specific innovation project may prove difficult. Nevertheless, as energy innovation proposals estimate gains in energy efficiency or in carbon reduction, those estimates can be measured.

Assessment is a different process than benchmarking and is aimed at measuring the overall success of individual and collective projects. A project, for example, may meet or exceed its benchmarks. However, after assessment, the

¹⁰¹ See David Popp, Richard G. Newell & Adam B. Jaffe, *Energy, the Environment, and Technological Change* 8 (NBER Working Paper, Paper No. W14832, 2009), available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1373342.

project may not serve the organization's mission to a sufficient degree. Innovations in battery technology, for example, may meet a benchmark of increasing battery life yet battery size may not significantly decrease or may be too costly to affect consumption at scale. Benchmarks may be satisfied, but the mission may not be advanced. Assessment, then, is the evaluation of the effectiveness of particular policy tools.¹⁰² The government has a wide range of regulatory tools at its disposal and it is vitally important that the particular tool chosen by the agency achieve its stated objective.

An organizational theory of change is more long term than either benchmarks or assessment.¹⁰³ A theory of change is a strategic planning tool that requires an organization be clear about its assumptions, establish long-term goals, articulate its measurement tools, and recognize the interconnections among all of these elements. The idea behind the theory is to define and measure outcomes throughout every step of the innovation process as a way to assess the feasibility of the organization's behavior, programs, and activities. It is not unusual, for the theory of change to be initially vague. The usefulness of the theory, however, comes as it is refined over time and as benchmarks and assessments contribute to measuring an organization's effectiveness in reaching its long-term goals.

The long-term goal of an energy innovation organization is to move policy away from fossil fuels to one which stresses energy efficiency and renewable resources for the purpose of energy security and independence as well as economic and environmental well-being. The organization, then, must test itself against those goals and ask whether or not, as an organization, it is making a significant contribution to that change. Developing a theory of change loops back to mission, ties into benchmarks and assessment, and incorporates organizational planning and underlying assumptions while continually focusing on long-term outcomes and goals.

IV. ENERGY INNOVATION AGENCIES

The principles outlined in Part III can lead to the design of an energy innovation agency that: (1) has an expansive approach to traditional R&D and relies on a wide portfolio of innovation strategies;¹⁰⁴ (2) understands its overall

¹⁰² See, e.g., CAROLYN FISCHER & LOUIS PREONAS, *RESOURCES FOR THE FUTURE, COMBINING POLICIES FOR RENEWABLE ENERGY: IS THE WHOLE LESS THAN THE SUM OF ITS PARTS?* (2010), available at <http://www.rff.org/documents/RFF-DP-10-19.pdf>.

¹⁰³ See *Theory of Change Community*, ACTKNOWLDGE, <http://www.theoryofchange.org/index.html> (last visited Mar. 25, 2011) (a website maintained by an action research organization that works with community organizations, non-profits, foundations, and governmental agencies with a goal of transforming "traditional institutions and environments for social change.").

¹⁰⁴ The range of innovation activities can be based on such elements as end use, cost and scale, time horizons, and different risk profiles, with the purpose of balancing these attributes against energy challenges, opportunities and cost constraints. Portfolios with

mission as transforming energy policy to create a clean energy future; (3) sets a target that the bulk of its work should achieve commercialization of new energy technologies at scale;¹⁰⁵ (4) is neutral regarding which technologies ought to be adopted; (5) operates in an open environment particularly regarding the intellectual property dimensions of its innovation policy; (6) promotes the diffusion and distribution of information and approaches to innovation;¹⁰⁶ (7) intends to move from regulation to market solutions;¹⁰⁷ and, (8) intentionally aims at systems change rather than linear product development.¹⁰⁸ Above all, the agency must be committed to the idea that an energy transformation can only occur through an accelerated and sustained level of technology development beginning now.¹⁰⁹ Further, that policy must incorporate "elements of science, technology, and economic policy that explicitly aim to promote the development, spread, and efficient use of new products, processes, services, and business or organizational models."¹¹⁰

We might then design a government office that satisfies all of the Belfer Plus principles as supplemented. That office will also have a multiyear and reliable budget and will be charged to deploy energy technologies specifically for the purpose of reducing dependence on fossil fuels. It will be monitored and assessed to determine whether it is satisfying its mission to bring new technologies to commercial scale. The office will have the flexibility of operating as a for-profit company with a nonprofit mentality. In other words, success will be regularly measured, unpromising programs will be terminated, and the office will have the authority to earn a return on its RDD&D (Research Design Development and Deployment) investments as long as it places those returns back into its innovation investment portfolio. The office will also have the authority to leverage funds from other public and private sector actors.

It would seem that the DOE would be the logical locus for energy innovation agencies. The DOE can serve where the private sector falters and can fund those

multiple options can hedge against risk and government can maximize chances of success by backing multiple technologies. *See* Gallagher, Holdren & Sagar *supra* note 83, at 222; Watson, *supra* note 54, at 15.

¹⁰⁵ *See, e.g.,* Anadon & Holdren, *supra* note 81.

¹⁰⁶ *See, e.g.,* CLEAN ENERGY GRP. & MERIDIAN INST., ACCELERATED CLIMATE TECHNOLOGY INNOVATION INITIATIVE (ACT II): A NEW DISTRIBUTED STRATEGY TO REFORM THE U.S. ENERGY INNOVATION SYSTEM 19–22 (2009), available at http://www.cleaneenergy.org/Reports/ACTII_Report_Final_November2009.pdf.

¹⁰⁷ *See* LEWIS BRANSCOMB & JAMES KELLER, INVESTING IN INNOVATION: CREATING A RESEARCH AND INNOVATION POLICY THAT WORKS 474 (1999).

¹⁰⁸ *See, e.g.,* Brown & Hagel, *supra* note 82; Bonvillian & Weiss, *supra* note 53.

¹⁰⁹ NAT'L ACAD. OF SCI., NAT'L ACAD. OF ENG'G & NAT'L RESEARCH COUNCIL, AMERICA'S ENERGY FUTURE: TECHNOLOGY AND TRANSFORMATION Preface (2009).

¹¹⁰ STEPHEN J. EZELL & ROBERT D. ATKINSON, THE GOOD, THE BAD, AND THE UGLY (AND THE SELF-DESTRUCTIVE) OF INNOVATION POLICY, THE INFO. TECH. AND ENERGY FOUND. (2010), available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1722845.

projects that are too costly or too long-term for private investors.¹¹¹ The DOE, however, is not without its critics. Institutional problems include the narrowness of its programs, inability to stop failing projects, poor coordination across program boundaries, poor coordination of basic and applied research, variable congressional earmarking, lack of leadership, and limited technical skills of management.¹¹² The DOE was cobbled together by combining multiple agencies in 1977 and the organization has significant fragmentation.¹¹³ Moreover, the DOE budget is heavily defense laden and non-defense R&D enjoys a fraction of the innovation budget. Moreover, until recently, the DOE R&D budget had been declining and, perhaps more troubling, DOE funding for clean energy projects have been volatile thus making a continuous commitment to clean energy innovation difficult.¹¹⁴ The Obama administration has ramped up clean energy funding and recent administration budgets have increased investments in renewable energy and innovation, yet more sustained funding is needed.¹¹⁵

Nevertheless, despite the criticisms, DOE currently hosts a suite of energy innovation agencies and several others have been proposed.

¹¹¹ DR. LAURA DIAZ ANADON ET AL., BELFER CTR. FOR SCI. & INT'L AFFAIRS, U.S. PUBLIC ENERGY INNOVATION INSTITUTIONS AND MECHANISMS: STATUS AND DEFICIENCIES 2 (2010), available at <http://belfercenter.ksg.harvard.edu/files/US-Public-Energy-Innovation-Institutions-and-Mechanisms.pdf>.

¹¹² Gallagher, Holdren & Sagar, *supra* note 83, at 222.

¹¹³ Joseph P. Tomain, *Institutionalized Conflicts between Law and Policy*, 22 HOUS. L. REV. 661 (1985); Alfred C. Aman Jr., *Institutionalizing the Energy Crisis: Some Structural and Procedural Lessons*, 65 CORNELL L. REV. 491 (1980); Clark Bye, *The Department of Energy Organization Act: Structure and Procedure*, 30 ADMIN. L. REV. 193 (1978); see also *Department of Energy Organization Chart*, DEP'T OF ENERGY (Jan. 10, 2011), <http://www.energy.gov/organization/orgchart.htm>.

¹¹⁴ See, e.g., JOSH FREED ET AL., CREATING A CLEAN ENERGY CENTURY: RECAPTURING THE LEAD IN CLEAN TECH INNOVATION, THIRD WAY (2010), available at http://content.thirdway.org/publications/351/Third_Way_Report_-_Creating_a_Clean_Energy_Century.pdf; J.J. DOOLEY, U.S. FEDERAL INVESTMENTS IN ENERGY R&D: 1961-2008 (2008), available at http://www.pnl.gov/main/publications/external/technical_reports/PN-NE-17952.pdf; FRED SISSINE, RENEWABLE ENERGY R&D FUNDING HISTORY: A COMPARISON WITH FUNDING FOR NUCLEAR ENERGY, FOSSIL ENERGY, AND ENERGY EFFICIENCY R&D (2008), available at <http://www.nationalaglawcenter.org/assets/crs/RS22858.pdf>.

¹¹⁵ See, e.g., Gregory F. Nemet & Daniel M. Kammen, *U.S. Energy Research and Development: Declining Investment, Increasing Need, and the Feasibility of Expansion*, 35 ENERGY POL'Y 746 (2007); Ian Talley & Siobhan Hughes, *Energy: Reduced Tax Breaks Sought for Oil Industry*, WALL ST. J. (Feb. 1, 2010), <http://online.wsj.com/article/SB10001424052748704107204575039200881610236.html>; Gautham Nagesh, *OMB Asks Agencies to Focus on Science and Technology in 2011*, NEXTGOV (Aug. 5, 2009), http://www.nextgov.com/nextgov/ng_20090805_2153.php.

*A. Energy Frontier Research Centers*¹¹⁶

In 2009, the Obama administration, through the DOE, funded forty-six energy frontier research centers (EFRCs) for a commitment of approximately \$777 million as part of its strategy to invest in an energy transformation.¹¹⁷ EFRCs are based upon the idea that a successful energy transformation is basically a scientific challenge.¹¹⁸ The concept for the centers is based on a 2001 report of the Basic Energy Sciences Advisory Committee (BESAC) which conducted a study to assess the scope of fundamental scientific research necessary to achieve energy efficiency, greater use of renewable resources, improved use of fossil fuels, safe nuclear energy, future energy sources, and reduced environmental impacts.¹¹⁹ The BESAC study brought together a wide group of scientists, which further refined the most critical issues for our energy economy. Further reports identified the most pressing challenges to achieving that future and the response to those challenges was the creation of the EFRCs.¹²⁰ Those reports, for example, examined the conversion of matter into energy at the atomic and subatomic levels, studied advanced nuclear energy systems, investigated the creation of energy from biological and chemical materials, and studied the feasibility of advanced electrical storage systems as well as the development of a hydrogen economy.¹²¹

Under the EFRC initiative universities, national laboratories, nonprofit organizations and for-profit firms are invited to compete to create a center and to engage in basic and advanced scientific discovery in a broad array of fields.¹²² Supported in part by the American Recovery and Reinvestment Act, the EFRCs are intended to accelerate scientific breakthroughs and will be housed at various universities, national laboratories, nonprofit organizations, and private firms.¹²³

¹¹⁶ See *Energy Frontier Research Centers*, DEP'T OF ENERGY OFFICE OF SCI., <http://www.sc.doe.gov/bes/EFRC/index.html> (last visited Mar. 25, 2011) [hereinafter *Research Centers*].

¹¹⁷ DEPT. OF ENERGY, ENERGY FRONTIER RESEARCH CENTERS (EFRCs) (Aug. 2009), available at http://www.science.doe.gov/bes/EFRC_Award_List.pdf [hereinafter EFRCs].

¹¹⁸ See generally EZELL & ATKINSON, *supra* note 110.

¹¹⁹ See DR. JAMES F. DECKER, U.S. DEP'T OF ENERGY OFFICE OF SCI., OVERVIEW OF THE OFFICE OF SCIENCE FOR THE BESAC WORKSHOP ON BASIC RESEARCH NEEDS TO ASSURE A SECURE ENERGY FUTURE (2002), available at http://www.er.doe.gov/bes/besac/Appendix_D_intro_vgs.pdf.

¹²⁰ Capsule descriptions of these reports can be found at *Research Centers*, *supra* note 116, at 10–15.

¹²¹ *Id.*

¹²² See *id.*

¹²³ See *DOE Announcements: EFRCs: EFRCs Launched*, DOE OFFICE OF SCI., http://www.er.doe.gov/bes/EFRC/ANNOUNCEMENTS/DOE_announcements.html (last visited Mar. 25, 2011).

The forty-six projects under this initiative are funded at between \$2 million and \$5 million per year for a planned initial five-year allocation.¹²⁴ The awards fall into four basic categories including: (1) renewable and carbon neutral energy such as solar and advanced nuclear power; (2) energy efficiency in the areas of clean and efficient combustion as well as superconductivity; (3) energy storage and nanotechnologies; and, (4) crosscutting science including materials science.¹²⁵ For fiscal year 2011, the administration included a request for \$140 million which is an increase of \$40 million over the previous year's appropriation.¹²⁶ The EFRCs, thus, are directed to harness basic science and advanced discovery in order to establish a sound scientific foundation for a fundamentally new United States energy economy.

B. DOE Energy Innovation Hubs¹²⁷

Energy Innovation Hubs are intended to serve as multidisciplinary, multi-investigator, and multi-institutional integrated research centers. The Hubs are modeled after major United States R&D initiatives such as the Manhattan Project and Project Apollo and they are based upon the design of public and private national laboratories. The Hubs are intended to bring together top scientists, engineers and researchers from industry, the academy, and government and they are charged with addressing technological barriers to transformative advances in energy technology. The more specific mission is to help promote United States leadership in a clean energy economy.

The core idea behind Energy Innovation Hubs is to engage long-term funding for the integration of basic and applied research from engineering through potential commercialization. The Innovation Hubs will involve large and integrated teams directed to solve priority technology challenges. National labs have been criticized, recently, for not creating technological breakthroughs and the creation of these Hubs is an attempt to construct an innovation program modeled after the early successes of national labs as well as those private sector labs such as Bell Labs, Xerox, and IBM Research.¹²⁸

¹²⁴ The list of forty-six projects can be found at *Research Centers*, *supra* note 116, and specific funding information may be found at DEPT. OF ENERGY, ENERGY FRONTIER RESEARCH CENTERS (EFRCs) (Aug. 2009), available at http://www.science.doe.gov/bes/EFRC_Award_List.pdf.

¹²⁵ See OFFICE OF SCI., U.S. DEP'T OF ENERGY, ENERGY FRONTIER RESEARCH CENTERS: TECHNICAL SUMMARIES (2010), available at http://www.sc.doe.gov/bes/EFRC/files/EFRC_technical_summaries_Jan_2010.pdf.

¹²⁶ See *DOE Announcements: EFRCs: EFRCs Launched*, DOE OFFICE OF SCI., http://www.er.doe.gov/bes/EFRC/ANNOUNCEMENTS/DOE_announcements.html (last visited Mar. 25, 2011).

¹²⁷ *Energy Innovation Hubs*, DEP'T OF ENERGY, <http://www.energy.gov/hubs/> (last visited Mar. 25, 2011) [hereinafter *Energy Innovation Hubs*].

¹²⁸ See ANADON ET. AL., *supra* note 111, at 3.

Funding is to be based upon five-year renewable contracts commissioned for promoting scientific excellence and for developing a cadre of professional staff dedicated to such research.¹²⁹ Funding has been proposed at \$135 million with initial year funding at \$22 million with up to \$10 million for infrastructure start-up costs, equipment, and instrumentation.¹³⁰ It is anticipated that each Hub will be funded at up to \$25 million a year for the remaining four years of the project.¹³¹ The Hubs are to be truly interdisciplinary and will involve non-science and technology specialties such as energy policy, economics, and the market analysts.¹³²

The DOE has launched three Hubs that are expected to pursue transformative breakthroughs in technology to meet our energy needs.¹³³ The Hubs are intended to engage energy science and engineering from the early stages of research to the point where technology can be then handed off to the private sector. The Hubs are to involve cross-disciplinary collaborations between science and technology and will be directed to address three challenges: (1) deriving fuels from sunlight in efficient and economical ways; (2) design, construct, and retrofit commercial and residential buildings to enhance energy efficiency; and (3) employ modeling and simulation technologies to significantly improve nuclear reactor design and engineering. These efforts are directed to producing technologies on a large scale equal to the challenge of weaning ourselves from fossil fuels and achieving significant reductions in greenhouse gas emissions that will lead to a clean and secure energy future. The Hubs will organize research teams from universities, private industry, non-profits, and government laboratories with the intent to become a world-leading R&D center in each of these three topical areas.¹³⁴ Additionally, the Hubs are intended and are designed to conduct systems-level R&D while accelerating current state-of-the art energy science and technology by supporting high-risk/high-reward research projects intended to produce transformative changes in how we produce and consume energy.¹³⁵

The Hubs are distinguishable from the EFRCs by their scale, their mission to integrate scientific research and engineering development, and their more specific focus on driving energy technology solutions to their limits.¹³⁶ Similarly, the Hubs are distinguishable from another DOE energy innovation agency, called Advanced Research Projects Agency-Energy (ARPA-E) and discussed immediately below. In

¹²⁹ See *Research Centers*, *supra* note 116.

¹³⁰ ANADON ET AL., *supra* note 111, at 3.

¹³¹ *Id.*

¹³² *Energy Innovation Hubs*, *supra* note 127.

¹³³ See *Energy Innovation Hubs: Q & A*, DEP'T OF ENERGY, <http://www.energy.gov/hubs/qanda.htm> (last visited Mar. 25, 2011).

¹³⁴ *Id.*

¹³⁵ See *Energy Information Hubs: Overview*, DEP'T OF ENERGY, <http://www.energy.gov/hubs/overview.htm> (last visited Mar. 25, 2011).

¹³⁶ See *Energy Innovation Hubs: Q & A*, DEP'T OF ENERGY, <http://www.energy.gov/hubs/qanda.htm> (last visited Mar. 25, 2011).

brief, ARPA-E has a more commercial focus, while the Hubs concentrate on linking science and technology. Combined, these three DOE energy innovation agencies comprise a portfolio of innovation initiatives that are intended to complement each other and approach energy transformation in a comprehensive fashion.

*C. Advanced Research Projects Agency - Energy*¹³⁷

ARPA-E was established under the DOE as part of the America Competes Act of 2007¹³⁸ and was also based upon a National Academies report recommending increased investment in science and technology.¹³⁹ ARPA-E was modeled on the successful Defense Advanced Research Projects Act which is responsible for stealth technologies as well as the Internet. ARPA-E was initially funded at \$400 million in 2009 under the American Recovery and Reinvestment Act. Its mission is to fund projects to develop transformational energy technologies and accomplish the goals of a smart energy policy. The agency is specifically directed to increase our energy independence, reduce greenhouse gas emissions, improve efficiency, and ensure that the United States remains a technological and economic leader in deploying advanced energy technologies.¹⁴⁰

ARPA-E is based on the idea that business as usual is not an option for our energy future. The first round of funding was considered successful by the DOE; the agency received 3,700 concept papers and 334 full proposals leading to the funding of thirty-seven projects.¹⁴¹ While promising and highly selective, only 1 percent of the proposals received awards and the agency recognized the need for greater funding even as it attempts to invest in major ideas that are ready to be adopted by the market.¹⁴² ARPA-E has created a website connecting potential applicants and investors to act as partners as well as customers for technological breakthroughs that result through its funding.¹⁴³ In this way, then, ARPA-E is acting as a facilitator and convener of an energy transformation helping to bring energy technology innovations to commercial scale.

¹³⁷ See *Advanced Research Projects Agency-Energy*, ARPA-E, <http://arpa-e.energy.gov/> (last visited Mar. 25, 2011).

¹³⁸ America Competes Reauthorization Act of 2010, Pub. L. No. 111-358, 124 Stat. 3982.

¹³⁹ See NAT'L ACAD. OF SCI., NAT'L ACAD. OF ENG'G, & INST. OF MED., *RISE ABOVE THE GATHERING STORM: ENERGIZING AND EMPLOYING AMERICA FOR A BRIGHTER ECONOMIC FUTURE* (2007), available at <http://www.utsystem.edu/competitive/files/RAGS-fullreport.pdf>.

¹⁴⁰ *About*, ARPA-E, <http://arpa-e.energy.gov/About.aspx> (last visited Mar. 25, 2011).

¹⁴¹ *ARPA-E Projects (Current)*, ARPA-E, <http://arpa-e.energy.gov/About/FAQs/ARPA-EProjectsCurrent.aspx> (click "How were these projects selected") (last visited Mar. 25, 2011).

¹⁴² *Id.*

¹⁴³ *See id.*

It is also understood that ARPA-E will focus exclusively on high risk, high payoff concepts to dramatically change the way we generate, store, and utilize energy. The agency has initially funded projects involving building efficiency, carbon capture, direct solar power, biomass, energy storage, and others.¹⁴⁴ Funding was also provided in such esoteric areas as fuel-secreting bacteria, liquid batteries, and creating solar energy by mimicking photosynthesis. Currently, ARPA-E projects are funded for three years and, given the high risk nature of these investments, in the future, the projects may need to be of longer duration and, in any event, will need to be protected from political intrusion should the risks appear to overtake the rewards.

One criticism of ARPA-E is precisely that it was modeled after DARPA, which was a technology driven model of innovation.¹⁴⁵ The Defense Department was assigned the task to develop certain technologies without clear evidence of market demand. The needs in the energy sector, however, are intentionally market-driven. Without a direct and constant focus on commercialization, most energy innovations have little value or utility. Of course risks will be taken and failures will occur. Nevertheless, at the outset, most innovation initiatives will look to scale and marketability as well as commercial feasibility as measures of success if not for the initiation of projects.

ARPA-E may be enjoying some early success. In 2009, ARPA-E awarded \$151 million in grants to thirty-seven radical clean energy ideas such as advanced electric storage based upon the science of photosynthesis.¹⁴⁶ Since that time six of the projects have attracted \$108 million in private venture capital funding.¹⁴⁷ This is a 4:1 ratio of private to public dollars for these projects.¹⁴⁸ The agency recognizes that complete success or commercialization may be a decade or two away, nevertheless to be able to attract private money so shortly after initial funding is a significant sign of interest.¹⁴⁹ More importantly, this early success demonstrates the interrelationship between the public and private sectors and it demonstrates that energy innovation policy is working as intended.¹⁵⁰

This group of existing agencies is approaching energy integration from basic science to commercialization. The approach is wide ranging, the mission is transformative, and the intent is to integrate energy, the environment, the economy, and security into a coherent approach to our economic future. These DOE

¹⁴⁴ *ARPA-E Projects*, ARPA-E, <http://arpa-e.energy.gov/ProgramsProjects/ViewAllProjects.aspx> (last visited Mar. 25, 2011).

¹⁴⁵ See OGDEN, PODESTA & DEUTCH, *supra* note 94, at 10.

¹⁴⁶ *History*, ARPA-E, <http://arpa-e.energy.gov/About/History.aspx> (last visited Mar. 25, 2011).

¹⁴⁷ Matthew L. Wald, *Energy Firms Aided by U.S. Find Backers*, N.Y. TIMES, Feb. 3, 2011, at B1.

¹⁴⁸ *Id.*

¹⁴⁹ *See id.*

¹⁵⁰ *See id.*

agencies, however, are not the only ones under consideration. Several other energy innovation agencies have been proposed by non-governmental organizations.

D. Energy Innovation Council and Energy Technology Corporation

In a 2008 article, the Center for American Progress (CAP) outlined an innovation strategy to specifically respond to rising oil prices, the fragility of our dependency on foreign oil, and increasing carbon dioxide emissions.¹⁵¹ The report recognized that the emerging economies of China and India would only exacerbate problems associated with global warming. The report acknowledged that our energy economy must experience a transformation and that innovation and investment are essential for its success. The Center recommended the establishment of two interrelated entities—the Energy Innovation Council (EIC) and the Energy Technology Corporation (ETC).¹⁵² The EIC would be responsible for developing a national R&D strategy. The Council would develop a plan to integrate federal energy R&D programs over a multi-year period and would examine the use of both direct spending for technology support and indirect financial incentives intended to promote demonstration. Under the proposal, the EIC would be based in the White House and would be comprised of representatives from the key federal agencies involved with energy, the environment, and national security.

The national innovation strategy would set program priorities, schedules, and resource requirements. The strategy would be based upon modeling and simulation tools as well as relevant engineering and cost data. The national innovation strategy would identify alternative technological pathways as well as assess the inevitable trade-offs. The EIC would be assisted by a national advisory group from public and private sector institutions and the national strategy would be submitted to Congress for its review and endorsement. The strategy would then serve as the basis for a five-year budget authorization and appropriation for energy innovation programming.

In addition to developing an energy innovation strategy of national scope, the energy innovation policy would be integrated to the ends of discovering new ideas for energy supply and efficient use, accumulating scientific and engineering data as the basis of deployment, constructing needed R&D facilities, and, establishing mechanisms for interaction between technical experts and market savvy entrepreneurs. Once developed, these ideas and programs would be brought across the “valley of death” and marketed under the auspices of a semi-public ETC specifically focusing on demonstration. The ETC, then, would be the financing arm for the national energy strategy.

These innovation investments must assess cost, technological capability and performance, and environmental impact at each stage of development. The

¹⁵¹ OGDEN, PODESTA & DEUTCH, *supra* note 94, at 3.

¹⁵² *Id.*

approach must be multiyear and must provide roles for government, industry, universities, and laboratories. The government must use a variety of incentives including direct investment in early-stage and indirect support in the later stages as technologies goes to market. Together, these two organizations would build upon past R&D successes and extend them into a more thorough approach to marketability. Early-stage research and exploration, for example, is seen as a necessary step in a process leading to technological diffusion and adoption. The role of government funding in this process is central particularly at the early stages.

E. Energy Strategy Board

Another NGO, the American Energy Innovation Council, has also recommended the creation of an innovation agency along the lines of CAP's (EIC). AEIC's proposed Energy Strategy Board would be charged with developing a national energy strategy.¹⁵³ While it is true that the country has never developed a coordinated and comprehensive energy plan, it has, in part by default and in part by design, developed a *de facto* energy policy that relies upon and supports large-scale, capital-intensive, fossil-fuel firms and industries to satisfy our demand for energy.¹⁵⁴ As noted previously, the existence of such a pervasive and long-term approach to energy has resulted in significant investments and discontinuities. The country is caught between having invested extraordinary amounts of money and creating a national infrastructure dominated by fossil fuels only to reluctantly become aware of the social costs of dirty energy.

A national energy strategy would move us away from that tendency and move us toward an energy policy that is sensitive to environmental degradation while opening new markets and creating new jobs. Such a plan would not only focus on energy producers it would assess end use needs.¹⁵⁵ By way of example, a national energy policy would not develop new ways to support fossil-fuel suppliers; instead, it would address how the transportation sector can be made more efficient as we wean ourselves from oil, rely on new technologies, and create a new infrastructure.

The Energy Strategy Board (Board) would attempt to address past investments and discontinuities by focusing on the development and implementation of new energy technologies. The Board would be responsible for developing and monitoring a national energy plan for Congress and the White House. It would also be responsible for the oversight of government funded "challenge projects" to build large-scale demonstrations. The Board would not be housed within the United States government and would, preferably, be politically

¹⁵³ INNOVATION COUNCIL, *supra* note 48, at 4-5, 16-18.

¹⁵⁴ See Joseph P. Tomain, *The Dominant Model of United States Energy Policy*, 61 U. COLO. L. REV. 355 (1990).

¹⁵⁵ Gallagher, Holdren & Sagar, *supra* note 83, at 195.

neutral. It would also be comprised of a broad array of experts in energy technologies and their respective markets.

In order to assist the Board in implementing its national energy policy, AEIC further recommends that clean energy innovation be funded at \$16 billion per year at a minimal level.¹⁵⁶ Projects should be funded on a multi-year basis, and centers of excellence would be created to complement the work of DOE. The proposal is intended to provide an array of policies that can help stabilize market signals, encourage competition among technology providers, and steadily reward improvements in performance. Such principles are used by successful businesses in many different sectors.

F. Quadrennial Energy Review

The DOE has also proposed the creation of an integrating innovation activity that it calls the Quadrennial Energy Review (QER).¹⁵⁷ The QER is a process that would be carried out in the White House and provide a multi-year roadmap that looks at short, intermediate, and long-term energy objectives. Like the other proposals already discussed, the QER is dedicated to a clean, safe, and secure energy future through accelerating the pace of energy technology innovation. The idea is to develop an innovation policy which is coordinated with federal energy policy more generally.

The QER would outline legislative proposals for Congress as well as identify executive actions that cut across multiple agencies in order to further the development of energy technologies. Although located in the White House, the proposal calls for input from Congress, as well as industry and the academy, with a substantial role to be played by the Secretary of Energy. The QER would establish strategies for the development of energy technologies, involve national laboratories, and assess the deployment of pilot projects and funding needs for each technology.

From a funding perspective, the recommendation advocates financial support of \$16 billion per year.¹⁵⁸ Additionally, the proposal recommends an assessment of energy subsidies and incentives to determine how well they further clean energy policy. The recommendation is intended to promote transparency in the process of gathering information for policy formation. It is also intended to create connections between the executive and legislative branches with emphasis on future energy policy. First, the QER is intended to generate an array of technology options that

¹⁵⁶ Press Release, American Energy Innovation Council, American Business Leaders Call for Revolution in Energy Technology Innovation (June 10, 2010), *available at* http://www.americanenergyinnovation.org/press-release-pdf/AEIC_Press_Release.pdf.

¹⁵⁷ See PRESIDENT'S COUNCIL OF ADVISORS ON SCI. & TECH., REPORT TO THE PRESIDENT ON ACCELERATING THE PACE OF CHANGE IN ENERGY TECHNOLOGIES THROUGH AN INTEGRATED FEDERAL ENERGY POLICY (2010), *available at* <http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-energy-tech-report.pdf>.

¹⁵⁸ *Id.* at 14.

will be marketable. The process is not intended to promote any specific technology or to benefit any targeted clients. Second, the proposal recognizes that there is not a single path to a clean energy future. Instead, government action will be needed along a number of fronts including advanced nuclear power, carbon capture and sequestration, building efficiency options, and the like. To the extent that existing laws and regulations constitute barriers to innovation, then the QER should help identify those barriers and suggest ways around them for the express purpose of bringing emerging technologies to market.

G. Energy Discovery Innovation Institutes

Another NGO, the Brookings Institution, has suggested a method for stimulating innovation, as well as its commercialization, through the creation of a dozen Energy Discovery Innovation Institutes (e-DIIs) which then would comprise a national network of regionally based research centers.¹⁵⁹ The proposal calls for an interagency process to competitively award up to \$200 million per year for each institute operated by either an individual university, national laboratory, or a consortia.¹⁶⁰ The funding would be augmented by industry, investors, universities, and governments with the goal of reaching \$6 billion per year in innovation spending.¹⁶¹

The goal of the institutes would be to foster partnerships for cutting-edge and application-oriented research among a diversity of participants and disciplines. Additionally, the institutes would be designed to transfer innovation technologies and information about innovation processes rapidly and broadly.¹⁶² A midterm goal would include building a knowledge base and the human capital necessary to sustain energy innovation efforts. Further, the institutes would help encourage regional economic development by creating a number of startup firms, private research organizations, suppliers, and other aligned groups and businesses.

These institutes would not only be comprised of experts in science technology and business, it will also involve specialists in public policy, economic and legal analyses, as well as behavioral issues. As consumers, we might prefer to think that a radical energy transformation can occur without a radical transformation in consumer behavior and in our energy use habits. However, as we invest in energy innovation technologies, we should also be aware of the consequences of their deployment. The institutes, then, are to act as innovation clusters bringing together a diverse group of actors addressing similar problems bound together by a network

¹⁵⁹ Duderstadt et al., *supra* note 58; see also Jonathan Sallet, Ed Paisley & Justin Masterman, *The Geography of Innovation: The Federal Government and the Growth of Regional Innovation Clusters*, SCI. PROGRESS (Sept. 1, 2009), <http://www.scienceprogress.org/2009/09/the-geography-of-innovation/>.

¹⁶⁰ Duderstadt et al., *supra* note 57, at 3.

¹⁶¹ *Id.*

¹⁶² See Symposium, *Harnessing the Power of Information for the Next Generation of Environmental Law*, 86 TEX. L. REV. 1347 (2008).

of shared concerns and synergies particularly uniting our country's research universities linked with corporate R&D efforts and federal energy initiatives.¹⁶³

H. Legislative Solutions

In recent years, as climate bills have been introduced in Congress, proposals have been made to create a separate agency devoted to addressing clean energy. The Clean Energy Leadership Act, for example, proposed the creation of a Clean Energy Employment Administration.¹⁶⁴ Similarly, the failed American Clean Energy and Security Act of 2009 (ACES)¹⁶⁵ proposed the creation of a similar agency and prior to that the Green Bank Act had proposed another such agency.¹⁶⁶ The central idea behind all of these legislative proposals is to create a financing entity. The agency would provide loans, loan guarantees and other financial products specifically to provide affordable financing to accelerate and widely deploy clean energy technologies, build a clean energy infrastructure, promote energy efficiency, and related products and services.

Although each proposed agency differs in the design, structure, funding sources and priorities, they do share certain commonalities. All, for example, focus on technology. Similarly each agency is intended to promote clean energy and carbon reduction. In looking at the best of all proposals, certain principles emerge. It has been argued, for example, that such an agency should (1) only support low-carbon energy technologies, (2) concentrate on emerging technologies which are close to commercialization as distinguished from demonstration-stage or early-stage commercialization, (3) should have a higher tolerance for risk than general regulatory programs, and (4) should operate with adequate congressional oversight and protection.¹⁶⁷

At the heart of these proposals is a concept well known to venture capitalists and is crucial to the success of an innovative energy policy. In short, these agencies are intended to help new technologies over the "valley of death." Most simply, the valley of death is the period between concept and commercialization. While venture capitals are in the high risk/high reward business, and while many have been made wealthy during the digital revolution, clean energy technologies are structurally different than many of the information and communications technologies and that achieved great success.

In short, clean energy technologies place a significantly large capital demand on investors. Clean energy technologies, to succeed, must do so at a very large

¹⁶³ See, e.g., Sallet et al., *supra* note 159; see also Freed, Zevin & Jenkins, *supra* note 58.

¹⁶⁴ American Clean Energy Leadership Act of 2009, S. 1462, 111th Cong. (2009).

¹⁶⁵ American Clean Energy and Security Act of 2009, H.R. 2454, 111th Cong. (2009).

¹⁶⁶ H.R. 1698, 111th Cong. (2009).

¹⁶⁷ Allison S. Clements & Douglass D. Sims, *A Clean Energy Deployment Administration: The Right Policy for Emerging Renewable Technologies*, 31 ENERGY L. J. 397, 404 (2010).

scale and may not be market-ready for many years, if not for decades, due to long time horizons.¹⁶⁸ A full complement of clean energy technologies, for example, will include a smart infrastructure from meters to a transmission and distribution grid and will need to phase out existing technologies in which considerable investment dollars have been dedicated for decades.¹⁶⁹ Similarly, some energy technologies, for example, advanced batteries, need to develop better basic science in addition to commercial implementation and application. Another way of understanding the problem is that clean energy technologies are caught in a gap between venture capital and commercial lenders. Venture capitalists have a high tolerance for risk but must demand relatively short-term rewards. Commercial lenders reverse the pattern. Commercial lenders have more capital and are willing to lend for longer periods of time but they have low risk tolerance. Consequently, the private sector will underfund clean energy technologies even though their investments have been increasing regularly. To shore up this funding gap, government agencies and policies are necessary.¹⁷⁰ The public agency, instead of focusing only on return, can concentrate on making investment decisions based on the potential for "efficient and effective climate change mitigation, economic growth, and energy independence."¹⁷¹

V. CONCLUSION

The global energy market is estimated to be valued at \$6 trillion. It has also been estimated that over the next ten years the clean energy market can reach as much as \$2.2 trillion with annual growth of \$600 billion.¹⁷² Domestically, a clean energy market might support nearly 750,000 jobs by 2020 and result in clean energy exports of \$40 billion by 2020 and up to \$200 billion by 2050.¹⁷³ Currently, the United States is a bit behind the clean energy curve. Consequently, public and

¹⁶⁸ Duderstadt et al., *supra* note 57.

¹⁶⁹ See Gallagher, Holdren & Sagar, *supra* note 83, at 225; Watson, *supra* note 54, at 22.

¹⁷⁰ See BLOOMBERG NEW ENERGY FIN., CROSSING THE VALLEY OF DEATH: SOLUTIONS TO THE NEXT GENERATION CLEAN ENERGY PROJECT FINANCING GAP (2010), available at http://www.cleaneenergy.org/Reports/CEG_BNEF-2010-06-21_valleyofdeath.pdf; L. M. MURPHY & P.L. EDWARDS, NAT'L RENEWABLE ENERGY LAB., BRIDGING THE VALLEY OF DEATH: TRANSITIONING FROM PUBLIC TO PRIVATE SECTOR FINANCING (2003), available at http://www.cleanenergystates.org/CaseStudies/NREL-Bridging_the_Valley_of_Death.pdf.

¹⁷¹ Clements & Sims, *supra* note 167, at 408.

¹⁷² FREED, *supra* note 114, at 13; see also PEW CTR. ON GLOBAL CLIMATE CHANGE, IN BRIEF: CLEAN ENERGY MARKETS: JOBS AND OPPORTUNITIES (2010), available at http://www.pewclimate.org/docUploads/Clean_Energy_Update_Final.pdf.

¹⁷³ See ED GERWIN, ANNE KIM, AND JOSH FREED, THIRD WAY, GETTING OUR SHARE OF CLEAN ENERGY TRADE 2 (2010), available at <http://www.thirdway.org/subjects/8/publications/264> (follow the "View/Download PDF" link).

private investment in a clean energy economy not only addresses environmental and security concerns, it will help define our future position in the world.

Energy technology innovation is an essential element to our country's economic prosperity. Innovation policy alone, of course, will be insufficient to achieve a radical transformation in the energy sector. However, innovation policy coupled with incentive regulations, trade and competition policies, and government leadership can move us away from our dependence on dirty energy to a more self-sustaining and reliable energy economy. Climate change presents extraordinary challenges to us. Nevertheless, it is imperative that the country adopt a clean energy portfolio. We can either adopt that portfolio simultaneously with addressing climate change or independently of it. As President Obama noted in his 2011 State of the Union message, energy and the environment pose a heroic challenge, yet our past history reveals that we can meet it.