Committee on Appropriations, Subcommittee on Energy and Water
United States House of Representatives
Testimony for the February 28, 2007 Hearing on:

A Ten Year Outlook for Energy

by

Daniel M. Kammen

Professor in the Energy and Resources Group (ERG)
Professor of Public Policy in the Goldman School of Public Policy
Co-director Berkeley Center for the Environment
Director, Renewable and Appropriate Energy Laboratory (RAEL)
University of California, Berkeley

http://socrates.berkeley.edu/~kammen *http://rael.berkeley.edu*

Introduction & Summary

Chairman Peter Visclosky, Ranking Member Dave Hobson, and other members of the House Energy and Water Subcommittee, I appreciate your invitation to appear before you today. I am particularly thankful of Chairman Visclosky's efforts to increase federal energy research, development and deployment spending, and hope that the hearing today firmly cements in the minds of all lawmakers the critical role that federal leadership will have to play in developing a national agenda that will make clean, affordable and secure energy our national priority.

I am grateful for the opportunity today to speak with you on the energy, climate, and security issues that face our nation and the planet. I am also particularly appreciative of the unusual and timely nature of this hearing. This country must assert leadership on energy issues, something that has been absent for far too long.

At the heart of my comments is the finding that leadership in protecting the environment and improving our economic and political security can be achieved not at a cost, but instead with political and economic benefits to the nation in the form of reasserted leadership both technologically and financially, through increased geopolitical stability and flexibility, and through job growth in the 'clean energy' sector. To accomplish these goals, not only will a comprehensive strategy – **a plan** – be needed (Augustine, 2005; Kammen and Nemet, 2005), but we must develop a balanced approach that utilizes 'technology push' and 'demand pull' mechanisms equally in the emerging clean energy sector.

Developing a balanced portfolio of energy research, development, and deployment projects (RD&D) is central to my testimony today, but I must stress at the outset that 'technology push' projects must be accompanied by 'demand pull measures'. Among the most important demand-pull options available to us today are renewable energy portfolio standards, low-carbon fuel standards, carbon taxes, and international collaborations designed to commercialize clean energy technologies. I will feature each of these measures in the Appendices of this testimony.

Developing a National Energy Strategy

Before we debate particular technologies, funding decisions, and specific economic measures, it is critical to recognize that we currently *do not* have an energy plan. We have arguably not had an energy plan since the efforts by Presidents Ford and Carter.

Recently, however, integrated planning on climate and energy has begun to emerge, although largely at the state and regional level. Supreme Court Justice Louis D. Brandeis wrote in 1932 that:

> … a single courageous state may, if its citizens choose, serve as a laboratory; and try novel economic and social experiments….

Conservative and liberal justices have quoted this line over 30 times in subsequent Supreme Court Opinions. These courageous experiments are now taking place in a number of U. S. states, and can form the basis of needed federal legislation and leadership. AB32 in California, as well as the regional Greenhouse Gas Initiative (RGGI, http://www.rggi.org/) in the Northeast and Mid-Atlantic States are such examples. By contrast, the Federal Administration's current target will require only a slight change from the business as usual case (
Figure 1) (EPA 2005). More relevant to the climate problem, reaching this target would actually allow emissions to grow by 12 to 16%. This target would thus represent a larger increase than the 10% increase that occurred in the previous decade. If we are to be serious about meeting the climate challenge we need to set a goal consistent with the Department of Energy's Climate Change Technology Plan (CCTP) objective of moving toward zero net emissions.

The California climate change protection plan is one that this committee should carefully consider in developing a comprehensive climate plan. The Governor of California's five decade GHG emissions targets of 80% below 1990 levels (EE 3-05) and the 25% GHG reductions adopted via AB32 (the Pavley/Nuñez Bill, or, formally the 'California Global Warming Solutions Act of 2006') include both near-term and longer-term goals – including market-based cap and trade mechanisms -- that delineate a path of emissions *reductions* toward climate stabilization. Congress should act to set a series of targets that show a clear path to meaningful emissions reductions.

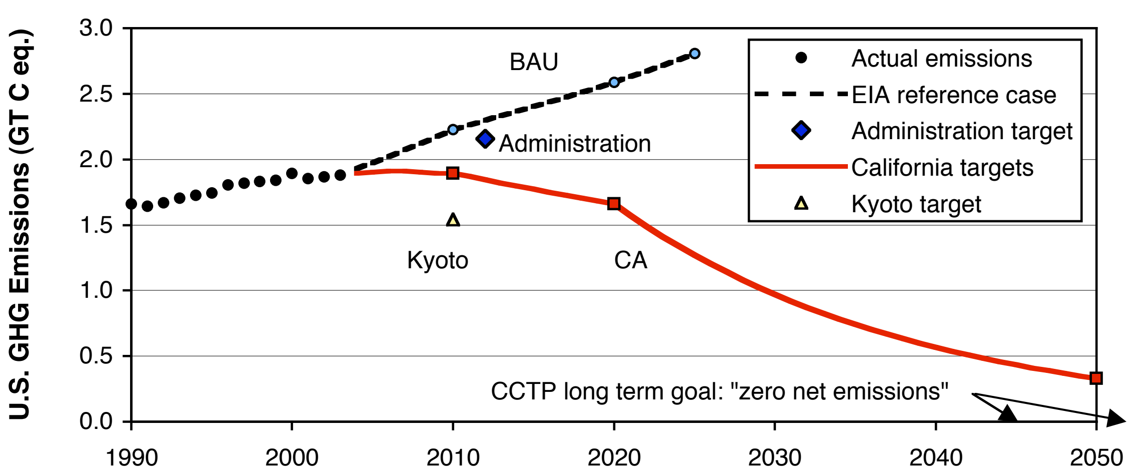

Figure 1 Historical U.S. GHG emissions and targets

Actual U.S. GHG emissions from 1990 through 2003 (EPA 2005) in giga-tons of carbon equivalent. Four future paths for future U.S. emissions are shown; circles show the business-as-usual (BAU), or "reference case," as calculated by the Energy Information Agency (EIA). The diamond shows the Administration's GHG intensity target for 2012 of 18% below 2002 level in tons of carbon per unit of GDP, or a 3.6% reduction in emissions from BAU. The squares show U.S. emissions if the nation were to meet the percentage reductions that have been announced in California for 2010, 2020, and 2050 (California Executive Order 3-05, and California AB32, the "Pavley-Nuñez Bill'). The triangle shows the U.S.'s target for 2010 under the Kyoto Protocol. Arrows indicate the levels required to meet the U. S. Department of Energy's Climate Change Technology Plan (CCTP) long-term goal of "levels that are low or near zero" (p. 2-2).

What is needed is a serious and sustained commitment to emissions reductions and a time scale that conveys to the country the urgency of the need to open future options. The California plan, for example, does not start or end with AB32, but includes a set of mutually reinforcing laws and executive orders. The most recent of which, the Low Carbon Fuel Standard (EE 1-07) makes a significant advance in our regulatory power to discriminate between the full range of liquid (petroleum or fossil-fuel based) fuels or electricity to power plug-in hybrid vehicles.

A Self-Consistent Energy Plan: Recent California Energy and Climate Legislation

California Renewable Energy Portfolio Standard (RPS)
Renewables to constitute 20% by 2010 (& 33% by 2020)
AB 1493 (Pavley)
30% reduction in automobile GHG emissions (MY2016)
Executive Order S-3-05
Statewide GHG emission reduction targets (~25% in 2020)
AB 32 (Pavley/Nuñez – California Climate Solutions Act of 2006)
30% GHG reduction from stationary sources/statewide plan
CPUC action further requires that electricity sold into California meet a carbon standard based, today, on the current generation of natural gas-fired power plants. Further reductions will proceed as CA meets
AB 1007 (Pavley 2)
"develop a comprehensive strategy…alternative fuels"
and measure the Cleanenergy jobs dividend
Executive Order 06-06
Statewide biofuels production targets (40% in 2020)
Executive Order 1-07
California Low-Carbon Biofuel Standard (& State of the State address, January 2007)

The California plan represents only one such path to a low-carbon society, but it embodies the key features that are required in federal legislation: an integrated, consistent approach that both initiates early action *and* clarifies the long-term roadmap to a decarbonized future.

A Roadmap to a De-carbonized Economy

1. Raise Clean Energy Research, Development, and Deployment Spending to Reasonable Levels

The U. S. has under-invested in energy research, development, and deployment for decades, and sadly the FY2008 budget request is no exception. This history is shown in Figure 2: federal energy research and development investment is today back at *pre-OPEC* levels – despite a panoply of reasons why energy dependence and *in-security,* and climatic impact from our energy economy are dominating local economics, geopolitics, and environmental degradation.

At $2.7 billion, the overall energy RD&D FY08 request is $685 million higher than the FY06 appropriated budget. Half of that increased request is accounted for by increases in fission, and the rest is in moderate increases in funding for biofuels, solar, FutureGen, and $147 million increase for fusion research. However, the National Renewable Energy Laboratory's (NREL) budget is to be cut precisely at a time when concerns over energy security and climate change are at their highest level, and level of need. The President further proposes to cut assistance to low-income families by 41% from FY06 levels for weatherization to improve the energy efficiency of their homes is startling.

The larger issue, however, is that as a nation we invest *less* in energy research, development, and deployment than do a few large biotechnology firms in their own, private R&D budgets. This is unacceptable on many fronts. The least of which is that we *know* that investments in energy research pay off at both the national and private sector levels.

In a series of papers (Margolis and Kammen, 1999; Kammen and Nemet, 2005) I have documented a disturbing trend away from investment in energy technology—both by the federal government and the private sector, which largely follows the federal lead (Figure 3). The U.S. invests about $1 billion less in energy R&D today than it did a decade ago. This trend is remarkable, first because the levels in the mid-1990s had already been identified as dangerously low, and second because, as our analysis indicates, the decline is pervasive—across almost every energy technology category, in both the public and private sectors, and at multiple stages in the innovation process. In each of these areas investment has been either been stagnant or declining. Moreover, the decline in investment in energy has occurred while overall U.S. R&D has grown by 6% per year, and federal R&D investments in health and defense have grown by 10 to 15% per year, respectively.

Figure 1 shows all U.S. federal R&D programs since 1955. Notice the thin (red) strip showing how small the energy R&D program is relative to the other sectors. The current budgets for energy R&D would continue this situation, or even reduce R&D investment (Kammen and Nemet, 2005)**.** This is not in the best interests of the nation.

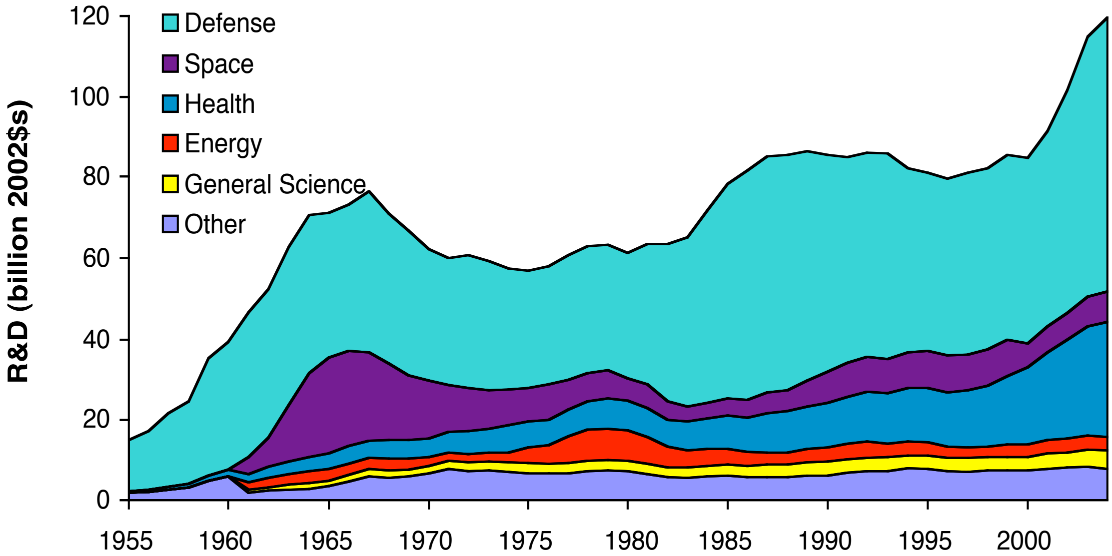

Figure 2. Overall federal investment in science and technology, with energy highlighted as the third sliver from the bottom. Note the comparison with the life sciences R&D budget, directly over the energy component. The federal health R&D budget experienced a doubling from the mid-1980s to today, and at the same time, private sector health investment increased by a factor of 15. Source: *Margolis, R. and Kammen, D. M. (1999) "Underinvestment: The energy technology and R&D policy challenge", Science, 285, 690 - 692.*

One of the clearest findings from tracking actual investment histories, is that there is a direct and strong correlation between investment in innovation and demonstrated changes in performance and cost of technologies available in the market.

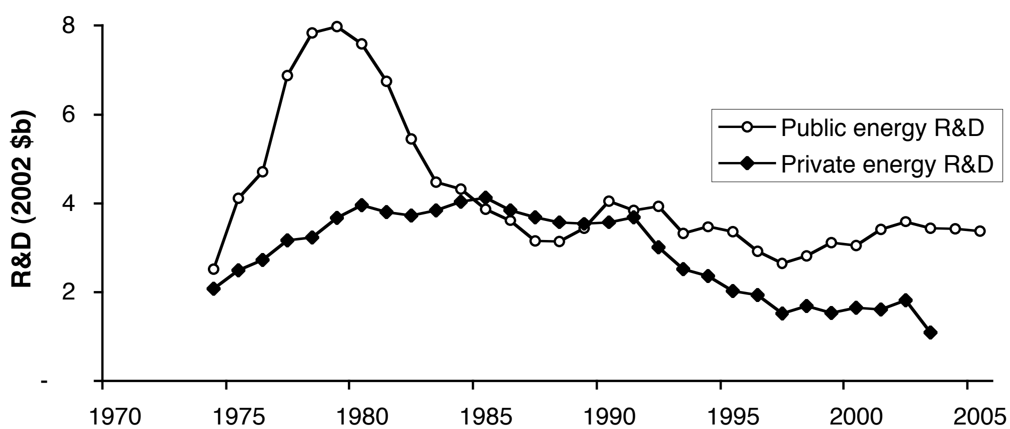

Figure 3. Declining energy R&D investment by both public and private sectors
Source: Kammen and Nemet (2005) *Issues in Science and Technology.*

In the case of solar photovoltaics, a 50% increase in PV efficiency occurred immediately after unprecedented $1 billion global investment in PV R&D (1978-85). From there, we observed significant efficiency improvements, which accounts for fully 30% of the cost reductions in PV over the past two decades (increased plant size, also related to the economic viability of PV accounts for the largest segment, 40% of the cost decline over the same period of time.

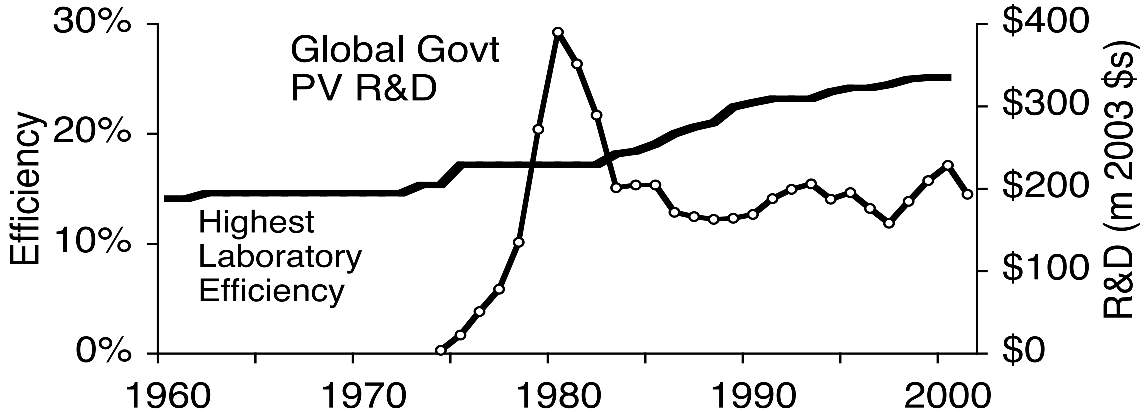

Figure 3: Benefits of R&D Investments in Improving Products in the Market. Directly after a significant increase in federal funding for solar photovoltaics, a 50% rise in cell efficiency occurred. This increase in efficiency has been shown to be the second largest single contributor to the cost effectiveness of solar cells. Source: Nemet, G. F. (2006). "Beyond the learning curve: factors influencing cost reductions in photovoltaics, *Energy Policy* **34(17),** 3218 - 3232.

The U. S. experience is not at all unique. Figure 4 provides a summary of the Japanese 'sunshine' solar PV Program. Note that the funding levels are in billions of yen. In reviewing this data, focus on the following key facts:

- The R&D investment in Japan was sustained (above the zero line), and in fact grew as the commercialization program developed.
- Funding for the commercialization effort (below the zero line) developed after the R&D phase, and was not only steady, but was consistently increased as the program grew.
- The result of the Japanese program was striking: the cost of installed solar PV systems *fell* by over 8% per year for a decade. A smaller effort in California, but without significant R&D spending, resulted in *one-half* that level of innovation and cost improvement. California has now embarked on a much larger (10 years, $320 million/year) commercialization effort, and several other states are following suit.

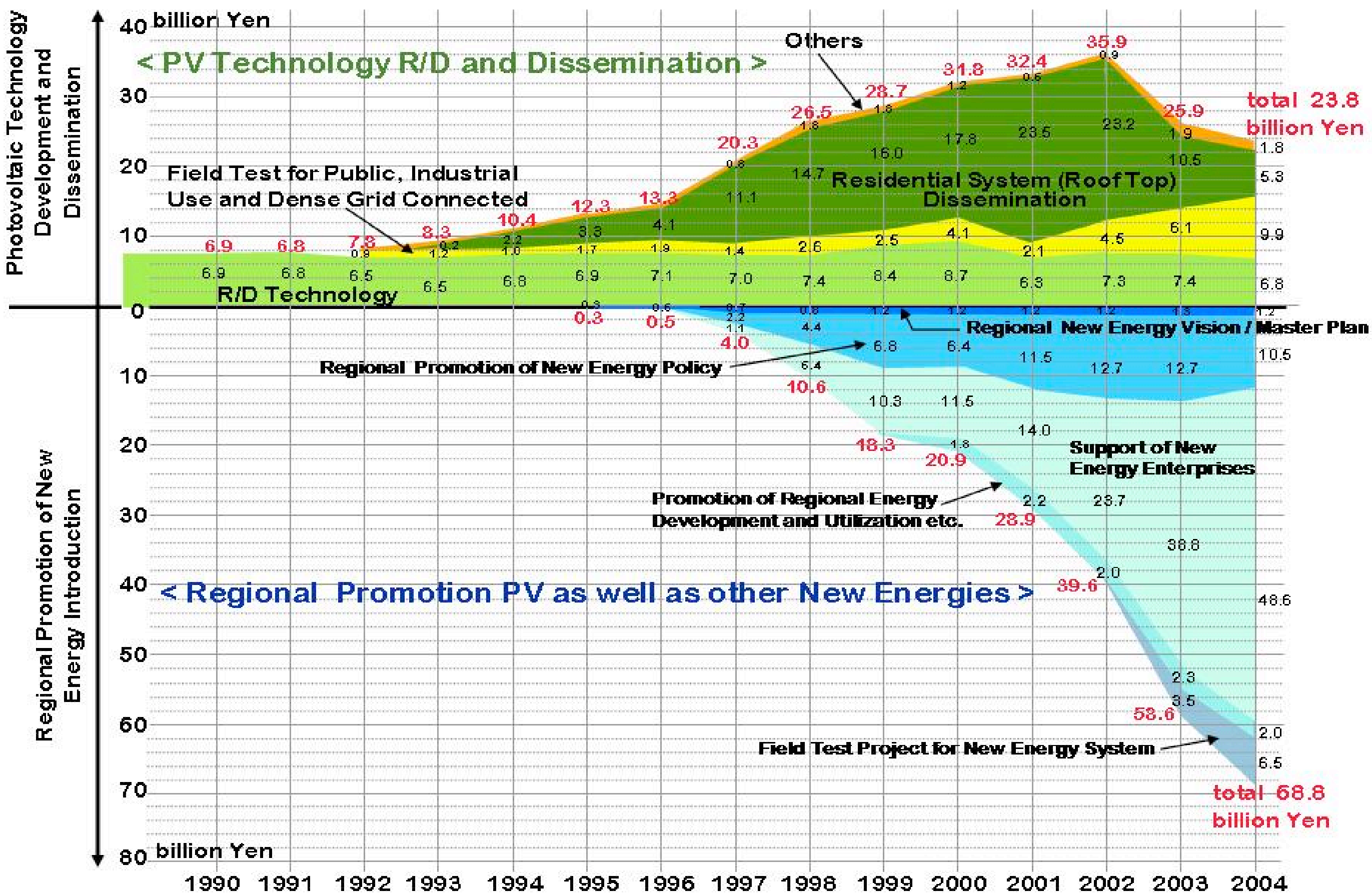

Figure 3: Benefits of integrating R&D Investments *and* market development policies in Improving Products in the Market. Units are billions of Yen, and both the magnitude and the timing of the 'technology push' and the 'demand pull' components of the program are critical. Source: Charlie Gay, formerly of Sunpower. One billion Yen = $8.3 million dollars.

The case of solar photovoltaics is not at all unique. By looking at individual energy technologies, we have found that in case after case, R&D investment spurs invention. For example, in the case of wind power patenting follows the wild swings in R&D budgets Figure 4 (top left), and similar trends are seen in other energy technologies.

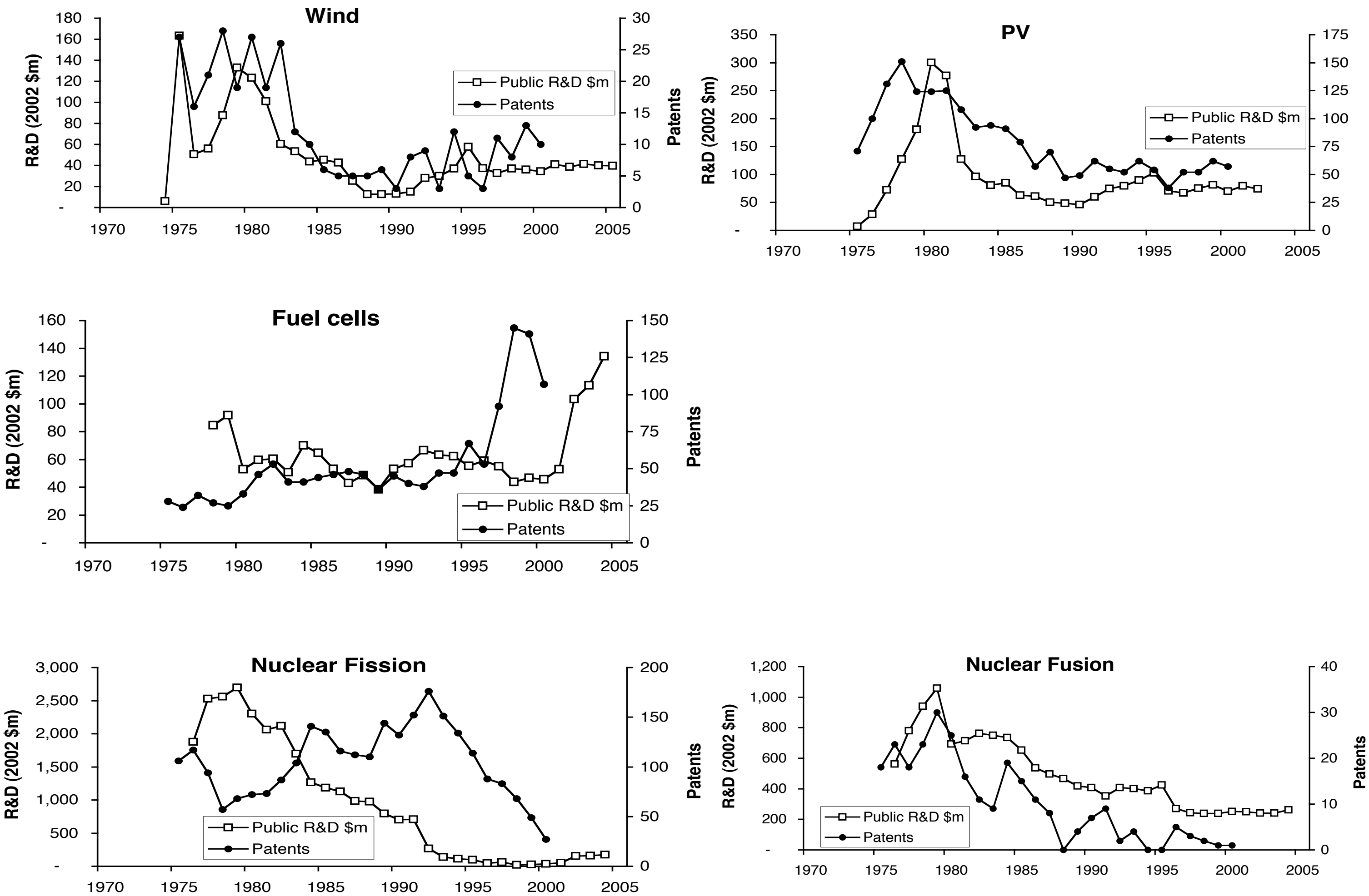

Figure 4. Federal R&D and patents in a range of energy technology areas. Note the strong correlation between funding levels and innovation, measured in patents granted, for *each* technology. The one exception is arguably nuclear fission, where (significantly subsidized) commercial viability has already been achieved. Source: Kammen, D. M. and G. F. Nemet (2005). "Reversing the Incredible Shrinking U.S. Energy R&D Budget." *Issues in Science and Technology* 22: 84-88.

We also see steady cost declines in solar and wind technologies, although the bulk of the manufacturing for each technology has been outside the U. S. for many years.

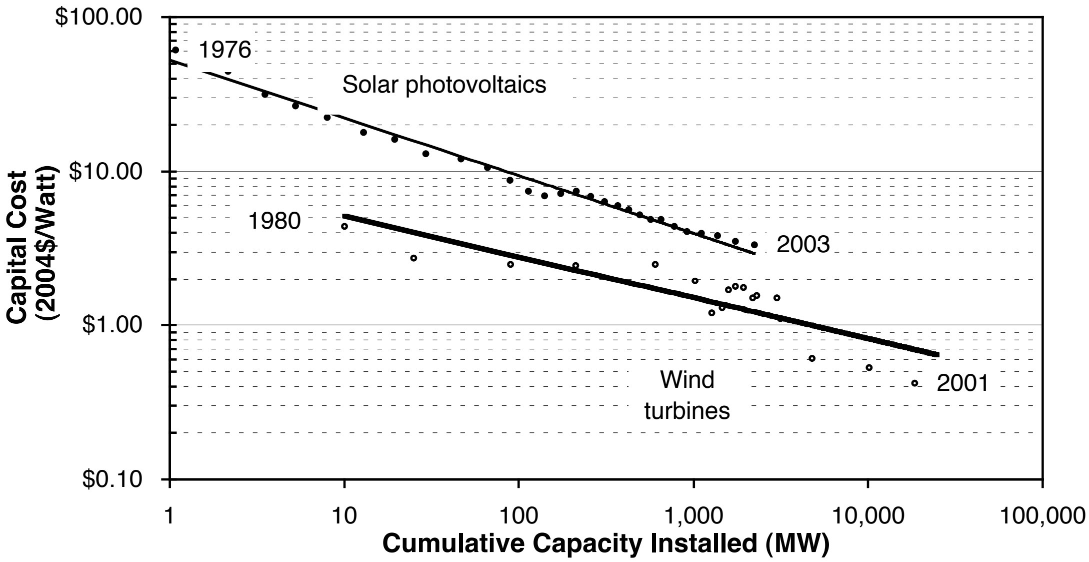

Figure 5. Cost reductions in carbon-free energy technologies

Figure 5. Capital costs of photovoltaics and wind turbines (constant 2004$/Watt.) The horizontal axis shows cumulative worldwide installations of each technology (Duke and Kammen, 1999). Expanding production, driven by research, development, and deployment directly *pays off in cost declines for the technology, and larger domestic markets further result in greater economic activity and job creation (Kammen, Kapadia, and Fripp, 2004).*

An Energy R&D Action Plan – Investing in the Most Promising Sectors

In our recent work we have asked how feasible it would be to raise investment to levels commensurate with the energy-related challenges we face. One way to consider the viability of such a project is to set the magnitude of such a program in the context of previous programs that this committee has participated in launching and monitoring. Scaling up R&D by 5 or 10 times from current levels is not a 'pie in the sky' proposal, in fact it is consistent with the scale of several previous federal programs (
Table 1), each of which took place in response to a clearly articulated national need. While expanding energy R&D to five or ten times today's level would be a significant initiative, the fiscal magnitude of such a program is well within the range of previous programs, each of which have produced demonstrable economic benefits beyond the direct program objectives.

In fact, I recommend a focus not on the entire energy R&D budget, but on a subset of technologies which are both low and no-carbon emitters on a life-cycle basis, and where the U. S. could reclaim global leadership *and* generate significant job growth as a 'cleantech' dividend. In analysis published in 2004 (Kammen, Kapadia, and Fripp), my laboratory estimated that tens of thousands of new, domestic, jobs would be the result of an effort to achieve a 20% federal renewable energy portfolio standard. This estimate, of 30,000 – 50,000 new jobs in the wind and solar sectors alone, would be more than doubled by advances in energy efficiency (Apollo Alliance, http://www.apolloalliance.org/). Similar attention to the biofuel sector would likely dwarf even these numbers.

Table 1. Comparison of energy R&D scenarios and major federal government R&D initiatives

Program	**Sector**	**Years**	**Additional spending over program duration (2002$ Billions)**
Manhattan Project	Defense	1942-45	$25.0
Apollo Program	Space	1963-72	$127.4
Project Independence	Energy	1975-82	$25.6
Reagan defense	Defense	1981-89	$100.3
Doubling NIH	Health	1999-04	$32.6
War on Terror	Defense	2002-04	$29.6
5x energy scenario	***Energy***	***2005-15***	***$47.9***
10x energy scenario	***Energy***	***2005-15***	***$105.4***

"Major R&D initiatives" in this study are federal programs in which annual spending either doubled or increased by more than $10 billion during the program lifetime. For each of these eight programs we calculate a "baseline" level of spending based on the 50-year historical growth rate of U.S. R&D, 4.3% per year. The difference between the actual spending and the baseline during the program we call additional program spending. Kammen, D. M. and G. F. Nemet (2005). "Reversing the Incredible Shrinking U.S. Energy R&D Budget." *Issues in Science and Technology* 22: 84-88.

Specific Spending Recommendations – Building Technology Push to Match Demand Pull

Instead of a simplistic, and largely unworkable effort to develop an across-the-board increase, a set of targeted increases makes the most sense. Below is a table showing the 5x and 10x scenarios based on the Kammen and Nemet (2005) paper – which should be considered over a four to five year period – for some of the most promising technologies to address the needs of the sectors that can have the greatest impact on the ability of states to meet their Renewable Energy Portfolio Standards (Appendix A).

Current ($m)	**2006 Actual**	**President's FY2008 request**	**5x Scale Up**	**10x Scale up**
Solar	82	148	409	818
Wind	38	40	192	383
Biomass	90	179	449	898
Battery Technology, Storage, Transmission	146	103	730	1,459
TOTALS	**356**	**470**	**1,780**	**4,199**

In this scenario the funding increases, instead of being determined by an arbitrary political battle over appropriation levels, is based on an evaluation of what funding level for key technology areas would dramatically expand their market share, saving the nation carbon emissions, moving these technologies significantly down their 'learning curves' (Duke and Kammen, 1999), and matching up well with the market creation program seen for solar in Japan, as well as for wind in

Germany. This level of funding is also found to be optimal in work on stabilizing greenhouse gas concentrations in work performed by researchers at the Lawrence Livermore National Laboratory (Schrock and Fulkerson, 1999).

In addition, a budget increase – as opposed to the President's inexplicable call for a decrease in energy efficiency is warranted.

Energy efficiency has a unique role to play in a secure, low-carbon, and cost-effective energy policy. Not only is energy efficiency – from high-efficiency lighting, to improved water heaters and windows, to all manor of efficiency improvements for the home, offices, and industry – the least cost way to reduce energy demand and carbon emissions, but it is the *facilitator* of every other innovation. Lower energy demand reduces the amount of new, low-carbon energy systems that must be installed. California, New York, and a number of states have been able to keep electricity use *per capita* virtually unchanged for *the past three decades*, a remarkable achievement that has saved billions of dollars per year.

A number of energy efficiency measures can be developed. One of the simplest is to support and reward states that exempt Energy Star products from a Sales Tax. A number of state legislatures are considering or have enacted such measures. States enacting sales tax waivers for Energy Star products, energy efficient water heaters, and other appliances approved by the U. S. Environmental Protection Agency should be eligible for federal rebates. A federal direct customer rebate could also be implemented to reward purchase of the most efficient appliances.

2. Provide Research Support Jointly to the Departments of Energy and Agriculture, and the Environmental Protection Agency to Study a Federal Low Carbon Fuel Standard

The recent explosion of interest in biofuels, including ethanol and biodiesel, has been a major advance in diversifying our transportation fuels markets. On January 27, 2006, our research group at the University of California, Berkeley, published a paper in *Science*, the magazine of the American Association for the Advancement of Science, and an accompanying website (http://rael.berkeley.edu/ebamm) that provided a calculator to compare the greenhouse gas benefits of ethanol derived from a range of input biofuels, and produced in distilleries powered by different fuels (e.g. coal, natural, gas, or through the use of renewables).

The conclusion of that work was simple: not all biofuels are created equal in terms of their carbon content. The next logical step was to rank, and then regulate fuels, based on their carbon content.

In January 2007 California Governor Arnold Schwarzenegger signed Executive Order 1-07 to establish a greenhouse gas standard for fuels sold in the state. The new Low Carbon Fuel Standard (LCFS) requires a 10 percent decrease in the carbon intensity of California's transportation fuels by 2020. The state expects the standard to more than triple the size of the state's renewable fuels market while placing an additional seven million hybrid and alternative fuel vehicles on the road. The standard will help the state meet its greenhouse gas reduction goals set by Assembly Bill 32, which the governor signed last year.

On February 21, 2007 Governor Schwarzenegger and Senator McCain called for a federal LCFS. An important piece of the LCFS should be the inclusion of electricity as a fuel to support the development and use of plug-in hybrid vehicles in areas where the average grid power is sufficiently low-carbon to result in a net reduction in greenhouse gas emissions.

3. Begin a Serious Federal Discussion of Market-Based Schemes and Funding Avenues to Make the Price of Greenhouse Gas Emissions Reflect their Social Cost.

A greenhouse gas tax and a tradable permit program both provide simple, logical, and transparent methods to permit industries and households to reward clean energy systems and tax that which harms our economy and the environment. Cap and trade schemes have been used with great success in the US to reduce other pollutants and several northeastern states are experimenting with greenhouse gas emissions trading. Taxing carbon emissions to compensate for negative social and environmental impacts would offer the opportunity to simplify the national tax code while remaining, if so desired, essentially revenue neutral. A portion of the revenues from a carbon tax could also be used to offset any regressive aspects of the tax, for example by helping to compensate low-income individuals and communities reliant on jobs in fossil fuel extraction and production.

A number of innovative opportunities exist ease the implementation of a greenhouse gas, or a carbon tax. One avenue is to institute a national program of 'Energy Savings Accounts' where each American pays – for example on gasoline purchases and via utility bills – a federally agreed greenhouse gas fee. Instead of simply sending this to the U. S. Treasury in the form of a tax, an alternative plan is to place the funds into individual Energy Savings Accounts, which can be used by each individual or family on purchases from a list of federally approved investments. The U. S. Department of Energy and the U. S. Environmental Protection Agency could be charged with developing a list of approved investment areas – such as on high efficiency, hybrid, or plug-in hybrid vehicles, on solar photovoltaic or solar thermal home energy systems, etc. Garrett Gruener, founder of AskJeeves (now Ask.com) and I proposed this in a recent (1/31/07) Op Ed in *The Los Angeles Times*.

Appendix A: Enact a Federal Renewable Energy Portfolio Standard

Twenty-three states and the District of Columbia have now enacted Renewable Energy Portfolio Standards, which each call for a specific percentage of electricity generated to come from renewable energy. Federal legislation should, *at minimum*, support state action with federal support. A great deal would be achieved if Congress took the logical step and instituted a federal standard. A 20% federal RPS, by 2020 is reasonable and achievable.

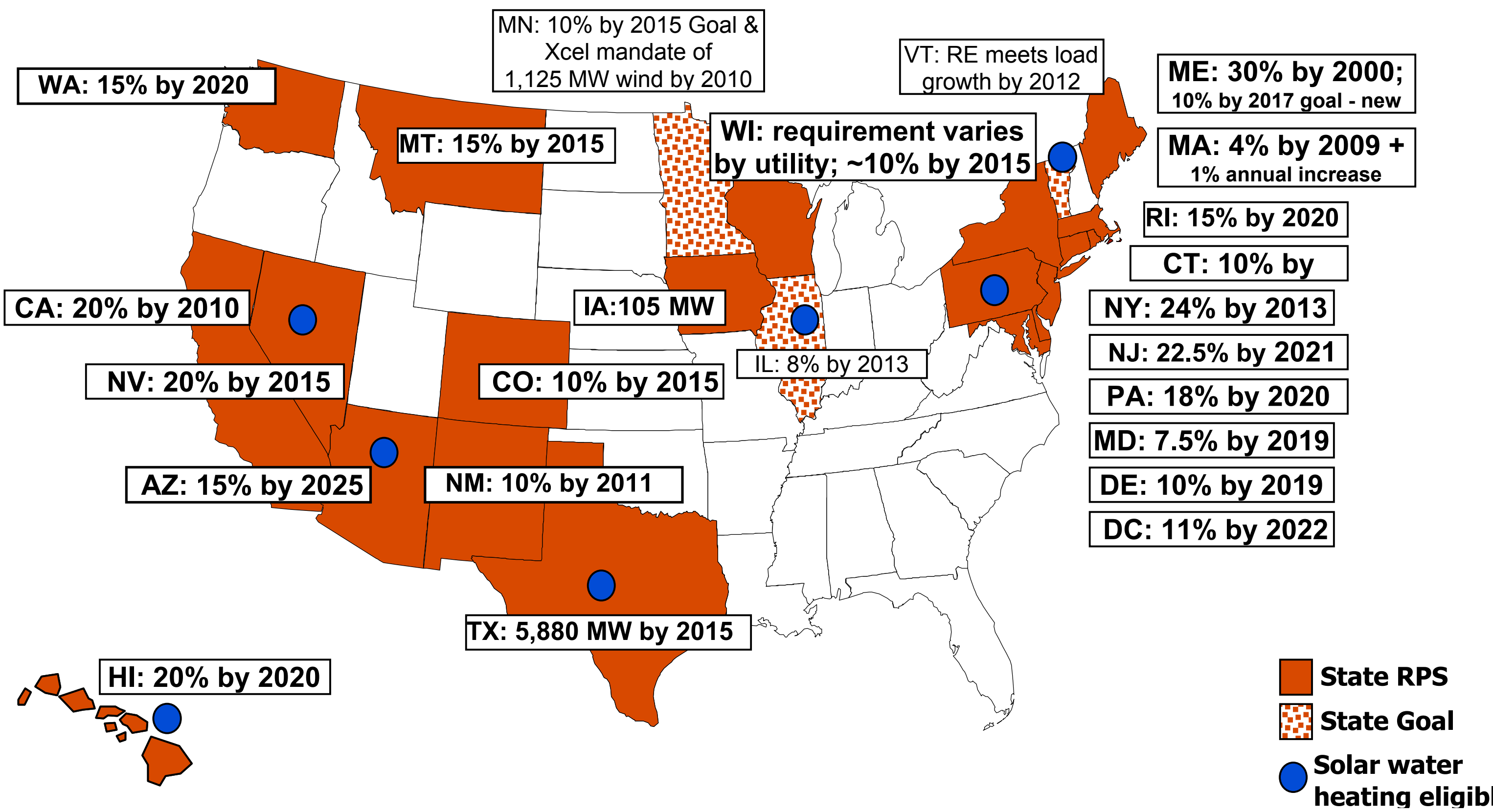

Figure 7. Map of States with Renewable Energy Portfolio Standards

As of January 2007, 23 states and the District of Columbia have enacted or voted to adopt renewable energy standards. These plans represent a diversity of approaches and levels, but each reflect a commitment to clean and secure energy that could be emulated at the federal level. In addition 13 states have specific measures to increase the amount of solar photovoltaic power in use. These range from specific solar energy targets, to double (MD) or up to triple credit (DE, MN, & NV) for solar.

Appendix B: Increase the Corporate Average Fuel Economy (CAFE) Standards on an Annual Basis

Recent advances in vehicle design and materials, has made the prospect of significantly increasing the fuel efficiency of our vehicles. President Bush has called for 4% annual increases, which should be the minimum. A 40 mpg standard by 2015 is possible, and would annually save the nation billions of gallons of gasoline and diesel. In addition, a *feebate* program should be instituted to reward the purchase of more efficient vehicles. A feebate is a tax paid at the time of purchase on vehicles that fail to meet a federal efficiency standard, with the revenues transferred to those vehicle purchases that exceed the federal standard. The net cost of such a program is zero, with the full cost of inefficient vehicle purchases transferred as a rebate to the purchases of efficient vehicles. A number of variants of this plan exist to reflect features of different vehicle lines, such as separate feebate structures for light-duty vehicles, trucks and SUVs.

Appendix C: Expand International Collaborations that Benefit Developing Nations at a Carbon Benefit.

The needs of many developing nations are focused on the challenges meet fundamental economic and environment goals for their people. At the same time, these are our goals as well, both as a nation that must lead the charge to a sustainable and equitable world, and as citizens of a world where we share the rights and responsibilities to protect the atmosphere. Greenhouse gases emitted anywhere impact us all, not only today but for decades to come. In many cases, tremendous opportunities exist to offset future greenhouse gas emissions and to protect local ecosystems both at *very* low cost, but also to directly address critical development needs such as sustainable fuel sources, the provision of affordable electricity, health, and clean water.

Globally over one billion people meet their energy needs primarily with traditional biofuels: dung, wood, straw, and forest and agricultural residues. My research group, the Renewable and Appropriate Energy Laboratory has recently detailed the local development, health, *and* the global carbon benefits of research programs and partnerships on improved stoves and forestry practices (Bailis, Ezzati, and Kammen, 2005) across Africa. In many cases, we have found that stoves that cost \$1 – 2 can reduce fuel use and pollution emissions by 1/3 or more. These dramatic savings can reduce respiratory illness by 50 percent. Far from an isolated example, such opportunities exist everywhere, with the recent wave of interest in 'sustainability science' (Jacobson and Kammen, 2005) a resource, international aid, and business opportunity that the U. S. should embrace.

Appendix D: Make Energy and the Environment a Core Area of Education in the United States

Public interest and action on energy and environmental themes requires attention to make us 'eco-literate and economically savvy.' We must develop in both K-12 and college education a core of instruction in the linkages between energy and both our social and natural environment. The Upward Bound Math-Science Program and the Summer Science Program each serve as highly successful models that could be adapted to the theme of energy for a sustainable society at all educational levels. The launch of Sputnik in 1957 mobilized U. S. science and technology to an unprecedented extent, and should serve as a lesson in how powerful a use-inspired drive to educate and innovate can become. The Spring 2005 Yale Environment Survey found overwhelming interest in energy and environmental sustainability. Contrast that interest with the results of the Third International Mathematics and Science Study (TIMSS) where American secondary school students ranked 19th out of 21 countries surveyed in both math and science general knowledge. The United States can and should reverse this trend, and sustaining our natural heritage and greening the global energy system is the right place to begin.

Brief Biography – Daniel M. Kammen

I hold the Class of 1935 Distinguished Chair in Energy at the University of California, Berkeley, where I am a professor in the Energy and Resources Group, the Goldman School of Public Policy, and the Department of Nuclear Engineering. I am the founding director of the Renewable and Appropriate Energy Laboratory, an interdisciplinary research unit that explores a diverse set of energy technologies through scientific, engineering, economic and policy issues. I am also the Co-Director of the University of California, Berkeley Institute of the Environment. I have served on the Intergovernmental Panel on Climate Change (IPCC), and have testified before both U. S. House and Senate Committees on the science of regional and global climate change, and on the technical and economic status and the potential of a wide range of energy systems, notably renewable and energy efficiency technologies for use in both developed and developing nations. I am the author of over 200 research papers, and five books, most of which can be found online at http://rael.berkeley.edu

In July of last year the Honorable R. John Efford, the then Minister of Natural Resources Canada, announced my appointment, as the only U. S. citizen, to serve on the Canadian National Advisory Panel on the Sustainable Energy Science and Technology (S&T) Strategy. The Panel provides advice on energy science and technology priorities to help Canada develop sustainable energy solutions, and is tasked to produce a document similar in objectives to the Climate Change Technology Program Strategic Plan, which we are here today to discuss.

During the later half of 2006 I played a leadership role in developing the successful $500 million Energy Biosciences Institute Proposal

Acknowledgments

This work was supported by a grant from the Energy Foundation, the Karsten Family Foundation endowment of the Renewable and Appropriate Energy Laboratory, and the support of the University of California Class of 1935. I thank my doctoral student Greg Nemet for his analysis, input, and discussions of these policy recommendations.

References and further reading

Augustine, N. R. (2005) *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC, National Academies Press.

Bailis, R., Ezzati, M. and Kammen, D. M. (2005) "Mortality and greenhouse gas impacts of biomass and petroleum energy futures in Africa", **308**, *Science*, 98 – 103.

Duke, R. D., and Kammen, D. M. (1999) "The economics of energy market transformation initiatives", *The Energy Journal*, **20 (4)**, 15 – 64.

Farrell A. E., Plevin, R. J. Turner, B. T., Jones, A. D. O'Hare, M. and Kammen, D. M. (2006) "Ethanol can contribute to energy and environmental goals", *Science*, **311**, 506 – 508.

Gruener, G, and Kammen, D. M. (2007) "How to save the planet? You decide", *The Los Angeles Times*, January 31.

Intergovernmental Panel on Climate Change (2001) *The Scientific Basis* (Cambridge University Press; Cambridge, UK).

Jacobson, A. and Kammen, D. M. (2005) "Science and engineering research to value the planet", *The Bridge: the Journal of the National Academy of Engineering*, **Winter,** 11 - 17.

Kammen, D. M., Kapadia, K. and Fripp, M. (2004) *Putting Renewables to Work: How Many Jobs Can the Clean Energy Industry Generate?* A Report of the Renewable and Appropriate Energy Laboratory, University of California, Berkeley. Available at: http://socrates.berkeley.edu/~rael/papers.html#econdev

Kammen, D. M. and G. F. Nemet (2005) "Reversing the Incredible Shrinking Energy R&D Budget" *Issues in Science and Technology*, **22**: 84 - 88.

Margolis, R. and Kammen, D. M. (1999) "Underinvestment: The energy technology and R&D policy challenge", *Science,* 285, 690 - 692.

Nemet, G. F. (2006). "Beyond the learning curve: factors influencing cost reductions in photovoltaics, *Energy Policy* **34(17),** 3218 - 3232.

Schock, R. N., W. Fulkerson, *et al.* (1999 "How much is Energy Research and Development Worth as Insurance?" *Annual Review of Energy and Environment* **24**: 487 - 512.