United States House of Representatives
Select Committee on Energy Independence and Global Warming
Testimony for the September 10, 2008 Hearing on:

Investing in the Future: R&D Needs to Meet America's Energy and Climate Challenges

by

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Congressman Edward Markey, Committee Chairman, Ranking Member James Sensenbrenner, and the rest of the Committee on Oversight and Government Reform, I am very pleased to have the opportunity to appear before you. I very much appreciate the attention you are giving to the vital issues of greenhouse gas emissions reduction and climate protection.

I have served as a Coordinating Lead Author for the Intergovernmental Panel on Climate Change. Along with hundreds of other climate and energy scientists, economic and policy analysts, I am tremendously pleased to share in the honor and the continuing responsibility to provide our collective best assessments on the state of climate science, and of both the need and the opportunities to effectively and efficiently address this national and global challenge. My research group -- the Renewable and Appropriate Energy Laboratory -- at the University of California, Berkeley, is focused on energy efficiency and renewable energy science, technology, and implementation. In addition, I also serve on the Executive Committee of the $500 million Energy Biosciences Institute funded by BP, and am involved in the development of renewable energy technologies for use in both developed and developing nations.

The Low-Carbon Imperative

As a contributing researcher to the Intergovernmental Panel on Climate Change (IPCC) I can now state unambiguously that the risks of climate change – risks that the research community has been documenting for years -- are now coming into increasing local, regional, national and international focus. In fact, an ominous sign is that in field after field – from glaciology to oceanography to forestry – the most common refrain is that 'the experts who know the most, are the most worried." We may not know all of the details, but the risks of continuing the current trajectory of emissions are very clear. Most troubling from a policy perspective is the fact that as

individuals and as a society, we readily purchase home, vehicle, and other forms of insurance for events far less likely than the potentially devastating impacts of climate change.
In responding to a threat such as climate change, it is abundantly clear that knowledge and resources are our best and most vital defense, and they are the only resource that has the potential to turn this risk into an economic and social opportunity.

Before I address the specific questions posed by the committee, one vital over-arching statement needs to be made: the threat of climate change is so pervasive, and our patterns of energy use are so deeply intertwined with our economic system, that this issue *can not be approached without an integrated vision.*

It is not enough to design a few, or even many, well-structured programs. To confront climate change and to design a more sustainable energy system, a set of goals, public and private sector objectives, and organizing principles need to be developed, articulated, and applied fairly across the economy. Special attention needs to be given to the situation of poor and disadvantaged communities, as well as ways to encourage and disseminate innovative new clean energy technologies, practices, and accords. Such a policy framework must address basic research and dissemination and diffusion of technology, and must address energy and climate decisions made the household to community, to the national and international scales as well. To date we have no such organizing framework, although thankfully a number of states and regions have begun this process. Important examples include the California Global Warming Solutions Act (AB 32) and the Western Climate Initiative, the Regional Greenhouse Gas Initiative (RGGI) in the northeast and mid-Atlantic states, and the Midwest Governors Pledge to Fight Climate Warming. In addition, *a majority* of U. S. states now have renewable energy portfolio standards, targeting clean energy development as part of the required electricity blend (Kammen, 2007a). Finally, it is critical to recognize that a transformation of the energy system to a low-carbon one cannot be expected to succeed without sending the right economic signals. At present we have failed to put a price on global greenhouse pollution.

Developing a viable carbon emissions trading system must become a national priority.

What is the current state of R&D funding in the United States? How does it compare to past funding, and to funding in other countries?

Innovation is the life-blood of economic growth and renewal. In fact, it has been known for decades that the bulk of new economic growth results from the re-invention and invention of new scientific and technological opportunities. Economics Nobel Laureate Robert Solow estimated that over 90% of new economic growth results from public and private sector investments in innovation (Solow, 1957). A range of estimates using diverse methods from other researchers and government agencies support this finding.

By this measure, the energy field is sorely lacking. While investment in research and development is roughly 3% of gross domestic product, it is roughly *one-tenth* that in the energy sector. By contrast, R&D investments in the medical and biotechnology field are roughly 15% of sales, almost a staggering *40 times* more than in the energy field (Figure 1). Certainly energy is no less of a national priority than these other sectors – and arguably is our number one security threat. This argues that, *at minimum*, energy R&D should be increased to the national average of

3% of GDP, if not more. In a recent set of papers, my former student and now Professor at the University of Wisconsin, Madison, and I argue developed a set of metrics that led to the conclusion that as a starting point, the federal energy R&D investment should be increased from its current anemic level of $ 3 – 4 billion/year, to five to then times that amount. A tripling of that, to roughly $15 billion/year is a natural and achievable interim target.

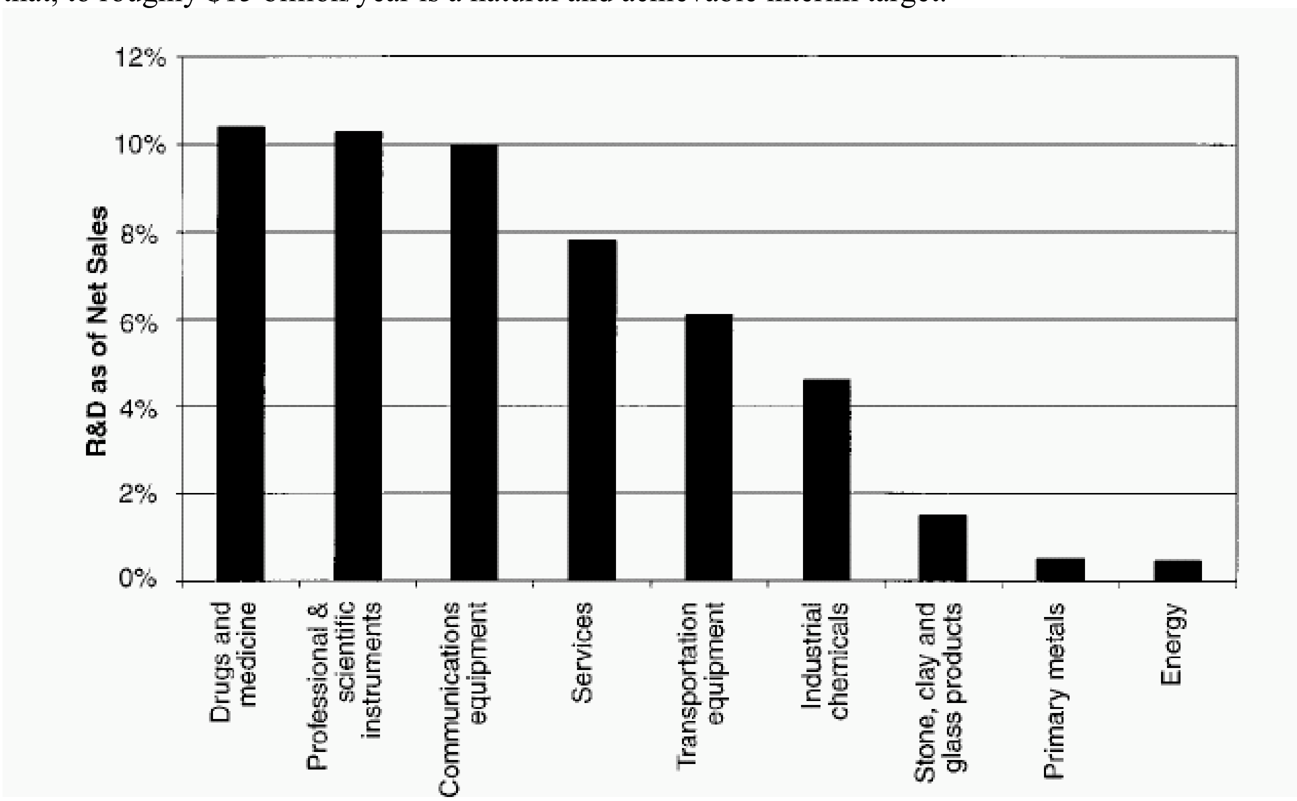

Figure 1: R&D 'intensity', or R&D as a percentage of net sales for selected sectors in the United States. The data shown include both public and private funding for R&D. Energy R&D as a percentage of net sales was calculated from total (public and private) industrial energy R&D (*17*) and total energy expenditures in the United States (*19*). Services include business, health, engineering, and other services. Source: Margolis and Kammen, 1999.

Total R&D funding in the United States is far too low given its importance to our economic and geopolitical security and to the sustainability of the environment. The Congress and the Executive Office need to recognize the vital role that leadership in energy can play in our outlook for economic growth.

In terms of federal investment – financially and in terms of commitment – is clean and secure energy, we have simply not become serious.

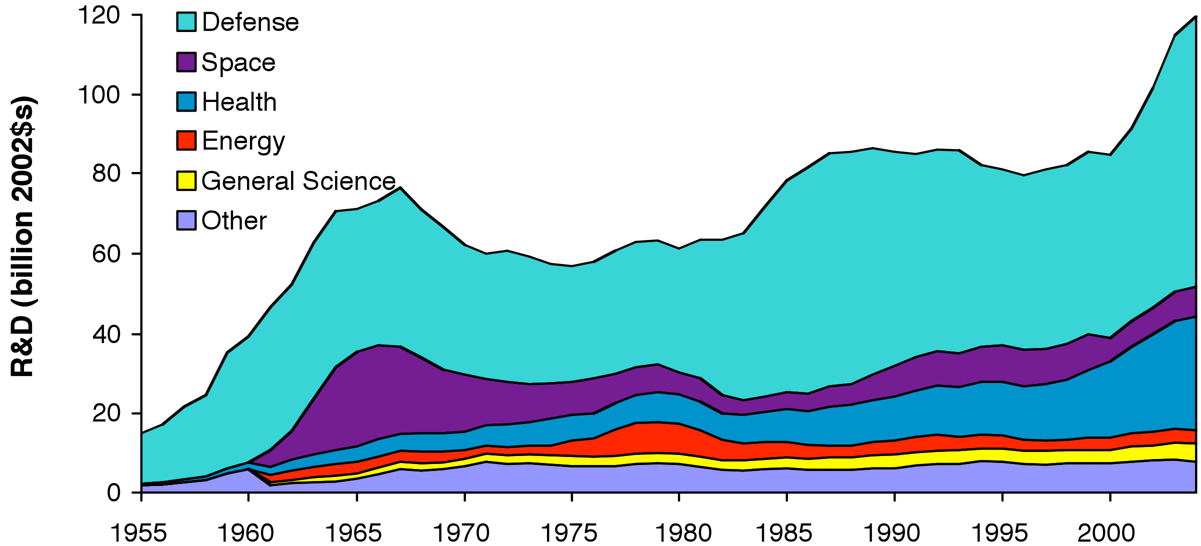

Figure 2: U.S. federal R&D programs since 1955. Energy is the the thin strip with the short-lived expansion during the late 1970s and early 1980s showing how small the energy R&D program is relative to the others. The current budgets for energy R&D would continue this situation, or even reduce R&D investment (Kammen and Nemet, 2005).

Figure 2, showing federal R&D investments in science and technology provides a number of lessons:

- The energy R&D budget has, once, been increased significantly, in fact by a factor of three between 1975 and 1979 in response to the OPEC oil embargo, but this increase was not sustained. In fact, the increase and then decrease in the budget was particularly wasteful because a number of potentially important programs were initiated, then cancelled, leaving talented individuals and innovative companies greatly disillusioned and distrustful of federal efforts in the energy area. In fact, retrospective analysis demonstrates that not only were a set of important technological innovations started during this brief period (e.g. greatly improved solar cells and wind-turbines that have, ironically, been generally commercialized by non-U.S. companies.

- The failure to engage in serious long-term planning in the energy area contrasts significantly with the story in the biotechnogy sector. During the 1980s and 1990s a widely discussed plan emerged to double federal support for medical/biotechnology research (Kaiser, 2002). This program was justified on the basis of its ability to energize private sector spending by demonstrating that the federal government would develop a plan to 'prime the pump' and to stick to that plan. The result was dramatic, particularly in contrast to the lack of federal commitment in the energy area. While the private sector did not respond to the short-term boost in federal energy support during the1975 – 1979 period (arguably because the 'crisis' in energy costs was seen as largely geopolitical, not one of either truly limited supply or other trends, such as global warming), the private sector *did* respond strongly to the changes in the biomedical research budget (Figure 3).

Although energy R&D exceeded that of the biotechnology industry 20 years ago, today R&D investment by biotechnology firms is an order of magnitude larger than that of energy firms (Figure 3). Today, total private sector energy R&D is less than the R&D budgets of individual biotech companies such as Amgen and Genentech. In fact, while private sector research in energy has never exceeded public sector spending by a significant amount, *private sector spending on biotechnology R&D is over eleven-times that of the federal government.* Sustained investment and commitment beget greater attention and returns in the private sector.

This dramatic difference between the private sector's response in the biotechnology and energy sectors – and the immediacy of the threat of climate change – has been wonderfully and sadly captured in the comments of energy analyst Joe Romm in his assessment of thise data. In reading our paper (Kammen and Nemet, 2006), Joe's poignant comment was that, "well, at least we will live long enough to see the folly of our ways."

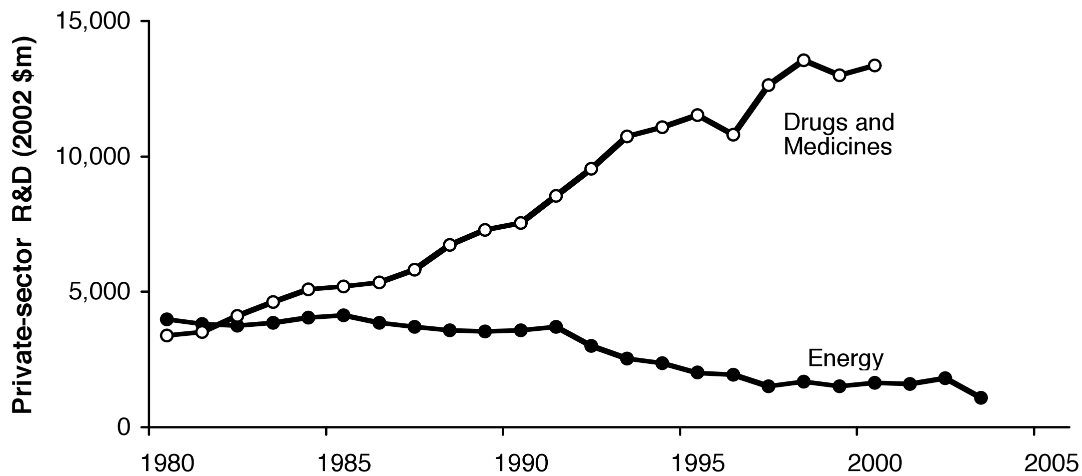

Figure 3: Private sector R&D investment: energy vs. drugs and medicines. Source: Kammen and Nemet, 2005.

The story is perhaps even more depressing because we know that investing in energy research *works.* In a series of studies, my students and I have documented that significant payoffs in innovation and commercialization *did clearly result from investments in energy research* (Margolis and Kammen, 1999; Kammen and Nemet, 2005, 2007; Nemet, 2007).

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

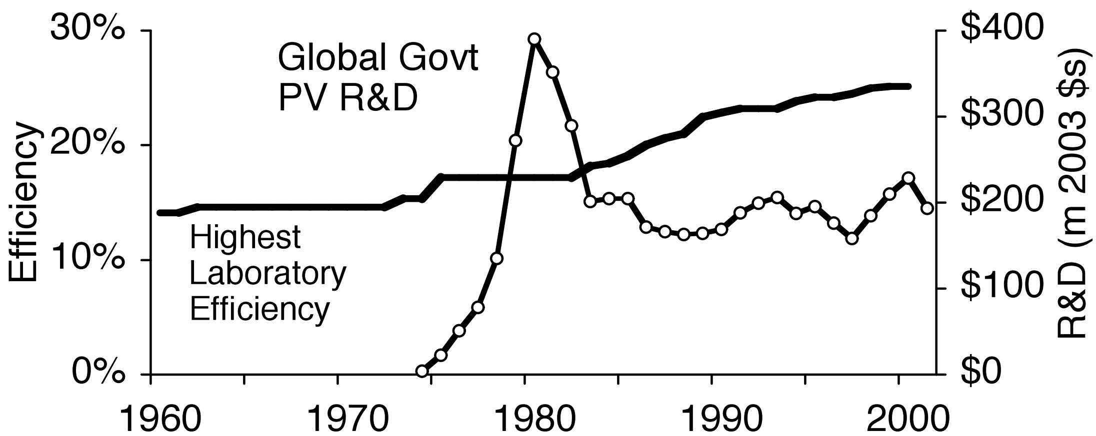

Figure 4: Clear Benefits of R&D Investments in Improving Products in the Market. ***Source: G. Nemet, Nemet, G. F. (2006). "Beyond the learning curve: factors influencing cost reductions in photovoltaics,: Energy Policy 34(17): 3218 - 3232***.

The story shown in Figure 4 for photovoltaics is not at all unique, as can be seen in Figure 5.

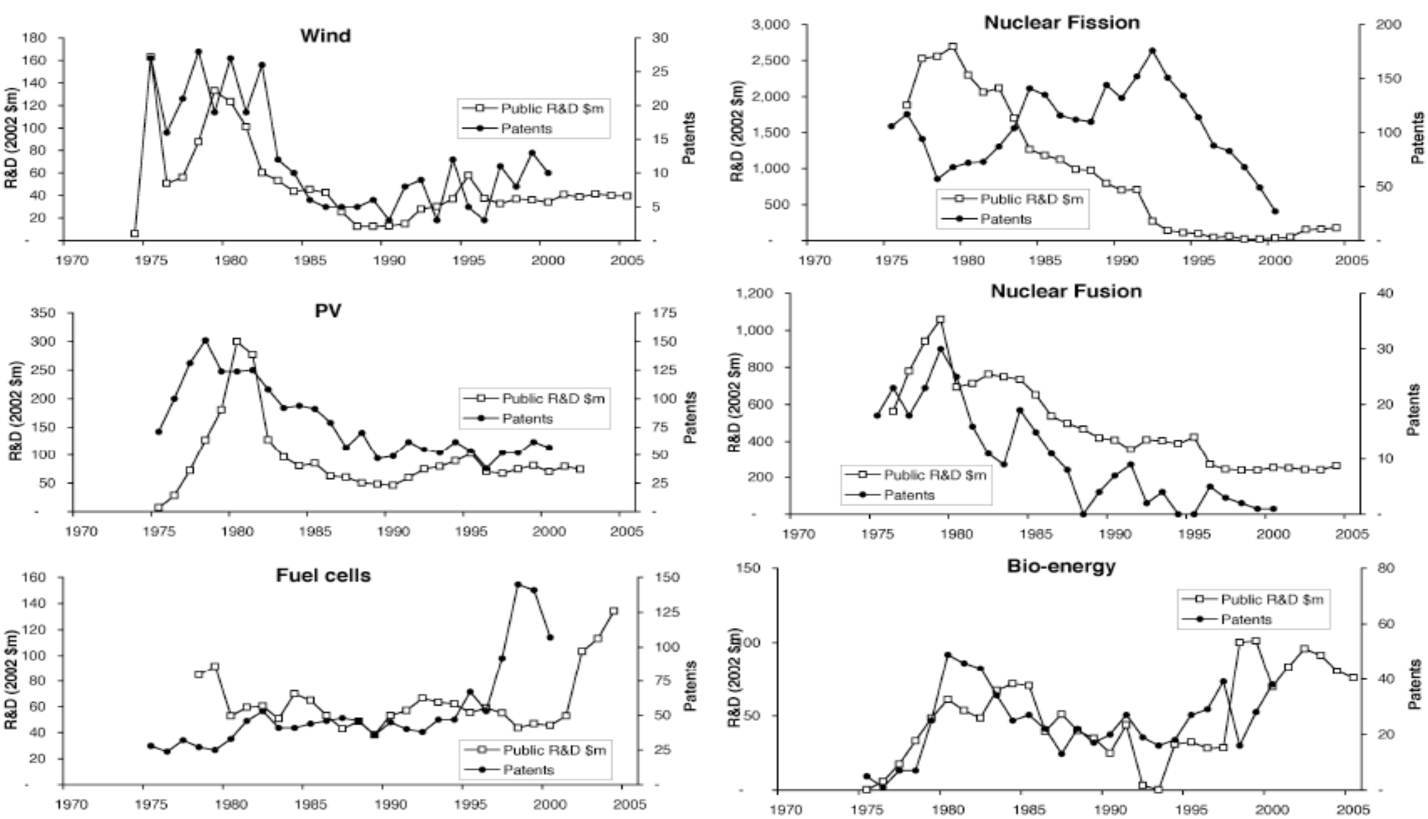

Figure 5: Correlation between funding and patents (innovation) for energy technologies (Kammen and Nemet, 2005; 2007).

A number of nations have been far more consistent, bullish, in fact, on the value of clean energy research and deployment. Denmark, Norway, Germany, Spain, and Portugal and other nations have invested substantially in clean energy, and it has paid important dividends. While different nations have focused on different technologies and market mechanisms to encourage adoption, wind power is above or approaching 20% of the total electricity supply in Denmark and Germany, and in each of the nations listed, factory orders for solar, wind, and other low- and no-carbon technologies has produced tremendous job growth (Kammen, 2007b) *and* long-waiting lists from overseas buyers. Green energy that is also early to rapidly deploy and to meet changing urban and rural demographics. A summary of investment growth by region is included in Figure 6.

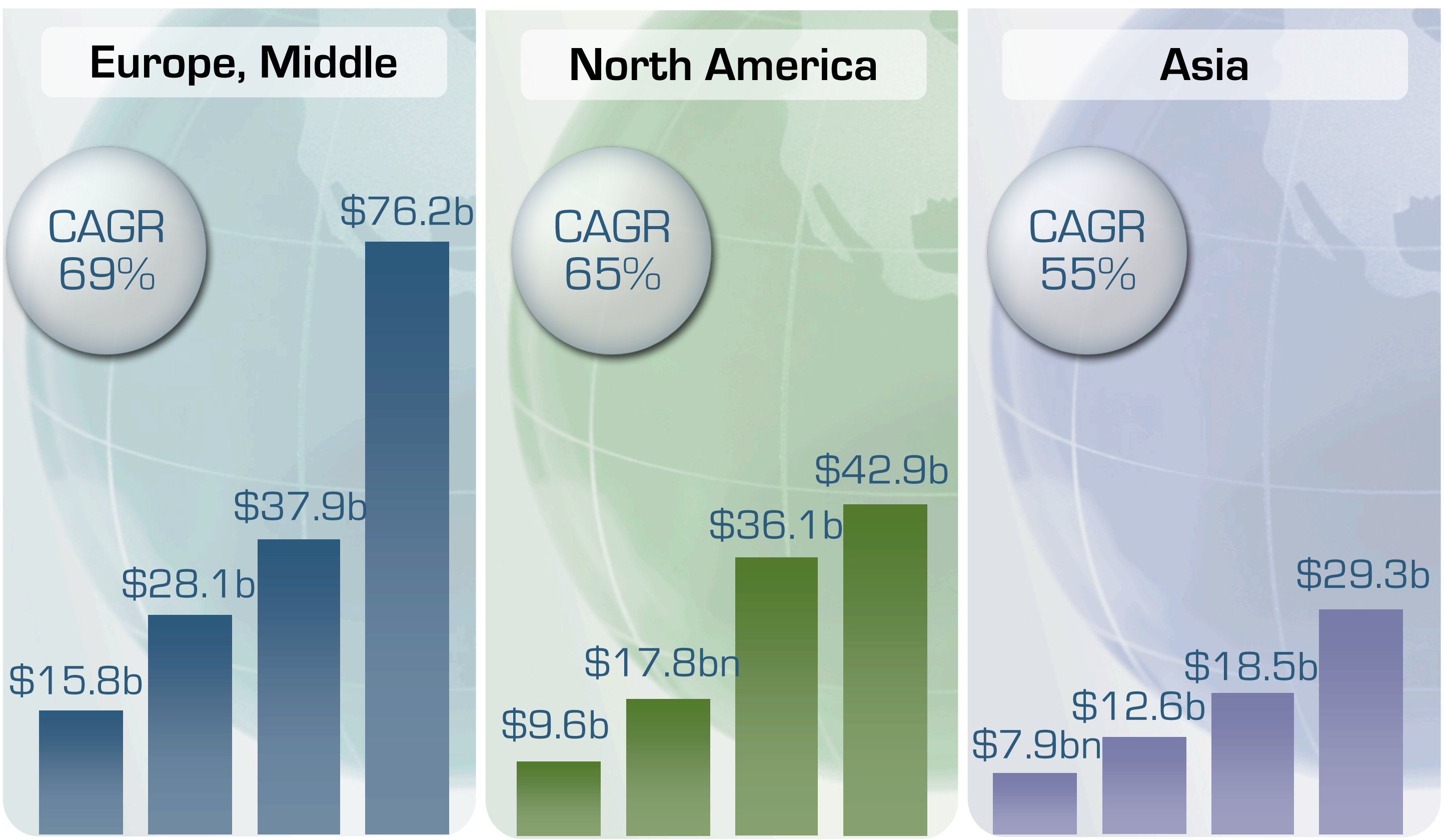

Figure 6: Global geographic breakdown of new investment in clean energy projects and rates of growth. Europe dominates clean energy technology development and commercialization, despite that fact that many of the basic innovations took place at U. S. institutions. CAGR: composite annual growth rate. Source: New Energy Finance.

The most consistent message from these 'cleantech' leaders is that a sustained and clearly articulated clean energy roadmap and strategy was developed and followed. Investment works; while, not surprisingly, neglect fails – both to provide us new business opportunities, as well as to provide critically needed options in a world changing due to greenhouse gas emissions.

Positive Signs to Build Upon with a National Clean Energy Agenda

A number of important developments have taken place that a visionary House, Senate, and Executive Branch can utilize to launch the clean energy economy.

First, innovations and funding flows are taking place across the 'cleantech' field. Figure 7 highlights the rapid growth in a truly diverse set of clean energy systems.

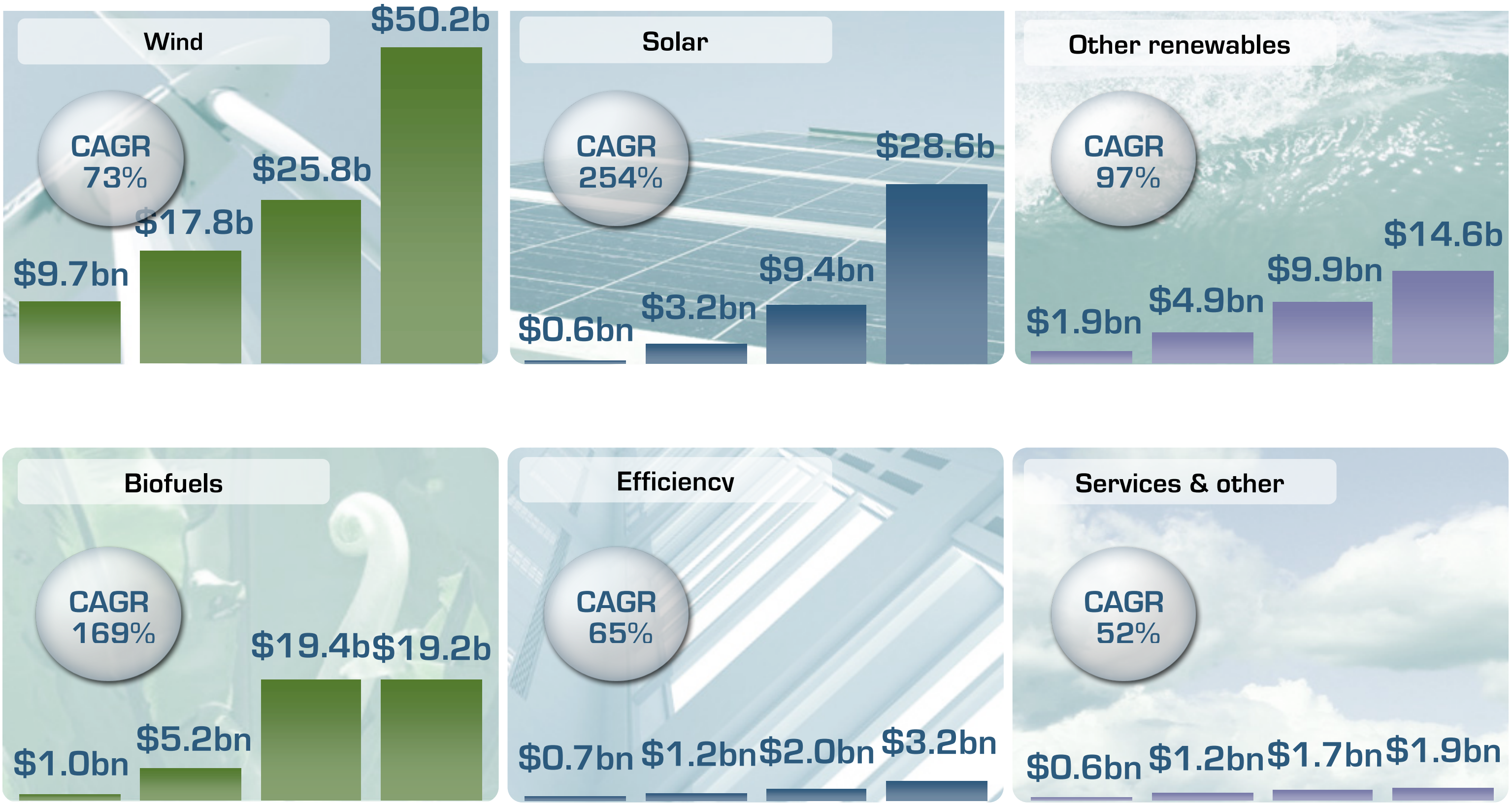

Figure 7: New Investment by Sector, 2004 – 2007. CAGR: composite annual growth rate. Source: New Energy Finance.

Second, a clear relationship exists been learning-by-doing in the manufacturing and deployment field, and the basic costs of new technology. Figure 8 documents this 'learning curve', where roughly a 20% cost decrease reliably occurs when the total number of units is manufactured and deployed. This process has been found to be robust for technologies such as solar panels and wind turbines that can be mass-produced, but is found *not* to hold for technologies where each unit is largely or partially unique, as is often the case for ultra-large, locally-tailored, goods.

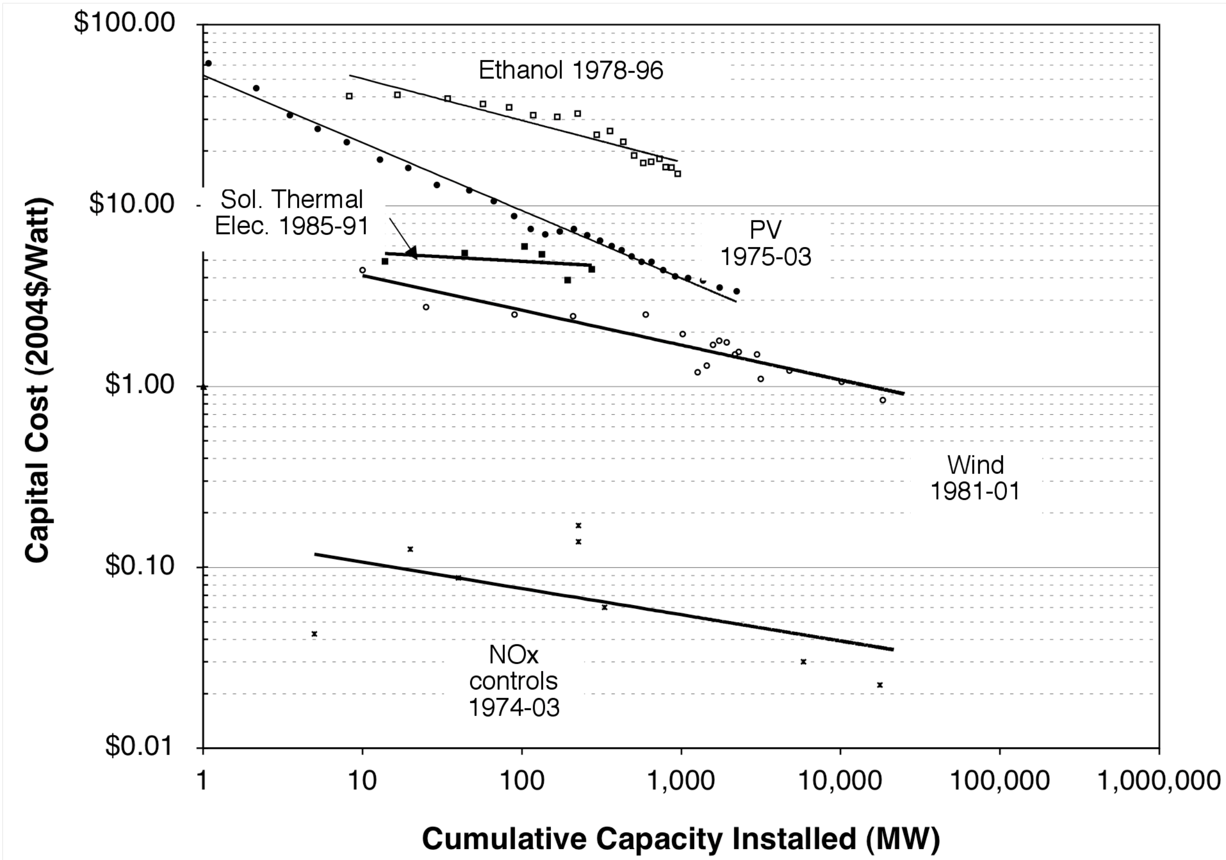

Figure 8: The 'learning curve', showing the cost declines in clean energy and pollution control technologies than accompanies expanded commercial production. A rougly 20% decrease in per unit cost typically accompanies each doubling of cumulative production (Duke and Kammen, 1999).

Finally, there is a consistent job creation dividend associated with building a new industry, which the clean, renewable, and energy efficiency fields remain today.

A number of analysts have charted an additional benefit of developing the clean energy options of efficiency and renewable energy technologies: job creation. My laboratory conducted a study of job growth in the clean energy industry across the nation relative to that seen in the fossil-fuel sector. We found (Kammen, Kapadia and Fripp, 2004; Kammen, 2007b) that on average, *three to five times as many jobs were created by a similar investment in renewable energy versus that when the same investment was made in fossil-fuel energy systems*.

The U. S. Government Accounting Office conducted its own study of the job creation potential of a clean energy economy (GAO, 2004). In an important assessment of rural employment and income opportunities, they found that:

> … a farmer who leases land for a wind project can expect to receive $2,000 to $5,000 per turbine per year in lease payments. In addition, large wind power projects in some of the nation's poorest rural counties have added much needed tax revenues and employment opportunities.

Recommendations

- **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 19^{th} 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.

  A clean energy education act could reward internship work in the clean energy sector - both domestically and in service to developing nations and poor communities, with semesters of paid college tuition.

- **Develop and Deploy a 'Smart' Grid as a Clean Energy Superhighway**
  Invest in both the development and deployment of a federal backbone for clean energy commerce: 1) grid expansion linking clean energy resources with population centers (as Texas has authorized to bring west Texas wind to Dallas/Ft. Worth); and 2) energy storage and power electronics must become areas of national research and deployment priority.

- **Establish a Set of Energy Challenges Worthy of Federal Action.** Establish *SustainableEnergy USA* awards – modeled after the successful efforts of the Ashoka Innovators awards for social entrepreneurs and the Ansari X Prize initially given for space vehicle launch - that inspire and mobilize our remarkable resources of academia, industry, civil society, and government. These initiatives would support and encourage groups to take action on pressing challenges. An initial set of challenges include:

  - Buildings that cleanly generate significant portions of their own energy needs ('zero energy buildings');

  - Commercial production of 100 mile per gallon vehicles, as can be achieved today with prototype plug-in hybrids using a low-carbon generation technologies accessed over the power grid, or direct charging by renewably generated electricity, and efficient biofuel vehicles operating on ethanol derived from cellulosic feedstocks.

  - Zero Energy Appliances (Appliances that generate their own power)

- ‘Distributed Utilities’; challenges and milestones for utilities to act as markets for clean power generated at residences, businesses, and industries.

It is vital, however, to *make sure that technology development is linked to market access* through such policies as a federal renewable energy portfolio standard, a ten-year extension of the production and investment tax credits (PTC and ITC) that bring market stability to clean energy investments, evaluation and design of a national Feed-In Tariff. These mechanisms ensure that a balanced ‘technology push’ and ‘demand pull’ dynamic exists in the economy.

- **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. My 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. Far from an isolated example, such opportunities exist everywhere, with the recent wave of interest in ‘sustainability science’ (Jacobson and Kammen, 2005) a resource, aid, and business opportunity that the U. S. should embrace.

  Consider international debt-relief based on deployment of low-carbon technologies in poorer nations.

- **Begin a Serious Federal Discussion of Market-Based Schemes to Make the Price of Carbon Emissions Reflect their Social Cost.** A carbon 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.

Commit to a Culture of Clean and Secure Energy Innovation and Commercialization

History shows that investing in innovation pays significant and long-lasting dividends – but it requires thoughtful and sustained support. Frivolous programs based on the ‘flash’ of a specific technology are far less successful – both in terms of technical breakthroughs and on a cost/effectiveness basis.

Important examples exist that back this simple prescription, including:

- *Semiconductors*: In the wake of the U. S. losing its leading position to Japan during the mid 1980s, a well-designed effort involving federal planning, university research, and a public-private partnership yielded remarkable results. SEMATECH (the Semiconductor Manufacturing Technology) is a non-profit consortium that performs basic research into semiconductor manufacturing (Wessner, 2003). Sematech began operating in 1988 after a careful examination of the need for both a goal-setting and road-mapping effort to guide the industry. Sematech is a partnership between the United States government and 14 U.S.-based semiconductor manufacturers to solve common manufacturing, and was funded over five years by public subsidies coming from the US Department of Defense via the Defense Advanced Research Projects Agency (DARPA) for a total of $500 million. Today Sematech exists largely with private contributions, and has three subsidiaries, the Advanced Technology Development Facility (ATDF), the Advanced Materials Research Center (AMRC), and the International Sematech Manufacturing Initiative (ISMI).
- *Nanotechnology and Biotechnology*: The Stanford Research Institute reports a 19:1 return on sustained investments in nanotechnology, while in the medical and biotechnology case described above in Figure 3, a 11:1 return was realized on federal investments in biotechnology.

Combining Technology and Financial Innovation – the Next Wave of Greenhouse Gas Abatement

As states and cities explore greenhouse gas emission reduction opportunities, new and important financial models are also emerging. The City of Berkeley, California provides one recent example that has already attracted international attention.

A Sustainable Energy Financing District is being developed as part of the City of Berkeley's implementation of Measure G – a successful 2006 ballot measure setting greenhouse gas reduction targets of a full 80% reduction in emissions by 2050.

The financing mechanism is loosely based on existing "underground utility districts" where the City serves as the financing agent for a neighborhood when they move utility poles and wires underground. In this case, individual property owners would contract directly with qualified private solar installers and contractors for energy efficiency and solar projects on their building. The City provides the funding for the project from a bond or loan fund that it repays through assessments on participating property owners' tax bills for 20 years. Cities may also be able to aggregate bonds, and states governments can facilitate this program in a number of ways.

No property owner would pay an assessment unless they had work done on their property as part of the program. Those who choose to pay for energy efficiency first, and then solar and energy installations through this program would pay only for the cost of their project, interest, and a small administrative fee.

The Financing District solves many of the financial hurdles facing property owners. First, there would be little upfront cost to the property owner. Second, the total cost of the solar system and energy improvements may be less when compared to financing through a traditional equity line or mortgage refinancing because the well-secured bond will provide lower interest rates than is commercially available. Third, the tax assessment is transferable between owners. Therefore, if an individual sells their property prior to the end of the 20-year repayment period, the next owner takes over the assessment as part of their property tax bill.

This mechanism, announced publicly on October 23, 2007, has attracted statewide attention as other cities, and now the state government, looks to find ways to expand the Financing District model statewide. Further, the U. S. Department of Energy has expressed its willingness to facilitate the dissemination of the program to other cities, states, and regions. My laboratory works with the Cities of Berkeley, Austin, Lisbon (Portugal), and others in their efforts to implement this financial innovation.

Thank you for the opportunity to appear before your committee and I welcome the opportunity to address any questions.

Acknowledgments

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