Witness Testimony of
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Hearing on Investing in the Future: R&D Needs to Met America's Energy and Climate Challenges

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Introduction

Chairman Markey, Ranking Member Sensenbrenner and members of the Select Committee, thank you for the invitation to testify today. It is my great pleasure to contribute to the ongoing discussion over how our nation can best meet its biggest challenge of the 21st century: creating a new energy economy that frees us from dependence on foreign oil, is affordable and protects our global environment. This is a task of highest priority that will engage all of our citizens, our best ideas, and a consistent long-term will to attain our goals. Together with industry and the federal and state governments, America's research universities will play a special role as our nation charts its way toward its new energy future.

I joined the University of Michigan in January 2006 as its Vice President for Research. Prior to moving to Ann Arbor, I have worked at Bell Labs, then the University of Southern California, and Princeton University as a professor and entrepreneur. I have more than 180 U.S. patents, have published over 420 papers in scientific journals, many of them in the field of energy generation and use, and I have co-founded or have been a founding participant in several successful companies, including Sensors Unlimited, Epitaxx, Inc., Global Photonic Energy Corp., Universal Display Corporation, and Apogee Photonics. Presently, my own research focus is on energy devices – both those that

harvest energy from the sun, and new white light sources that will soon replace the highly inefficient incandescent bulb. Indeed, twenty percent of our electrical energy usage is devoted to room illumination. So, a few "bright ideas" in this area can lead to potentially huge energy savings.

My involvement in energy research and development (R&D) has spanned much of my career. Along with many of you, I have seen how interest in energy research has waxed and waned, often in correlation with the price of fossil fuels. Today, we are hearing a crescendo of concern about our current situation, as the cost of energy has skyrocketed and has begun to seriously affect the economic prospects of our nation. And while many different perspectives and prescriptions are on the table, it is everyone's hope that the scientists, engineers and policy makers of America can, once again, make the discoveries and produce the solutions that will help us toward our goal of the new energy economy. I am here to tell you that our research universities are ready and eager to join with our colleagues in government and business to take up the challenge.

Every day, a wide cross section of faculty and students at the University of Michigan is actively engaged in energy research and teaching. Just as one example, to respond to the increasingly intense interests expressed by our students, U-M's College of Literature, Science, and the Arts has devoted this year's education and research theme to our "Energy Future." Just yesterday, U-M held its 13th annual Energy Fest on campus which showcased the university's efforts and commitment to energy conservation, energy efficiency and alternative energy technologies.

In direct response to the challenges faced in meeting our energy needs, in 2006 U-M initiated a new research institute called the Michigan Memorial Phoenix Energy Institute (MMPEI). It is named after our Phoenix Memorial Laboratory, home of the Ford Nuclear Reactor that was founded as part of the *Atoms for Peace Program* in the 1950s, whose original purpose was to explore the peaceful uses of nuclear energy. Prior to founding MMPEI, the Phoenix Memorial was built to honor University of Michigan alumni, students and faculty who gave their lives in World War II. Today, the mission of MMPEI has broadened to move beyond just nuclear energy, and now covers all aspects of renewable energy research. The Institute works to convene world experts in energy science and technology to develop new ways to generate, convert, and store all forms of energy. But, beyond science and technology, the Institute has a broad mission to explore the "third dimension" of energy research: the policy, economic and societal facets of our energy system. We must understand how potentially disruptive energy technologies may (or may not) be adopted by the public, and how the new inventions or policies might lead to unintended consequences. MMPEI's focus is essential because, as the subcommittee knows all too well, the pathway to successful implementation of technological solutions is often guided by public policy decisions, economics and societal change.

For the remainder of my remarks, I will focus on our mutual goal: pursuing research opportunities needed to bring about a transformed energy economy, and how my own state of Michigan can serve as a model for future federal research initiatives.

Our Nation's Energy Crisis

There are few contemporary challenges facing the nation – and the world -- more threatening than the unsustainable nature of our current energy infrastructure. Our economy and communities are dependent upon the secure availability of clean, affordable and flexible energy resources.

Yet, our current fossil fuels-dependent energy infrastructure is unsustainable. This is a problem with potentially catastrophic consequences. Global oil production is expected to peak within the next ten years (if it hasn't already done so), with natural gas production peaking soon thereafter. This is in the context of a rapidly increasing need and competition for low-cost energy coming from the developing world, most notably China and India. While there are substantial reserves of coal and tar sands, the mining, processing and burning of these fossil fuels poses increasingly unacceptable biological and environmental risks, particularly within the context of global climate change. Furthermore, the security of our nation is threatened by our reliance on foreign energy imports primarily coming from unstable regions of the world.

At this critical juncture, a bold and broad approach is needed to radically transform how the United States meets its energy needs. Inexpensive and carbon-free energy solutions that are renewable must be found – and I am confident that they are out there.

To just put things into context, in 20 minutes the sunlight falling on the earth delivers enough power to meet humankind's energy demand for an entire year. Put another way, if we constructed six solar cell fields 120 miles on a side and placed them in the temperate zones of the earth, we would more than exceed today's demand for electrical energy. But, the problem with solar, and other forms of renewable energy, is that they are often not cost-competitive with that supplied by fossil fuels purchased on the world's markets. Our challenge is to make the breakthroughs that will reduce the cost of existing alternative energy sources, and develop *new* energy production, conversion, and storage technologies.

To succeed at this task, which is acknowledged as the biggest challenge facing humankind in this century, we must truly harness the brainpower of scientists and engineers across the country. Scientists from both academia and industry already have a solid history in finding solutions to meet our energy priorities. For example, at MIT, research has led to the discovery of a new nanostructured cathode material for battery applications which has became the A123 battery to be used in General Motor's electric drive E-Flex system for its hybrid vehicles.

University of Chicago's Professor Roland Winston is the person behind an innovative light funnel called a "compound parabolic concentrator." His device can concentrate sunlight up to 84,000 times the natural level of sunlight at the earth's surface. This solar energy collector is very effective in producing electricity for large cities such as Chicago which, in 2004 purchased $5 million in solar energy systems based on Professor Winston's technological breakthrough.[1]

My own research in light sources has brought me to the Department of Energy's (DOE's) Solid State Lighting initiative. This program brings together a dynamic group of entrepreneurs, government experts, and university researchers that now stands on the edge of revolutionizing the lighting industry after 120 years dominated by the use of highly inefficient incandescent light bulbs.

Many of the young researchers I encounter are eager to join in and devote their entire careers to this grand effort. However, their enthusiasm is tempered by what has been the unpredictable and steadily declining level of support for energy R&D over the last two decades. Simply put, the U.S. has not responded in a manner proportionate to the threat posed by entering an energy-insecure future. It is essential that America's energy research campaigns be sustained over time and are sized to match the need. Now is not the time to approach this crisis through incremental change. Indeed, when faced with clear threats to our future and our well-being in the past, America has always responded forcefully and with a clear mission to accept nothing less than full success. We must do the same now, since the threat is clear, and the solutions are within our reach.

So how do we meet the challenges to rebalance our energy needs and sources? President Hockfield has highlighted a key step in her testimony – by dramatically increasing the funding for energy research. As she notes, a range of experts estimates that federal energy research must climb to up to ten times the current level.[2] There is no question that the range of proposed increases indicate that current federal investments are woefully inadequate when balanced against the urgency, complexity, and scale of the challenges in building a sustainable energy infrastructure for the United States. Whether this is funded through dollars derived from a Cap-and-Trade System, or through the regular appropriations process, it simply must be done to respond to the currently deepening energy crisis.

It is only a matter of recognizing priorities, and nothing today stands as a higher priority than filling our energy needs with clean, secure and renewable sources. Other countries have set such priorities. According to the attached tables in Appendix I based on statistics

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[1] *Solar Energy from the Windy City*. The Science Coalition, 2006. http://www.sciencecoalition.org/universityresearch.cfm?page=14

[2] Hockfield Susan. Testimony before the House Select Committee on Energy Independence and Global Warming, Washington, DC, September 10, 2008, p. 3.

from the International Energy Agency, Japan's energy Research, Development and Deployment (RD&D) dollars made up 0.08 percent of its Gross National Product while, in contrast U.S. energy RD&D makes up just ¼ of that investment.[3] To be the leaders that we believe ourselves to be, and to secure our energy security and competitiveness, we must have at least the same level commitment to transform the basis of our energy economy.

A high-level task force created by the Secretary of Energy's Advisory Board firmly stated that "America can meet its energy needs if and only if the nation commits to a strong and sustained investment in research in physical sciences, engineering, and applicable areas of life science, and if we translate advancing scientific knowledge into practice."[4] Yet, as my fellow witness, Dan Kammen, has pointed out in his research, energy R&D declined from ten percent of all U.S. R&D in 1980 to just 2 percent in 2005.[5]

Today, only 1.6 percent of all federal R&D goes to DOE research including nuclear energy.[6] The entire FY08 allocation for DOE R&D is $9.66 billion (with $3.57 billion dedicated to basic research programs at the Office of Science). This stands in sharp contrast to the FY08 National Institutes of Health budget of $29.46 billion and the $77.78 billion R&D budget for the Department of Defense. This is especially troubling considering that the energy sector of the U.S. economy, at $1.9 trillion, is our largest single industry, larger than the $1.7 trillion health sector and the $1.2 trillion national defense sector. Clearly, energy independence has not been given the priority it deserves to make the U.S. an economic leader, as well as energy secure.

Alternative energy technologies such as electric cars, hydrogen fuels, and renewable sources such as solar, wind or biofuels still require considerable R&D before they evolve to the point of affordable use by American families. Without a consistent vision for achieving these goals, progress will move in fits and starts at best, and we will be rapidly overtaken by our global competitors. Indeed, that is happening even now.

In addition to sufficient R&D funding, organizational changes must be made in the ways that our federal government, academic institutions and energy industry coordinate and collaborate in their research initiatives. The process must become more nimble, creative

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[3] *R&D Statistics Database*, International Energy Agency, 2008. http://www.iea.org/Textbase/stats/rd.asp

[4] Vest, Charles M. (Chair), Critical Choices: Science, Energy and Security. Final Report of the Secretary of Energy Advisory Board Task Force on the Future of Science programs at the Department of Energy. October 2003.

[5] Kammen, Daniel M. and Nemet, Gregory F. Reserving the Incredible Shrinking Energy R&D Budget, Issues in Science and Technology, Fall 2005.

[6] American Association for the Advancement of Science Report XXXIII: R&D FY 2009, February 2008. http://www.aaas.org/spp/rd/fy09.htm

and streamlined to succeed in the competitive worldwide environment pursuing alternative energy sources and technologies.

The Role of Universities in Energy R&D

The academic environment provides a unique freedom to explore, where university researchers are encouraged to look for revolutionary, not simply evolutionary, ideas to solve large-scale problems. This approach is often not accessible to the private sector, as the risks may outweigh potential economic rewards. However, by forging close partnerships between industry and university, companies can identify the most promising new ideas developed in the research lab, and take them rapidly through to commercialization.

The freedom to explore at America's university campuses creates a dynamic climate that, since the Second World War, is among the most precious assets our country possesses. Today, university researchers are looking for solutions to our energy challenge from all vantage points – hydrogen research, improved lighting sources, biofuels, energy storage, urban planning, solar cells, wind, geothermal, and alternative fuel cars, as only a few examples. As this research proceeds, universities are training the new workforce – building the supply of future scientists, engineers and entrepreneurs who's talent and innovative thinking will bring concepts to reality.

Michigan: A Model for Energy and Economic Transformation

As you know, the Midwest is struggling to overcome what appears to be permanent structural shifts in our economy. Nowhere is this economic change felt stronger than in Michigan where the latest unemployment statistics shows the state continuing to post the highest jobless rate in the country at 8.5 percent – 2.4 percent higher than the national average of 6.1 percent.[7] Michigan households are among the least likely to encourage their children to go on to a college education – a ranking we share with Mississippi, Alabama and Tennessee.

So, it may come as a surprise when I say that the future of Michigan is bright. This is a great time to invest in the Great Lakes Region, because when things are looking bleakest, the opportunities for finding new directions leading to economic advantage are the greatest. In Michigan, our state government, industry and universities have indeed seized this pivotal moment of change to develop new ways to collaborate to ease the economic travails of our state. A focus of our economic transformation, as emphasized by Gov. Granholm in her State of the State Address, is on developing the enormously rich and broad prospects of the alternative energy industry.

[7] *Regional and State Employment, July 2008.* Bureau of Labor Statistics, August 15, 2008.

Michigan's economy is rooted in the manufacturing business that fueled America's greatness throughout the 20th century. These historical assets give it the potential to share and drive the economic successes of the new century, and in doing so address the energy challenges facing the United States. That is where universities come in. We are fortunate in that our state is home to remarkably strong and competitive higher education institutions. Together, our public colleges and universities draw more than $1.5 billion in R&D funding each year into the state and work together to create a nearly unlimited and constantly renewable resource of creativity, innovation, human and physical capital, and business acumen ready to be leveraged to our state's and our nation's advantage.

The opportunities in Michigan, and specifically with the participation of great state institutions of higher education, have never been better with regard to the new challenges we face in energy. Much has been said about the vulnerability of our automobile industry posed by rising fuel costs, and global competitiveness leading to loss of market share. However, I argue that never has there been a more exciting time than the present for this same industry. In effect, the automobile is facing the most exciting time for innovations since the invention of the internal combustion engine. Given the concerns about fuel costs and the costs associated with limiting carbon emissions, we now are entering a period when the automobile must be re-invented. In effect, like Edison's light bulb, the 100-year run of the internal combustion engine is drawing to a close. How do American manufacturers rise to meet this challenge, and thereby reclaim their leadership role in the world? The answer is simple: through rapid, focused and successful innovation that starts today. And in this effort, their collaboration with universities must play a central role to be successful.

In recognition of these emerging opportunities, the Michigan Economic Development Corporation (MEDC) has launched a new Centers of Energy Excellence program. This innovative grant program brings businesses, universities and the state together to create jobs in the alternative and advanced energy industry. To quote Mr. James Epolito, the President and CEO of the MEDC, "With our world-class universities and pool of highly skilled workers, Michigan has the potential to lead the nation in the growth and development of the alternative energy field."[8] The program will identify companies with the necessary infrastructure to bring cutting-edge energy technology to the market. It then will match such companies with universities, federal labs, and training facilities to accelerate next generation research, workforce development and commercialization. The centers will focus on areas where our state has competitive advantages in workforce and

[8] "MEDC Launches Centers of Energy Excellence Program." Michigan Economic Development Corporation Press Release, August 28, 2008. http://www.themedc.org/News-Media/Press-Releases/Detail.aspx?ContentId=18c230b5-e597-4faf-a6e7-d025396d18d5

intellectual property, but where funding is still needed to overcome technical and supply chain hurdles that could prevent or stall the final commercialization process.

The University of Michigan is similarly dedicated to such partnerships, and is taking large steps to ensure a seamless linkage with industry to spur the rapid economic success so vital to our state and nation. Given U-M's renowned breadth of excellence, the concentration of entrepreneurs and business leaders seeking collaboration and assistance at the University of Michigan have sometimes found themselves overwhelmed by the sheer volume and variety of the research underway. Therefore, last fall, we established the *Business Engagement Center (BEC)* to strengthen ties to our business and community partners. With the goal of helping to revitalize and diversify Michigan's economy, the BEC serves as an information portal where entrepreneurs can rapidly be connected with leading faculty members who have expertise that overlaps with the needs of their companies. The university also will build on its numerous and long-standing energy research collaborations with firms in Michigan. These include not only the Big Three automotive companies, but also solar energy companies such as UniSolar, energy technology providers such as DTE, and chemical companies such as Dow Chemical which is headquartered in Midland.

A second example is the outreach efforts of the University Research Corridor (URC) partners -- University of Michigan, Michigan State University and Wayne State University. Along with industry and government, the URC was founded with the purpose of creating new economies based on innovations that emerge from the research labs of its large cadre of researchers. Formed to connect the scientists and engineers of the three campuses with the economic planners of the state, the URC has made approximately $1 million in seed investments in several revolutionary but feasible research projects that employ nanotechnology to address our energy challenges. This is one of many examples of how we are putting our own resources to work to ensure a bright and competitive future for our state, region, and nation.

The theme of government-industry-university collaboration is common in all these endeavors, and based on a long and productive history, one that we are confident will succeed. Now is the time to harness such efforts and maximize the return on investment of federal, academic and private funds. Meeting the energy challenge will require all of us to re-think how we do business together.

The Role of the Department of Energy in Energy Research

As you know, DOE plays a critical role in advancing U.S. scientific interests. Today, it is the leading source of federal funds and resources for research in the physical sciences –

providing two-thirds of the federal investment in this area.[9] The DOE is the primary government sponsor of high energy and nuclear physics, nuclear medicine, heavy element chemistry, plasma physics, and magnetic fusion. It also ranks high in overall federal support for research in computer science and engineering, and it sponsors research in biology and environmental sciences. DOE's programs and facilities have promoted the work of thousands of researchers, and played vital roles in many significant discoveries. However, to face today's energy predicament head on, our nation needs a new research model. In the past, we have relied on large industrial labs, such as Bell Laboratories, for rapid-response cutting-edge technological innovations. But these labs have all but vanished, leaving the university community with the responsibility, and opportunity, to fill this gap.

Nearly half the DOE Science research and development budget goes to supporting our system of National Laboratories.[10] The National Laboratories play a crucial role in meeting a wide range of important needs, such as nuclear weapons development, energy security, providing widely available computational resources, new energy sources, and homeland security. They set standards, plot specific directions that the energy community should follow, implement solutions, and provide massive and often costly resources to support energy research. However, to conduct the critical research needed to alter the basis of our fossil fuel dependence, emphasis on their core missions (*e.g.* nuclear weapons development) must be augmented by more research in the private and educational sectors to provide the breadth of solutions that times demand.

What Should Be Done: Advanced Research Project Agency for Energy

As I mentioned in my April 2007 testimony to the House Science and Technology Subcommittee on Energy, I strongly support the recommendation made in the National Academies' 2005 report, *Rising Above the Gathering Storm Gathering Storm*: create an Advanced Research Projects Agency for Energy, or ARPA-E. It is heartening to see seed funding for the agency in the FY09 House Energy and Water Appropriations bill. This flexible and independent federal agency, authorized by the America COMPETES Act at $300 million per year, "would be charged with sponsoring research and development programs to meet the nation's long-term energy challenges."[11] According to the National Academies report, the new agency "would support creative 'out-of-the-box' transformational generic energy research."[12]

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[9] American Association for the Advancement of Science, *DOE Science Leads the Pack in 2008*, Washington, DC (March 21, 2007), page 6.
[10] Ibid, page 2.
[11] The National Academies, *Rising Above the Gathering Storm: Executive Summary*, Washington, DC (2005), page 7.
[12] Ibid.

ARPA-E is modeled on the Pentagon's successful Defense Advanced Research Projects Agency (DARPA). Created in response to the Soviet technological threat, DARPA became a critical bridge between the defense needs of the time and the experts at universities and private corporations who could provide the answers.[13] Over the course of its history, it has nurtured long-term innovative research and development investments in a way that private industry could not always afford to. Through DARPA's support came ground-breaking technological advances such as the internet, gallium arsenide semiconductor technology now the backbone of cell phones, and high volume optical communications.

A similar independent research agency at DOE can bring together the best minds from around the country to guide us in developing solutions for the future. It is designed to have the autonomy and freedom from bureaucratic impediments to encourage collaborations to solve immense and common problems facing the energy sector. Ultimately, funding from this new agency will lead to the generation of a robust private industry that would provide solutions while strengthening our domestic markets.

An agile, mission-oriented ARPA-E will connect universities with large and small industry hungry for new advances in technology. With their more practical perspectives, the companies can take university innovations through to commercialization. With ARPA-E as a bridge between the two worlds, the best ideas will rapidly emerge to find their place in the commercial marketplace.

Furthermore, ARPA-E sponsorship of university research would contribute to the training of the workforce – helping to create the future scientists, engineers and entrepreneurs who will continue to innovate to solve the energy crisis that is now upon us. As America fights to maintain its competitive edge in the world, this next generation of experts will become increasingly important.

Hence, while the establishment of ARPA-E represents a milestone in our thinking of how best to address the current and growing crisis in energy independence, the time to fully fund this agency cannot be delayed. We have already lost too much time in our race to create a secure and clean energy future for our nation and planet. The U.S. can and must lead in this race if we are to maintain our global competitiveness and economic independence. ARPA-E represents a critical step in accomplishing these goals.

What Should Be Done: Discovery Innovation Institutes

To develop and successfully implement new pivotal energy technology and policies we must create significant additional opportunities for regional energy research initiatives. In

[13] William Bonvillian, Power Play: the DARPA Model and U.S. Energy Policy, The American Interest, Washington, DC (November/December 2006), p. 44.

this area, I recommend looking into creating what are called Discovery and Innovation Institutes, or DIIs, recommended by the National Academy of Engineering. DIIs represent the new paradigm for addressing multidisciplinary challenges by linking federal agencies, research universities, industry, entrepreneurs, and the investment community. They manage and focus the strengths of each on the full spectrum of research, from basic science on through commercialization.

According to these recommendations, a national network of DIIs would be capable of rapid transfer of cutting-edge technologies and systems into specific sectors of the energy marketplace. These institutes would be operated by research university consortia as Federally Funded Research and Development Centers and would be closely linked to the National Labs and key industry partners. Each institute would be supported by federal funding that would eventually build to a level of $200 million per year and augmented with additional dollars from state, industry, foundation and university sources when possible.

Each DII would be responsive to the unique regional needs and capabilities where it is located. For example, for the energy-intensive Great Lakes region, which is dependent upon heavy manufacturing, agriculture and transportation, a DII could lead research in areas such as alternative transportation fuels, advanced energy efficient automobiles, and energy efficient manufacturing technologies. In contrast, a DII for the Intermountain West could focus on the energy needs of a rapidly growing population and activity dispersed over fragile ecosystems with limited water resources but significant primary energy sources.[14]

Since a successful sustainable energy infrastructure depends as much on socioeconomic, political and policy issues as upon science and engineering, these institutes also would provide a comprehensive approach that would encompass disciplines ranging from the social and behavioral sciences, business administration and public policy. Furthermore, they would serve as unique training grounds for the new generations of scientists and entrepreneurs who will have to look at every possibility from all angles to find cutting-edge answers to our energy needs.[15]

Conclusion

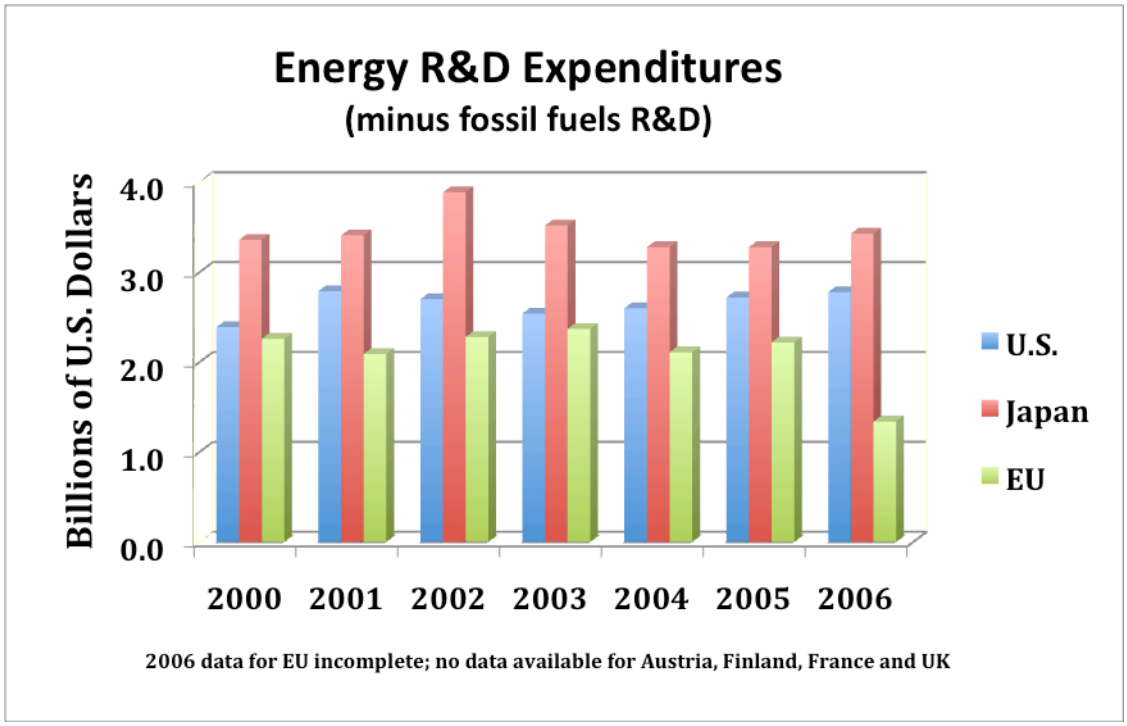
Thank you again for the opportunity to testify today. I look forward to continuing this discussion. Generating and deploying pivotal new technologies is vital as the nation faces the likely collapse of our traditional fossil fuel economy in the not-too-distant future.

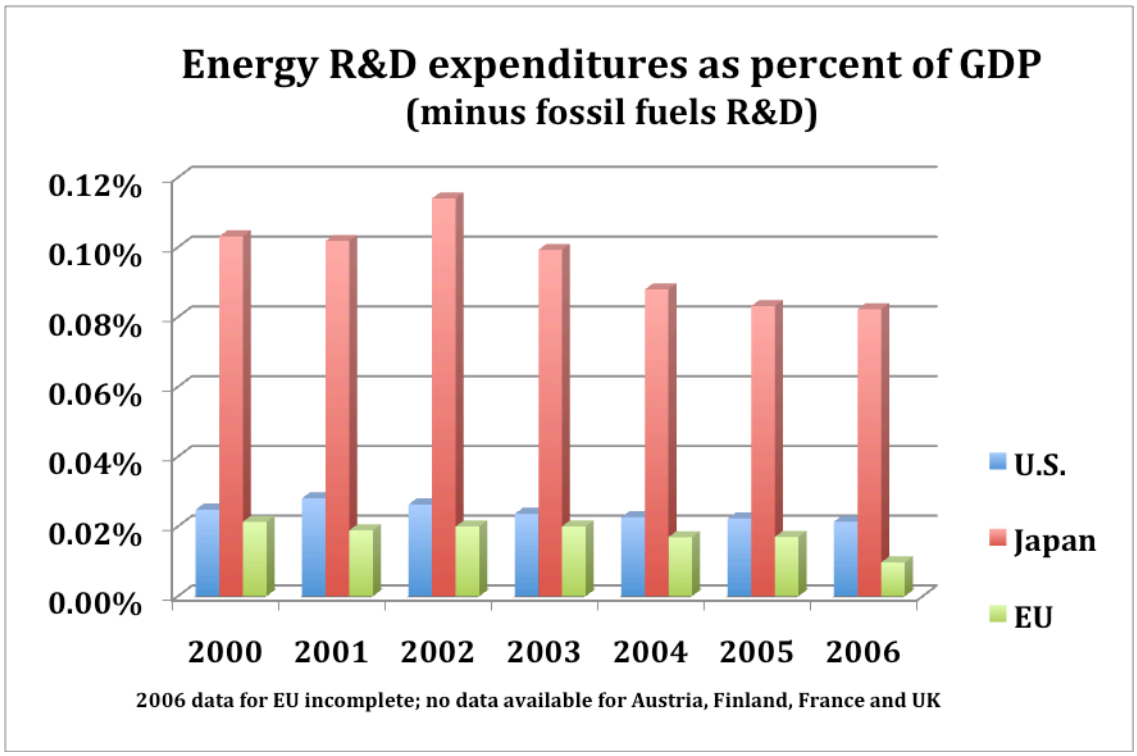
[14] "Creating a National Energy Research Network: A Step toward America's Energy Sustainability" (draft). Next Energy Project Working Group, May 1, 2008.
[15] Duderstadt, James J. *Engineering for a Changing World: A Roadmap to the Future of Engineering Practice, Research, and Education*, The Millennium Project, p. 76-79.

There is no single, simple solution, but our nation's security, our standard of living, and the health of the planet hinges on our ability to the shift away from our current reliance on fossil fuels. The state of Michigan is taking steps in that direction. ARPA-E and the DIIs also represent the kind of new and bold partnerships between academia, industry and government that must be forged to make this transformation successful. We must all pull together – academia, industry, the investment communities, government (both federal and state) and foundations.

Our solutions will require openness to new ideas, and a willingness to invest in these changes over the long term. In setting national priorities, it is increasingly apparent that transforming our energy economy now represents the single highest priority to assuring a bright future for our nation. America's research universities are up to the challenge and are eager to play a major role. It is an honor to contribute our intellectual depth and productivity to help the country survive what will be a long and disruptive transition in its energy use away from traditional fossil fuel sources. If given the opportunity, I am certain that we will succeed. As in meeting the grand challenges faced by our nation in the past, we simply have no alternative.

Appendix I





Source of R&D expenditure data: R&D Statistics Database, International Energy Agency, 2008.
Source of GDP data: International Monetary Fund.