PUSHING THE EFFICIENCY ENVELOPE: R&D FOR HIGH–PERFORMANCE BUILDINGS, INDUSTRIES, AND CONSUMERS

HEARING

BEFORE THE

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT

COMMITTEE ON SCIENCE AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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PUSHING THE EFFICIENCY ENVELOPE: R&D FOR HIGH–PERFORMANCE BUILDINGS, INDUSTRIES, AND CONSUMERS

TUESDAY, APRIL 28, 2009

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON ENERGY AND ENVIRONMENT,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, DC.

The Subcommittee met, pursuant to call, at 10:05 a.m., in Room 2318 of the Rayburn House Office Building, Hon. Brian Baird [Chairman of the Subcommittee] presiding.

BART GORDON, TENNESSEE
CHAIRMAN

RALPH M. HALL, TEXAS
RANKING MEMBER

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Subcommittee on Energy and Environment

Hearing on

Pushing the Efficiency Envelope: R&D for High-Performance Buildings, Industries, and Consumers

Tuesday, April 28, 2009
10:00a.m. – 12:00p.m.
2318 Rayburn House Office Building

Witness List

Mr. Steven Chalk
Principal Deputy Assistant Secretary
Energy Efficiency and Renewable Energy
U.S. Department of Energy

Mr. William J. Coad
President
Coad Engineering Enterprises, and
Chairman, High-Performance Building Council
National Institute of Building Sciences

Mr. Paul Cicio
President
Industrial Energy Consumers of America

Dr. Karen Ehrhardt-Martinez
Research Associate
Economic and Social Analysis Program
American Council for an Energy-Efficient Economy (ACEEE)

Dr. J. Michael McQuade
Senior Vice President
Science and Technology, United Technologies Corporation

HEARING CHARTER

SUBCOMMITTEE ON ENERGY AND ENVIRONMENT
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

Pushing the Efficiency Envelope: R&D for High-Performance Buildings, Industries, and Consumers

TUESDAY, APRIL 28, 2009
10:00 A.M.–12:00 P.M.
2318 RAYBURN HOUSE OFFICE BUILDING

PURPOSE

On Tuesday, April 28 the Subcommittee on Energy and Environment will hold a hearing to receive testimony on the role of the Department of Energy's research and development programs in developing technologies, codes, and standards to enable deployment of net-zero energy, high-performance buildings and support energy efficiency in domestic industries.

WITNESSES

- **Mr. Steven Chalk—**Principal Deputy Assistant Secretary, Energy Efficiency and Renewable Energy, U.S. Department of Energy
- **Mr. William J. Coad—**President, Coad Engineering Enterprises; Chairman of the High-Performance Building Council of the National Institute of Building Sciences
- **Mr. Paul Cicio—**President, Industrial Energy Consumers of America
- **Dr. Karen Ehrhardt-Martinez—**Research Staff, Economic and Social Analysis Program, American Council for an Energy-Efficient Economy (ACEEE)
- **Dr. J. Michael McQuade—**Senior Vice President, Science and Technology, United Technologies Corporation

BACKGROUND

Addressing public concerns about the high costs of energy, the looming threat of global climate change and the Nation's economic health requires continual assessment of federal programs designed to mitigate the impacts of various economic sectors, including heavy industry and the built environment. The construction, operation, and demolition of buildings are recognized as major contributing factors to the increase in energy consumption, emission of greenhouse gases, depletion of valuable natural resources, and degradation of ecological services such as water supply. The domestic industrial sector, while making considerable gains in energy and resource efficiency in recent years, still comprises a significant portion of the country's emissions, and is more vulnerable than ever to rising costs of energy and raw materials. To reduce both emissions and waste, and improve the Nation's overall energy efficiency new advancements in industrial and building technologies must be pursued by both the public and private sector.

Buildings consume more energy than any other sector of the U.S. economy (40 percent), including transportation (28 percent) and industry (32 percent). From 1980 to 2006, total building energy consumption in the United States increased more than 46 percent, and is expected to continue to grow at a rate of more than one percent per year over the next two decades. In addition, almost three-quarters of our nation's 81 million buildings were built before 1979. Because buildings are long-lived assets, significant improvement of their energy efficiency will require either retrofits or total replacement. Deployment of high-performance buildings can reduce the environmental impact of buildings while making them cheaper to operate.

Industry accounts for approximately one-third of all energy consumed in the U.S. with much of that usage concentrated in heavy industries such as chemical, glass, cement, and metals production, mining, petroleum refining, food processing, and forest and paper products. These industries also have relatively high carbon dioxide (CO_2) emissions. Despite their relatively high energy and emissions intensity, many industrial firms face competitive pressures that make it difficult to justify the technical and financial risks of R&D projects. Therefore, federal programs are essential to promote development and deployment of technologies and process improvements that increase energy efficiency, raise productivity, reduce and reuse wastes, and trim costs.

Building and Industrial Efficiency Technology Programs at DOE

The importance of energy efficiency and sustainability in the building and industrial sector has been recognized in various federal laws, executive orders, and other policy instruments in recent years. Among these are the energy policy acts (EPAct) of 1992 and 2005 (P.L. 102–486 and P.L. 109–58), the *Energy Independence and Security Act of 2007* (EISA, P.L. 110–140), and the *American Recovery and Reinvestment Act of 2009*. Through these laws the Department of Energy (DOE) is authorized to carry out a range of activities to increase energy efficiency in a number of economic sectors.

Within the DOE Building Technologies Program both the High-Performance Buildings partnerships and Zero-Net Energy Commercial Building Initiative, work to improve the efficiency of buildings and the equipment, components, and systems used to control temperature, provide lighting, and plumbing.

A high-performance building as defined by EISA is a building that integrates and optimizes, on a life cycle basis, all major high-performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality and operational considerations. As part of this approach, DOE selected building industry groups to form a High-Performance Green Building Consortium that works to accelerate the commercialization of high-performance building technologies. DOE and the National Renewable Energy Laboratory (NREL) also created the High-Performance Buildings Database, which seeks to improve building performance measuring methods by collecting data on various factors that affect a building's performance, such as energy, materials, and land use. It is a unique central repository of detailed information and data on high-performance, green building projects across the United States and abroad.

The Net-Zero Energy Commercial Building Initiative aims to realize marketable net-zero energy commercial buildings by 2025. In general, a net-zero energy building produces as much energy as it uses over the course of a year. The program brings architects, engineers, builders, contractors, owners, and occupants together to optimize building performance, comfort, and savings through a whole-building approach to design and construction. The program is divided into three interrelated strategic areas designed to overcome technical and market barriers: research and development, equipment standards and analysis, and technology validation and market introduction. Key research areas include: commercial lighting solutions; indoor environmental quality; building controls and diagnostics; and space conditioning.

The Department also participates in a variety of activities to aid in standards and codes development for new building technologies, appliances, and compliance and design tools. For example the Building Technologies Program's Building Energy Codes initiative works with the National Institute of Standards and Technology, State and local governments, national codes organizations, and industries to help develop improved national model energy codes. Unlike conventional building codes which dictate only minimum requirements for construction, "model" building codes are designed to push the technological envelope of what can be achieved in building design, construction and operation. Ultimately, there may need to be a comprehensive and unified framework of standards which accounts for the full range of metrics and benchmarks to maximize building performance. DOE also updates and improves appliances and equipment standards by testing products and technologies, and ultimately conducting rule-making through a public process.

The DOE Industrial Technologies Program (ITP) seeks to reduce manufacturing energy intensity and carbon emissions through coordinated research and development with industry, deployment of innovative energy efficient technologies, by providing energy assessments of industrial facilities, and through dissemination of industry best practices. The ITP invests in high-risk, high-value cost-shared R&D projects to reduce industrial energy use and process waste streams, while stimulating productivity and growth. Projects may be specific to a certain industry (ex: aluminum smelting), or applicable across a range of industrial applications (ex: fuel and feedstock flexibility). In addition, the ITP serves as an informational resource by making available information on other financial assistance and research opportunities, background on both existing and emerging technologies, as well as results of case studies from past ITP projects. The ITP also sponsors 26 University-Based Industrial Assessment Centers (IACs) that provide no-cost energy assessments primarily to small- and medium-sized manufacturers. By operating through university engineering programs the IACs serve as a training ground for the next-generation of energy and industrial engineers.

Pushing the Energy Efficiency Envelope

While these programs continue to demonstrate success in developing technologies and practices for high-performance buildings and sustainable industries, advancing the state of technology far beyond what is currently available will require the programs to incorporate entirely new technologies and approaches into their R&D agendas.

For instance, buildings of the future will be designed to operate as a singular system of inter-operable components—a concept that is not possible today. A typical building is comprised of a complex array of components (wood, metals, glass, concrete, coatings, flooring, sheet rock, insulation, etc.) and subsystems (lighting, heating, ventilation and air conditioning, appliances, landscape maintenance, IT equipment, electrical grid connection, etc.) all of which are developed individually by independent firms that do not often design and test their performance in conjunction with other components and systems. Even after building completion, systems are rarely optimized together to improve overall energy efficiency and environmental performance. The inefficiencies attributable to this fragmentation of the building components and systems, and the lack of monitoring and verification of a building performance, point to a critical need for a more integrated approach to building design, operation, and technology development. An approach that couples buildings sciences, architecture, and information technologies could lead to entirely new "self-tuning" buildings with subsystems that are able to continuously communicate with each other and respond to a range of factors. Wide-scale deployment of these types of net-zero energy high-performance buildings will likely require federal programs to play a larger coordinating role in the development of the common technologies, codes, and standards.

Pushing the efficiency envelope will also require engaging the social sciences in providing a much greater understanding of how people and organizations make energy-related decisions. Individual and collective behavior plays a critical role in efficiency, not only through direct demand for energy, but also by creating or failing to create market demand for more energy efficient technologies. Consumers make these decisions every day when weighing options such as what vehicle or appliance to purchase, whether to drive or take public transportation, what light bulbs to install, or whether to shut down their computers at night. In aggregate these decisions have an impact on the supply and demand curves that drive both energy prices and, ultimately, energy technology development.

In 2005, the National Academy of Sciences (NAS) produced a report on "Decision Making for the Environment: Social and Behavioral Science Research Priorities." In the chapter on *Environmentally Significant Individual Behavior,* the NAS panel states: "A basic understanding of how information, incentives, and various kinds of constraints and opportunities, in combination with individuals' values, beliefs, and social contexts, shape consumer choice in complex real-world contexts would provide an essential knowledge base for understanding, anticipating, and developing policies for affecting environmentally significant consumer behavior."[1] Integrating social science research into the larger energy R&D field will provide greater insight into the best ways to convey information to consumers and help them make decisions regarding energy efficiency and conservation. For instance, understanding consumer behavior will help in development of a whole building approach to design and operation of building systems, where components are integrated to reduce energy consumption through displaying information to occupants.

[1] National Research Council. 2005. *Decision Making for the Environment: Social and Behavioral Science Research Priorities.* Washington, DC. P. 78.

Chairman BAIRD. This hearing will now come to order.

I want to welcome Members of the Subcommittee and our distinguished panelists to today's hearing on advancing the state of science and technology for energy efficiency in buildings and industrial sectors.

Energy efficiency and conservation will have the greatest near-term impact of any approach to our energy security and global overheating problems. I don't refer to it as warming or climate change. It is lethal overheating and ocean acidification, and if we start calling it by what it is, we will be more effective at combating it, I believe. Today's buildings consume 40 percent of our country's energy, more than any other sector of the U.S. economy. Together the building and industrial sectors are responsible for almost three-quarters of U.S. energy consumption. Given that, it makes sense that we would start there to try to reduce that consumption, and our most rapid way of stimulating the economy, reducing spending, reducing ocean acidification and global warming gases is through conservation, in my judgment.

As many of you know, this committee oversees a broad range of activities designed to push the energy technology envelope, including R&D programs through the Department of Energy, programs that support the development of codes and standards that are vital to ensuring the performance and inter-operability of energy technologies.

The DOE Building Technologies Program, and within this, the activities of the High-Performance Buildings and Net-Zero Energy Commercial Buildings initiative, support advanced technology development for buildings and their associated equipment, material and systems. The Industrial Technologies Program works to reduce energy intensity and carbon emissions of industry through cost-shared R&D, energy auditing and dissemination of best practices.

While these programs have proven successful over the years, we still have a very long way to go in maximizing the Nation's efficiency. Pushing the efficiency envelope will require us to combine the expertise of multiple disciplines or look in entirely new directions for scientific and technological insight.

For example, coupling building sciences, architecture and information technologies can lead to entirely new self-tuning buildings with subsystems that continuously communicate with each other and respond to a range of environmental factors. We should also enlist the expertise found in the social sciences to provide greater understanding of how people and organizations make energy-related decisions. Insight into how consumers receive and react to information will be critical for progress in areas such as the development of a whole-building approach to design and operation of building systems.

The Committee has a long and distinguished history in this area. As the Congress moves forward with climate and energy legislation, we will continue our efforts to assess the Federal Government's role in building and industrial R&D and standards development and to lay the groundwork for new activities if needed.

With that, I look forward to working with you all and exploring ways in which federal programs can be improved to support cleaner, more efficient and sustainable buildings and industry in the United States.

I now recognize my distinguished colleague and friend from South Carolina, our Ranking Member, Mr. Inglis, for his opening statement.

[The prepared statement of Chairman Baird follows:]

PREPARED STATEMENT OF CHAIRMAN BRIAN BAIRD

I want to welcome Members of the Subcommittee and our distinguished panelists to today's hearing on advancing the state of science and technology for energy efficiency in the buildings and industrial sectors.

Energy efficiency and conservation will have the greatest near-term impact of any approach to our energy security and global *over heating* problems. Today's buildings consume 40 percent of our country's energy—more than any other sector of the U.S. economy. And together, the building and industrial sectors are responsible for almost three quarters of U.S. energy consumption.

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With that, I look forward to working with you all in exploring ways in which federal programs can be improved to support cleaner, more efficient, and sustainable buildings and industries in the U.S.

I now yield to my distinguished colleague from South Carolina, our Ranking Member, Mr. Inglis, for his opening statement.

Mr. INGLIS. Thank you, Mr. Chairman, and thank you for holding this hearing. When it comes to words, I am convinced that less is more and people who write well can express themselves in a few words. If you give me 30 minutes to speak, I don't need to do any preparation, but limit me to two minutes and I have got to really prepare.

You know, when we are blessed with much, we can get by with a lot of inefficiencies. Electricity is cheap so we leave the lights on. Material is cheap so we build big when we might actually get more utility out of small. Gas is cheap so we bought guzzlers instead of sippers. And so the challenge for us is to figure out how to get more utility out of buildings and get building codes that actually will improve efficiencies and deliver for us more by having less, less use and less waste.

My wife and I have five kids and I designed the house with the help of an architect, the house that we live in, and quite often I am thinking if I could just have made it smaller because you know your possessions come to possess you and so all those porches that need to be washed at least twice a year, man, that was a bad idea. All that space that needs to be heated, gee, couldn't we have thought of a better way to get that job done. So I am excited about hearing about some of the technology that may drive better building codes and better opportunities for us to get more out of less, and thank you, Mr. Chairman, for holding the hearing.

[The prepared statement of Mr. Inglis follows:]

PREPARED STATEMENT OF REPRESENTATIVE BOB INGLIS

Thank you for holding this hearing, Mr. Chairman.

When it comes to words, I'm convinced that less is more. People who write well can express themselves with few words. Give me thirty minutes to speak and I'll need no preparation. Limit me to two minutes and I'll have to plan carefully what to say.

When we're blessed with much, we can get by with a lot of inefficiencies. Electricity is cheap, so we leave the lights on. Material is cheap, so we build big, when we might get more utility out of small. Gas is cheap, so we've bought guzzlers instead of sippers.

But climate science, oil price hikes, and economic hardships remind us that we need more efficient practices. Today, we're here to specifically talk about how to encourage energy efficiencies in one of our most energy intensive sectors—buildings. While I support the government taking proactive measures to improve building codes and promote R&D programs that result in the deployment of net-zero energy, high-performance buildings, I think the answer lies in economics.

Attaching a price to carbon would be a built-in incentive for construction of more efficient spaces. Industries, seeking to save on costs and appeal to conscious consumers, will revamp wasteful practices. Tenants will seek space that promises a reduction in energy costs due to efficient lighting, heating and cooling appliances, and utilities. We'll also witness improvements outside the walls of these buildings. Demand will rise for efficient products, and jobs will be created in meeting that demand. Reduced fuel consumption will translate to increased national security, and efficient energy production will mean cleaner air.

This is the potential of a revenue-neutral carbon tax. Yes, there's a place to talk about developing positive codes and standards, but the real incentive lies in the market, not in regulation. Thank you again, Mr. Chairman, and I look forward to hearing from our witnesses today.

Chairman BAIRD. I thank Mr. Inglis. If other Members wish to submit additional opening statements, your statements will be added to the record at this point.

[The prepared statement of Mr. Costello follows:]

PREPARED STATEMENT OF REPRESENTATIVE JERRY F. COSTELLO

Good Morning. Thank you, Mr. Chairman, for holding today's hearing on the role of the Department of Energy in research and development (R&D) for high-performance buildings, industries, and consumers.

As Congress considers changes to our energy policy, we must consider ways to cut back on our emissions and improve our energy efficiency. The two sectors we are discussing today—building and heavy industry—are the largest consumers of energy in the country and significantly contribute to our greenhouse gas emissions. Discovering and developing ways to improve the energy efficiency of these two sectors will make major strides towards reducing our emissions while creating thousands of new, high-paying jobs around the country. I am seeing the results of investment in energy efficiency in my district in Southern Illinois. Two counties and the City of Belleville received over $4.5 million in funding from the *American Recovery and Reinvestment Act* to invest in energy efficiency projects. This money is putting people back to work while improving the efficiency of our buildings.

Investing in long-term, high cost R&D projects is not feasible for many of our heavy industries or building and contracting companies, particularly in this difficult economic climate. For this reason, I applaud the efforts of the Department of Energy to promote and accelerate new technology, methods, and tools to improve building and industrial energy efficiency. I am interested to hear more from Mr. Chalk about how Congress and this subcommittee in particular can continue to support DOE in these efforts.

I would also like to hear from our witnesses how these R&D projects can become commercially viable and widely dispersed across our domestic manufacturers and builders. In particular, I want to know what steps DOE and Congress can take to ensure this research results in sector-wide changes in building and heavy industry practices across the country.

Making these changes marketable to the American consumer will also be an issue to consider moving forward. I would like to hear from our witnesses regarding the incentives or other programs they believe might be necessary to encourage contractors, builders, and consumers to choose high-performance buildings or products made by high-performance manufacturers.

I welcome our panel of witnesses, and I look forward to their testimony.

[The prepared statement of Ms. Johnson follows:]

PREPARED STATEMENT OF REPRESENTATIVE EDDIE BERNICE JOHNSON

Good morning, Mr. Chairman.

High-performance buildings are those that are designed with environmental conservation in mind.

Solar paneled roofs; natural light; green roofs; sustainable construction materials: all are examples of architectural elements that do good, rather than harm, to the environment.

In Dallas, the Trinity River Audubon Center is a shining example of such a structure. Its green features include a vegetated roof, rainwater collection system, energy efficient systems, and recycled materials.

Audubon serves as the gateway to the 6,000 acre Great Trinity Forest.

As the largest urban hardwood forest in the United States, the Greater Trinity Forest supports a diverse community of plant and animal species, and contains a unique mixture of bottomland hardwoods, wetlands and grasslands.

Trinity River Audubon Center is the first building constructed by the City of Dallas Park and Recreation Department that is certified by Leadership in Energy and Environmental Design Green Building Rating System™.

The Center was actually built upon a part of land that is a remediated Brownfield site: the Deepwood Landfill.

The Deepwood Landfill comprised 1.5 million tons of construction debris illegally dumped over a 15-year period.

With the goal of returning this land to nature for the use of future generations and as a site of the Trinity River Audubon Center, the devised plan consolidated the waste into capped rolling hills replanted with tall prairie grass and hardwood trees once dominant on the Texas Blackland Prairie.

The permeable paving around the area and preservation of the Trinity River marsh helps with stormwater control. The Center even harvests rainfall to be used as irrigation. It has installed low-flow toilets to conserve water.

High-efficiency heating, ventilation, air conditioning and electrical systems help minimize the Center's carbon footprint.

The building's use of regional construction materials minimizes harmful emissions generated from transporting materials from the place of extraction to the manufacturing plant to the consumer.

The Trinity River Audubon Center is comprised of many local building materials, as well as cypress siding certified by the Forest Stewardship Council; recycled-content materials; rapidly renewable resources such as bamboo, wool, cotton, straw, wheat and cork; and low-volatile-emitting materials.

For the concrete, all the gravel and sand was extracted from local quarries.

Fly ash, a by-product from coal plants that would normally go into a landfill, was used as a partial substitute for the cement content.

Mr. Chairman, I am delighted to point out the Trinity River Audubon Center as a model of the architectural designs that this committee seeks to encourage.

With some thought and effort, "green" buildings can be built and are a beautiful addition to our communities.

I believe that it is appropriate for the Department of Energy to support research into green building technologies.

Current programs continue to demonstrate success in developing technologies and practices for high-performance buildings and sustainable industries.

I support advancing the state of technology beyond what is currently available by funding to incorporate entirely new technologies and approaches into their research agendas.

Mr. Chairman, thank you for your focus on this important subject. I want to welcome today's panel of witnesses, and I yield back the balance of my time.

Chairman BAIRD. At this point I would like to introduce our witnesses. I unfortunately need to express some disappointment and I am reluctant to do so but it is necessary. The Committee has a practice of asking that testimony be provided in advance of hearings so that we can study it and know what is happening. It is a reasonable request, especially given that we anticipate that our witnesses sort of by definition will have expertise in the field. When I am hiring staff, I sit them down with a challenge, an issue they have to deal with, and they have two hours to write a report to me, two hours. They are by and large brave young people and with the wizard of the Internet they are able to do some remarkable things. Hence, when we give several weeks' notice of testimony requests and it doesn't come and when it is coming from an agency of the Administration, we are particularly disappointed. That is the case today. The energy efficiency testimony we were asking for from the Department of Energy arrived about 20 minutes ago. It is disappointing that the Department of Energy either does not have its act together well enough to provide this in, I would imagine it should be virtually instantaneous manner, but certainly several weeks notice is more than adequate and it is either a sign of inefficiency or disrespect, neither of which are acceptable to this committee.

With that, I introduce Mr. Steven Chalk, Principal Deputy Assistant Secretary for Energy Efficiency and Renewable Energy at the U.S. Department of Energy. Mr. Paul Cicio is the President of the Industrial Energy Consumers of America. By the way, I should underscore my following comments. All the other panelists, we want to thank you for getting your information to us in a timely, informative manner so the initial comments were directed unfortunately at the Department of Energy. The rest of the panelists were most informative and prompt in their response and we are grateful for that including Mr. Coad as well. I didn't mean to jump over you. Karen Ehrhardt-Martinez, did I say that right? Ehrhardt?

Dr. EHRHARDT-MARTINEZ. Ehrhardt-Martinez.

Chairman BAIRD. I should have known Ehrhardt.

Dr. EHRHARDT-MARTINEZ. Just like Amelia.

Chairman BAIRD. I figured that, the pioneering aviator. Dr. Karen Ehrhardt-Martinez is a Research Associate at the Economic and Social Analysis Program at the American Council for Energy-Efficient Economy. Dr. Michael McQuade is Senior Vice President of Science and Technology at United Technologies Corporation. At this point I would like to recognize my friend, the gentleman from Missouri, Representative Russ Carnahan, to introduce our final witness.

Mr. CARNAHAN. Thank you, Mr. Chairman. It is great to sit in on this subcommittee today. I have got the honor to present a native of St. Louis, Dr. William Coad. He is President of Coad Engineering Enterprises. He is a consulting principal and Past Chairman and CEO of the McClure Corporation. For 17 years he has been an Affiliate Professor at Washington University in St. Louis teaching graduate courses in mechanical engineering. He is also currently a member of the National Institute of Building Sciences. He has served as Chairman of the High-Performance Buildings Task Force, which the initial report led to the formulation of the High-Performance Building Council under his leadership. I have been honored to chair the bipartisan High-Performance Buildings Caucus within the Congress and they have been very instrumental working with our caucus. So I appreciate especially him being here, his expertise nationally, but I am pleased with his roots from St. Louis.

Chairman BAIRD. I thank Mr. Carnahan, and thank you for your leadership on the caucus. Obviously you have recognized this well early on and your input has been very, very valuable. I thank the gentleman. At this point we will hear from the witnesses. I have been corrected. Actually, Mr. Chalk, apparently we had your testimony at 8:30 last night, still inadequate and certainly not very helpful to me as I had already retired for the evening to read the other stacks of material I get. But we will start with Mr. Chalk and then proceed. Each witness will have five minutes and then we will proceed with questioning for the panel. We have also been joined by Dr. Ehlers, the gentleman from Michigan. Thank you, Dr. Ehlers.

With that, Mr. Chalk, please enlighten us with your testimony and thank you again for being here.

STATEMENT OF MR. STEVEN CHALK, PRINCIPAL DEPUTY ASSISTANT SECRETARY, OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY, U.S. DEPARTMENT OF ENERGY

Mr. CHALK. Thank you, Chairman Baird, and no good excuses for the late testimony. We will make sure that doesn't happen again.

Chairman Baird, Ranking Member Inglis and other Members of the Subcommittee, thank you for the opportunity to discuss the Department of Energy's Building Technologies Program and the enormous potential for energy savings in the building sector. I commend you for holding this hearing. I look forward to working with you to continually innovate and invest in energy efficiency.

Energy security and climate change, or global overheating, if you will, are two of the most important challenges of our time and require urgent attention. It is clear that there is no single solution to the problem. The challenge is so massive and urgent that it requires multiple simultaneous responses and solutions. In 2008, our nation's 114 million households and more than 74 billion square feet of commercial floor space accounted for nearly 40 percent of our primary energy consumption, 40 percent of our greenhouse gases, but it is also about 70 percent of our electricity consumption. For every gain in building energy efficiency, there is a corresponding reduction in power plant generation and greenhouse gases and there is a greater conservation of natural resources, particularly water, which is consumed in large quantities in power plants today.

Today, with existing technologies and knowledge, we can cost-effectively increase U.S. residential building efficiency by 30 percent.

In temperate parts of the country, it is possible to increase efficiency by 40 percent with little additional first costs, and really no additional costs at all when savings for utility bills are factored in. Reaching these efficiency levels, particularly through means such as stimulating technology adoption via building codes, is one marker on the path to reaching DOE's ultimate goal, which is the widespread construction of affordable net-zero-energy buildings or buildings that produce more energy than they consume over the course of a year. The Department's building technologies portfolio is aligned to develop the techniques and tools necessary to make affordable residential and commercial buildings net-zero energy by 2020 and 2025, respectively.

I would like to use my time today to highlight some of the ongoing initiatives that help us reach those net-zero-energy goals. Our Commercial Buildings Initiative is the umbrella initiative that will guide and coordinate public and private partnerships to advance market adoption of net-zero-energy commercial buildings. In support of this initiative, we are focusing on building system integration, indoor environmental quality, control strategies, diagnostics and space conditioning.

In the area of energy codes and standards, the Department is working very closely with the American Society of Refrigeration and Air Conditioning Engineers, or ASHRAE, on its standard commercial building code. In 2007, DOE challenged ASHRAE to upgrade the 2004 standard 90.1 by 30 percent, to make it 30 percent more stringent by 2010. ASHRAE responded positively and is on track to achieve that 30 percent greater efficiency.

In addition, we work with the International Code Council on the residential standards and we have a similar effort with the ICC, or the International Code Council, to achieve 30 percent better efficiency than the 2006 residential code and we want to achieve that by 2012, and we are already halfway there. The 2009 code that was just released is 15 percent better than the 2006 version.

The Department's Appliance and Commercial Equipment Standard Program develops test procedures and the minimum energy conservation standards for residential appliances and commercial equipment. These standards save consumers money and energy, spur innovation and reduce greenhouse gas emissions and save water resources. President Obama shows interest and expectations for this program. Just 17 days after he took office, he visited DOE, issued a memorandum requesting that the Department take all necessary steps to expeditiously finalize the appliance standards rule-making in process. The Department is committed to fulfilling the President's request.

As I wrap up, I want to emphasize the *American Recovery and Reinvestment Act* places significant focus on buildings and building energy codes. The Act provides $3.2 billion for energy efficiency and conservation block grants and for such activities as endorsing building energy codes, conducting audits, establishing financial incentives and installing energy efficiency upgrades. The Department is gearing up now to provide technical assistance to States to implement these new codes and to enforce and evaluate compliance. The Department is committed to improving energy efficiency through innovative R&D, public outreach and collaborative partnerships. We look forward to working with Congress to continue to realize short-term energy savings and cost savings as well as a long-term goal of achieving affordable net-zero-energy residential and commercial buildings.

Thank you for the opportunity to appear before you this morning, and I will be happy to answer any questions. Thank you.

[The prepared statement of Mr. Chalk follows:]

PREPARED STATEMENT OF STEVEN CHALK

Chairman Baird, Ranking Member Inglis, Members of the Subcommittee, thank you for the opportunity to appear before you today to discuss the U.S. Department of Energy's (DOE) Building Technologies Program activities and the enormous potential for energy savings in the buildings sector. I have included, as an appendix to this testimony, an update on the Department's progress in implementing sections of the *Energy Policy Act of 2005* (EPACT 05) and the *Energy Independence and Security Act of 2007* (EISA), as requested by the Subcommittee.[1]

In 2008, the Nation's 114 million households and more than 74 billion square feet of commercial floor space accounted for nearly 40 percent of U.S. primary energy consumption, as well as:

- 73 percent of electricity and 34 percent of natural gas consumption,
- Energy bills totaling $418 billion, and
- 39 percent of Carbon Dioxide, 18 percent of Nitrogen Oxide, and 55 percent of Sulfur Dioxide emissions.

Additionally, construction and renovation accounted for nine percent of GDP, and eight million people were employed in the sector.[2]

The Department is committed to improving energy efficiency in buildings from advances in building technologies and systems, to energy codes for new construction, to weatherization retrofits and promotion of efficient appliances. The Administration continues to renew and build upon these efforts. I would like to give a broad overview of the Building Technologies Program and highlight some of its ongoing activities.

DOE's Building Technologies Program

The Building Technologies Program develops technologies, techniques, and tools, as well as minimum performance standards, for making residential and commercial buildings more energy efficient, productive, and affordable. The program's current goal is to create technologies and design approaches that enable net-zero energy buildings[3] at low incremental cost by 2020 for residential buildings and 2025 for commercial buildings. The program expects that efficiency technologies and designs will have application to buildings constructed before 2025, resulting in incremental reductions in energy use throughout the sector.[4]

The research and development (R&D) activities of DOE's Building Technologies Program are fully aligned toward enabling the widespread construction of net-zero energy residential and commercial buildings by 2020 and 2025, respectively. The Commercial Buildings Integration subprogram conducts systems integration R&D, works with national energy alliances on best practices, engages national accounts with research technical assistance to achieve deep energy retrofits and design of high-performance new building prototypes, and provides targeted mass procurement and technology solutions to the industry.

The Residential Integration subprogram works through the Building America public-private partnership to develop high-performance residential sub-systems and whole house energy improvements, and testing them on a community scale. In addition, the Residential Integration subprogram is implementing the Builders Challenge to deploy the results of the R&D activity, and is implementing DOE's portion of the Home Performance with Energy Star program to spur deep retrofits in homes throughout the Nation.

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[1] EPACT 05 was codified into law as Pub. L. No. 109–58; EISA as Pub. L. No. 110–140.

[2] DOE, *2008 Building Energy Data Book.*

[3] A net-zero energy building is a residential or commercial building with greatly reduced needs for energy through efficiency gains (60 to 70 percent less than conventional practice), with the balance of energy needs supplied by renewable technologies.

[4] DOE, *2008 Building Technologies Multi-Year Program Plan, http://www.eere.energy.gov/buildings/publications/pdfs/corporate/myp08complete.pdf*

Equipment and component research is designed to fill identified gaps in technical performance and/or cost reduction needed to fully achieve the net zero energy cost and performance goals of the Commercial and Residential subprograms. Component and equipment research is conducted on Solid State Lighting; Heating, Ventilation, Air Conditioning, Refrigeration and Water Heating; Solar Heating and Cooling; Thermal Envelope and Windows; and Design Tools.

The Appliances and Commercial Equipment Standards Program develops test procedures and energy conservation standards for residential appliances and commercial and industrial equipment. The Program develops regulations that manufacturers must adhere to in making energy efficiency claims as well as in manufacturing products for sale in the United States. These regulations apply to products manufactured in the United States as well as those imported into the United States.

The Department's Building Technologies Program and its partners strive to integrate energy efficient technologies into the marketplace through technology validation and market introduction activities such as Builders Challenge, Building Energy Codes, EnergySmart Hospitals, EnergySmart Schools, ENERGY STAR®, Solar Decathlon, and the Utility Solar Water Heating Initiative (USH_2O).[5]

I would like to underscore certain successes within Building Technologies Program, from net-zero energy commercial buildings to efficient appliances for consumers that have contributed to technological advancements and significant energy savings.

Commercial Buildings Initiative

Launched in August 2008, the Net-Zero Energy Commercial Building Initiative (CBI) is the umbrella initiative that will guide and coordinate public and private partnerships to advance the development and market adoption of net-zero energy commercial buildings (NZEBs). CBI works with researchers at DOE National Laboratories, as well as with public and private partners, to achieve the goal of marketable NZEBs by 2025.

In support of the CBI, DOE's key commercial buildings research includes whole building system integration, indoor environmental quality, control strategies and diagnostics, space conditioning, and process and miscellaneous equipment. Another major area is the development of technology solutions for achieving 30–50 percent savings at the building system level (lighting, heating, and cooling). The first technology solution, Commercial Lighting Solutions web tool design aid, launches in May 2009. We expect that designs for retail building that use this tool could save 30–40 percent on energy use compared with ASHRAE/IESNA Standard 90.1–2004.

Working with industry representatives and partners is critical to achieving the goal of marketable net-zero energy commercial buildings by 2025. We are engaged with building industry leaders through energy alliances and research partnerships to move us toward that goal. The key CBI alliances and partnerships include:

- Commercial Building Energy Alliances—Informal associations of commercial building owners and operators who work to significantly reduce energy consumption and carbon emissions. Currently, alliances exist for retail, commercial real estate, and hospitals.
- Commercial Building National Accounts (NAs)—Companies and organizations partnering with DOE to conduct cost-shared research, development, and deployment. NAs will construct buildings that achieve savings of 50 percent or retrofit buildings that achieve 30 percent savings above ASHRAE/IESNA Standard 90.1–2004, and deploy this knowledge through their portfolios. In FY 2008, 23 National Account partners agreed to work with DOE. Another 100 National Accounts are planned in FY 2009.
- High-Performance Green Building Consortium—DOE-selected building industry groups that work with DOE to accelerate the commercialization of high-performance building technologies by disseminating information on new technologies within the commercial building community. A high-performance commercial building offers improved energy, economic, and environmental per-

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[5] More information is available on each of these programs at the following links: Builders Challenge: *http://www1.eere.energy.gov/buildings/builderschallenge.html*; Building Energy Codes: *http://www1.eere.energy.gov/buildings/energycodes.html*; EnergySmart Hospitals: *http://www1.eere.energy.gov/buildings/energysmarthospitals/*; EnergySmart Schools: *http://www1.eere.energy.gov/buildings/energysmartschools.html*; ENERGY STAR®: *http://www1.eere. energy.gov/buildings/energystar.html*; Solar Decathlon: *http://www1.eere.energy.gov/buildings/solar_decathlon.html*; Utility Solar Water Heating Initiative (USH_2O): *http://www1.eere.energy.gov/buildings/ush2o/*

formance compared to standard practice. See the appendix for progress on related sections of EISA.

Building Energy Codes and Standards

The Department works closely with the American Society of Refrigeration and Air-Conditioning Engineers (ASHRAE) on its standard 90.1 and with the International Code Council (ICC) on its International Energy Conservation Code (IECC) in response to Title III of the *Energy Conservation and Production Act,* as amended (42 U.S.C. 6831 et seq.).

In 2007, DOE challenged ASHRAE to upgrade standard 90.1 to be 30 percent more stringent than its 2004 edition by 2010 and has been actively engaged in the ASHRAE standards process by providing technical assistance to support the upgrade of standard 90.1. ASHRAE reports that it is on track to achieve the 30 percent goal.

The Department has also joined many stakeholders in the International Energy Conservation Code process to upgrade the 2006 edition of the IECC by 30 percent by 2012. Significant progress has been made in the 2009 edition, upgrading it by about 15 percent. The Department is an active participant in the codes development process by providing engineering, economic and energy analyses of improvements to the code as well as specific code proposals.

Appliance Standards

In the 1970s, there was a debate over whether to set energy conservation standards for consumer products, including refrigerators. Many were concerned that standards would be too expensive to meet and that they would lead to higher prices for consumers. The Appliance Standards Program was established with the passage of the *Energy Policy and Conservation Act of 1975* (EPCA), which designated test procedures, conservation targets, and labeling requirements for certain major household appliances. The Act has been amended several times, changing the conservation targets to mandatory standards and adding many additional products to eventually include a broad range of residential and commercial products. As amended, the appliance standards requirements are among the broadest and most stringent of any country in the world. Once the standards passed, manufacturers put their engineers to work developing new products to meet the standards. Manufacturers were successful and developed new, energy efficient products that met the requirements.

For example, today, refrigerators cost less than they did before DOE's ENERGY STAR, research, and energy conservation standards programs. Yet, today's refrigerators are larger, have more features and use less than one-third as much energy as those earlier designs. DOE estimates DOE's programs have contributed to a decrease in refrigerator energy consumption on the order of 0.25 quads compared 1975, even though the number of refrigerators grew by 35 percent. This energy savings is equivalent to the amount produced by 58 coal power plants.[6]

President Obama showed his interest and expectations for the Appliance Standards Program just 17 days after his inauguration. The President visited DOE and set out his expectations for the Appliance Standards Program in a memorandum to Secretary Chu. The memorandum requests that the Department take all necessary steps to finalize legally required energy conservation standards rule-makings as expeditiously as possible and consistent with all applicable judicial and statutory deadlines. The Department is committed to fulfilling the President's request, and the Secretary has reinforced the importance of this program through expressing his support in ensuing public statements.

Builders Challenge and Home Performance with ENERGY STAR

The goal of Builders Challenge is to build 220,000 new high-performance homes by 2012. These homes exceed the energy efficiency of ENERGY STAR Homes by approximately 20 percent. To date, more than 1,000 homes have been qualified as meeting the Builders Challenge and 200 builders have agreed to build to meet the Builders Challenge in the future.

Home Performance with ENERGY STAR (HPwES) focuses on significantly increasing energy efficiency in existing homes. HPwES promotes improvements through home performance contracting, which includes comprehensive whole-house assessments. HPwES is implemented by utilities, State energy offices, and not-for-

[6] Source: 1975 to 2005 energy use—DOE refrigerator standards rule-making data developed by Lawrence Berkeley National Laboratory; 2015 projection—EIA's Annual Energy Outlook 2005; number of households—Buildings Energy Data Book Table 2.1.1.

profits that recruit and train home improvement contractors. Qualified contractors conduct a comprehensive assessment using diagnostic equipment. Based on this assessment, contractors offer a prioritized list of solutions; they then complete the needed renovations or work closely with other participating contractors. Common improvements suggested are sealing air leaks and ductwork, adding insulation, improving the heating-cooling system, and upgrading lighting. To date, more than 50,000 assessments and 15,000 installations have been completed since 2002.

Buildings Efficiency and Economic Recovery

The Department's Building Technologies Program is planning to address research focused on the systems design, integration and control of buildings for both new and existing buildings with Recovery Act funding. This project will move beyond component-only driven research and address the interactions among the many different aspects of buildings, approaching it as a whole, in order to progress development of integrated, high-performance buildings. Buildings need to be designed, built, operated, and maintained as an integrated system in order to achieve the greatest potential of energy efficient and eventually net zero-energy buildings. High-performance buildings will apply technology to improve the internal built environment through managing energy use, improving comfort, safety and environmental factors through integrating all the various systems of the building.

The Recovery Act places significant focus on buildings and building energy codes.[7] The Act provides $3.2 billion for Energy Efficiency and Conservation Block Grants for such activities as the enforcement of building energy codes; conducting building audits; establishing financial incentives for efficiency; and installing LEDs. It provides $5 billion for Weatherization assistance and $3.1 billion for the State Energy Program.

In response to Recovery Act requirements, the overwhelming majority of governors have advised the Secretary that they have take actions to ensure, within the authority of the governor's office, the implementation of the 2009 International Energy Conservation Code or equivalent for residential buildings, and Standard 90.1–2007 for commercial buildings. They have provided similar assurances that the state will implement a plan to achieve 90 percent compliance with their new codes by 2017. The relevant State Energy Program solicitation has been issued, and comprehensive applications from the states are due May 12, 2009.[8]

DOE is gearing up to provide technical assistance to the states to implement these new codes and to implement, enforce, and evaluate compliance.

The Department is committed to improving energy efficiency through innovative R&D, public outreach, and collaborative partnerships. Improved energy efficiency in buildings generally is a fast, low risk, and economical way to reduce energy consumption and associated environmental emissions, including greenhouse gases. We look forward to working with Congress to continue to realize short-term energy and cost savings, and to contribute to the goal of achieving net-zero energy residential and commercial buildings in the future.

Thank you for the opportunity to appear before you today, and I am happy to answer any questions.

[7] See Section 410 of the *American Recovery and Reinvestment Act* of 2009.
[8] See *http://www.energycodes.gov/news/arra/*

Appendix: Update on EISA and EPACT 05 Sections Requested by the Subcommittee

EISA/EPACT Section	Requirements	DOE Progress
EPACT 913	Requires an interagency group, led by the Office of Science and Technology Policy, to provide a Federal R&D agenda for high-performance green buildings.	In October 2008, the Building Technology Research and Development (BTRD) Subcommittee of the National Science and Technology Council (NSTC) issued through the Office of Science and Technology Policy (OSTP) of the Executive Office of the President a report entitled, "Federal Research and Development Agenda for High Performance Green Buildings" as fulfillment of EPACT 05 Section 913. The Department co-chairs the BTRD Subcommittee with the National Institute of Standards and Technology (NIST). Through its leadership, funding and technical support, and concurrence, the Department has signaled its full acceptance of the report. DOE's Buildings Technologies Program has incorporated report recommendations into its multi-year planning effort.
EPACT 914	Requires DOE to enter into an agreement with the National Institute of Building Sciences (NIBS) to: – Conduct an assessment (in cooperation with industry, standards development organizations, and other entities, as appropriate) of whether the current voluntary consensus standards and rating systems for high performance buildings are consistent with the current technological state of the art, including relevant results from the research, development and demonstration activities of the Department; – Determine if additional research is required, based on the findings of the assessment; and – Recommend steps for the Secretary to accelerate	The assessment, which was transmitted from NIBS to DOE in June 2008, contained several recommendations. However, none of these directly related to energy consumption or energy efficiency. As such, no additional work was undertaken in direct response to the recommendations contained in the report; however, DOE continues to work closely with the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), the U.S. Green Buildings Council, and other voluntary standards organizations to promote adoption of high-performance buildings standards.

	the development of voluntary consensus-based standards for high performance buildings that are based on the findings of the assessment.	
EISA 421	– Directs DOE to name a Director of Commercial High-Performance Green Buildings (HPGB). – Instructs the Director to coordinate high-performance green buildings activities with Federal and non-profit entities, – To coordinate directly with the Director of High-Performance Green Federal Buildings (named by the General Services Administration as specified in EISA Section 436), and – To name members of a HPGB Partnership Consortium. – Section 421 also requires a report describing the status of the high-performance green building initiatives under this subtitle and other Federal programs affecting commercial high-performance green buildings.	– DOE has determined that the Program Manager of the Building Technologies Program will also be the Director of Commercial High-Performance Green Buildings. This Senior Executive Service-level manager already has responsibilities in the areas covered by the statute, and there are significant synergies for the Building Technologies Program Manager to perform the functions of the Director. For example, the Commercial Buildings Initiative interacts with other building energy efficiency programs within DOE and other agencies, including the General Services Administration (GSA) and Environmental Protection Agency, to integrate the commercial R&D and deployment activities. – DOE has been coordinating with agencies listed in Section 421 to advance building efficiency technology development and deployment. The Department co-chairs the BTRD Subcommittee of the NSTC with NIST. The BTRD meets quarterly; in addition, the BTRD technical working group meets monthly in person or via phone conference. – The Directors of Commercial High-Performance Green Buildings and of Federal High-Performance Green Buildings, or their designees, have had regular direct

		communications. – Federal Register Notice[1] was issued in December 2008 to solicit self-nominated high performance green building consortia for recognition by the Federal government. A list of recognized consortia will be published on the DOE web site once the review of qualifications is completed. Once HPGB consortia are recognized, a solicitation will be issued to select a single supporting consortium, with which the Department will consult in the execution of the Commercial Building Initiative that was initially launched in August 2008. – The report is on track to be completed by December 2009, two years after EISA's enactment, as outlined in the section.
EISA 423	Directs the Directors of Commercial and Federal HPGB, in coordination with the Consortium, to carry out public outreach to inform individuals and entities of the information and resources available government-wide.	The implementation of the public outreach activities directed in EISA Section 423 is under discussion between the Department and GSA. As directed in Section 435 of EISA, GSA is establishing a Federal Green Building Advisory Committee to coordinate activities among relevant agencies (including the Department). A number of existing resources exist that may need to be enhanced and/or combined to meet EISA Section 423. A discussion of these provisions has occurred in the Building Technologies R&D Subcommittee of the NSTC as follow-up to the publication of the EPACT 913 report.

[1] FR Doc. E8–28504, Filed 12-1-08.

BIOGRAPHY FOR STEVEN CHALK

Steven Chalk is the Principal Deputy Assistant Secretary in the Office of Energy Efficiency and Renewable Energy (EERE) at the U.S. Department of Energy. In this capacity, Mr. Chalk is responsible for managing the programs, staff and policies of EERE and interfacing with constituent groups in the efficiency and renewable energy sectors.

Mr. Chalk recently held the position of EERE's Deputy Assistant Secretary for Renewable Energy, where he was responsible for the management of the government's research, development, and commercialization efforts in solar, wind, geothermal, biomass, and hydrogen technologies. Mr. Chalk also previously managed EERE's Hydrogen and Fuel Cell Technologies Program, the Solar Energy Technologies Program and Buildings Technologies Program.

In September 2008, Steve was honored with a Service to America Medal in the Science and Environment category. This award recognized his management of several innovative clean energy projects, as well as his leadership in the Federal Government's efforts to expand the use of renewable energy and energy efficiency, particularly in the communities of New Orleans and Greensburg, Kansas.

While leading the Solar Energy Technologies Program, Mr. Chalk was responsible for planning and implementing the Solar America Initiative, which aims to make solar technologies cost competitive by 2015. In the building technologies area, Mr. Chalk led DOE's efforts toward net zero energy homes and buildings. The portfolio includes component research such as solid state lighting, market transformation activities such as EnergyStar, and appliance standards regulations. Before this, Mr. Chalk led the President's Hydrogen Fuel Initiative where he oversaw development of a five-year, $1.2 billion research investment in hydrogen production, delivery, storage, and fuel cells. This portfolio also includes hydrogen safety, codes and standards, and education activities. In his early career at DOE, Mr. Chalk managed technology development programs in fuel cells, diesel emissions control, and materials for DOE's advanced automotive technology office. Steve also worked in the nuclear energy field where he oversaw DOE test programs for tritium production. Steve started his career with the Navy developing propellants and explosives for conventional weapons.

Mr. Chalk holds a Bachelor of Science in Chemical Engineering from the University of Maryland and a Master of Science in Mechanical Engineering from the George Washington University.

Chairman BAIRD. Mr. Coad.

STATEMENT OF MR. WILLIAM J. COAD, PRESIDENT, COAD ENGINEERING ENTERPRISES, AND CHAIR, HIGH-PERFORMANCE BUILDING COUNCIL, NATIONAL INSTITUTE OF BUILDING SCIENCES

Mr. COAD. Mr. Chairman, Mr. Ranking Member and other Members of the Subcommittee, as Mr. Carnahan said, my name is Bill Coad. I am a practicing mechanical engineer. I have been designing heating, refrigerating and air conditioning systems and electrical systems for large buildings for my entire career.

I am here this morning representing the National Institute of Building Sciences, acronym NIBS. NIBS is a private organization. It is not for profit. It was founded by this Congress in 1974 to coordinate the improvement in buildings and building systems in the United States for both public and private buildings. Our annual report goes to the President of the United States and to the Congress and you all will receive this year's report in another couple of weeks.

I would like to introduce Henry Green. Henry is the President of NIBS. He joined us in 2008, last year. Prior to that he was the president of the International Code Council, who is the developer of the International Building Code, which is used almost universally in the United States in our private-sector buildings. And when this Congress passed the Energy Policy Act of 2005, in that

Act, section 914, they mandated that NIBS should form a council or a group to try to coordinate all the standards that were available in the United States, all our consensus standards, and look at those standards and see if we had the information in any one place that we could use to expand the concept of high-performance buildings.

Now, we have heard some different definitions of high-performance buildings but I would like to give you just a very quick slant on what a high-performance building really is. As Mr. Chalk said, there are a lot of things going on out here in energy and the environment but it really boils down to one simple matter. It has to do with economics and the intrinsic link between economics and energy. The foundation for any economy is human productivity, and when this country was founded, human productivity had been pretty flat for hundreds of years and something happened in 1775 when George Washington was trying to stay out of the way of the British, something was happening on the other side of the world, the other side of the Atlantic. James Watt perfected his steam engine in 1775. He was able for the first time to take heat and turn it into work, and work for mankind and increase his productivity. Within about 100 years, that steam engine was driving locomotives across the continents. We had the steam engines in factories driving line shafts, manufacturing for people. One steam engine and one person could do the work of about 500 people. That is productivity and that happened through the entire 19th century, kept increasing productivity, and guess what happened? The economy kept getting stronger and stronger. In the 20th century, we really switched into high gear. Today we have machines to light the darkness, to preserve our food, to carry us wherever we want to go at any speed, exceeding the speed of sound, to refrigerate and preserve our food, to cook our food, to clean our house, to run our factories. It is all—every one of these things increases human productivity, keep our records, do our calculations, and today we have—because of this productivity, we have the strongest economy that mankind has ever had before.

Anybody 100 years ago couldn't possibly have predicted what was going to happen with this kind of productivity and we can be very proud of ourselves, but guess what? We made a little mistake. When we started building these machines that our total economy depends upon, there was a lot of fossil energy around. First we did it with wood and then we needed the wood for other things so we turned to coal, then oil in about the mid-19th century, and these are all fossil fuels. These fossil fuels took millions of years to generate into the Earth. Now, we have only been using them for about 150 years and we are using them at an exponentially increasing rate. It doesn't take anything beyond high school mathematics to realize if you have a limited resource and you are using it at a continually exponentially increasing rate, some day it is going to run out, and guess what happens? That some day—world production of oil is predicted now to run out[1] before the year 2010. That is next year. So we are in trouble. We are in big trouble with our economy because without the energy, we can't support the economy to keep

[1] Mr. Coad asked that "run out" be changed to read "peak." See attached June 19, 2009 letter.

the world running the way it is running. We are talking about the end of man on Earth if we can't support our economy.

Now, what can we do about that? That is why we are here today. This committee, this subcommittee is here handling what I think is the most important problem that this Congress and this country faces today, and that is the fact that we are going to run out of energy if we don't do something about it. Now, what can we do about it?

Chairman BAIRD. Mr. Coad, we try to keep the testimony to about five minutes. I know that is a minimum time but I am going to ask you to try to summarize at this point.

Mr. COAD. I am just now ready to, Mr. Chairman.

Chairman BAIRD. Great. Thank you very much. Go ahead.

Mr. COAD. I have lost my train of thought now. I am sorry. What we have to do, the only thing we can do is energy efficiency. Mr. Chalk said—no, Mr. Chairman, you said that buildings consume 40 percent of the energy roughly. They consume it but they don't use it. The efficiency is horrible in anything we do with energy. We have to redesign our complete structure of technology to consume much, much, much less energy. So efficiency is number one.

So with that, I am going to stop, Mr. Chairman, and I would be glad to handle any questions.

[The prepared statement of Mr. Coad follows:]

PREPARED STATEMENT OF WILLIAM J. COAD

Mr. Chairman and Members of the Committee,

My name is William J. Coad. I am testifying before this committee as a member of the National Institute of Building Sciences Board of Directors. I am a volunteer member of the Board. I am also President of Coad Engineering Enterprises and a consulting principal and past Chairman/CEO of The McClure Corporation.

I am a registered professional engineer in 38 states and a past President of the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE). For 17 years I was an Affiliate Professor at Washington University in St. Louis, teaching graduate courses in Mechanical Engineering and served as a thesis advisor in building environmental systems design.

I am here today to testify on expanding the effort you identified in Section 914 of the *Energy Policy Act of 2005.*

The National Institute of Building Sciences is a private, non-profit organization established by Congress as a single authoritative national source to make findings and advise both the public and private sectors on the use of building science and technology to achieve national goals and benefits. It is truly a public/private sector partnership, governed by a Board of Directors that represents all sectors of the building community, including appointees by the President of the United States.

I would like to introduce Henry L. Green, Hon. AIA, President of the Institute. Before coming to the Institute in 2008, Mr. Green was Director of the Bureau of Construction Codes for the State of Michigan. He is also a past President of the International Code Council, developer of the International Building Code.

The *Energy Policy Act of 2005* (EPACT) and the *Energy Independence and Security Act of 2007* (EISA) seek to reduce building-related energy consumption and dependence on foreign energy sources.

Title IX, Subtitle A, Section 914 of EPACT specifically directed the National Institute of Building Sciences to explore the potential for accelerating development of consensus-based voluntary standards to set requirements for less resource-intensive, more energy-efficient, high-performance buildings.

As a result of this Congressional directive, the Institute formed the High-Performance Building Council in 2007. In 2008, the Council issued a report entitled, "Assessment to the U.S. Congress and U.S. Department of Energy on High-Performance Buildings." My testimony today is based on the conclusions and recommendations of this report.

The Council currently has over 75 associations and federal agencies as members. They represent all the major sectors of the building community and including

- The American Institute of Architects,
- ASHRAE,
- ASTM International,
- The Associated General Contractors of America and
- The International Code Council, as well as many others.

Section 914 included no specific funding authorization, however, based on a small amount of funding from the Department of Energy the Council performed an initial assessment of the current knowledge, with the help of standards development organizations, professional societies, governmental agencies, and major trade associations. Representatives examined hundreds of existing standards to judge their relevance to high-performance buildings.

The Council was charged in Section 914 with determining what was needed to accelerate the development of voluntary, consensus-based standards for high-performance buildings. As our report demonstrates, many of the existing standards, guidelines, and recommended practices are developed independently, addressing only one aspect of the building, without communicating across disciplines or parties, or looking at the building as a whole.

Implementing the High-Performance Building Council's recommendations—based on a harmonized definition of high-performance buildings—would greatly accelerate the development and use of uniform voluntary consensus-based industry standards for new construction and renovation.

As Congress considers new legislation focused on implementing high-performance buildings, the High-Performance Building Council offers its technical expertise and guidance to help reach the Nation's goals.

At the time of EPACT the industry was fragmented in terms of performance requirements for high-performance buildings. That is still the case today. However we now have an organization ready to bring the industry together. The Council's vision is harmonized standards—in place and used—that result in high performing buildings. The mission of the Council is to seek industry consensus to establish and update the definition of high-performance buildings and to promote the harmonization of industry standards to meet that definition and encourage the production of high-performance buildings throughout the United States. The Council would develop an industry consensus model which would identify the range of metrics and benchmarks to define High-Performance. Federal agency research would assist in providing for these metrics and benchmarks and private voluntary standard development organizations would use the model to develop their individual standards and to harmonize these together for the final realization of whole high-performance buildings.

Congress can help by implementing the recommendations made in our report. I ask your support to implement the activities envisioned and authorized by section 914 of the *Energy Policy Act of 2005* through the High-Performance Building Council of the National Institute of Building Sciences.

New high-performance building standards have the potential to enable designers, developers, and owners to construct buildings that significantly exceed the minimum requirements of current codes and standards. The results could lead to high-performance buildings that use substantially less energy, and even potentially improve the health, comfort, and productivity of their occupants.

Thank you.

BIOGRAPHY FOR WILLIAM J. COAD

William J. Coad, President of Coad Engineering Enterprises is a consulting principal and past Chairman/CEO of The McClure Corporation (dba McClure Engineering Associates). Mr. Coad was President of the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) in 2001–2002. He received his degree in Mechanical Engineering from Washington University in 1957. Prior to forming Coad Engineering Enterprises, Inc., he had been with McClure Engineering Associates, a Mechanical/Electrical Consulting Firm, for 40 years (following five years as a design engineer, estimator, and corporate officer of a mechanical contracting company). He is a registered professional engineer in 38 states. He is a member of the Board of Directors of Mestek Corporation of Pittsburgh, Pennsylvania, Exergen Corporation of Watertown, Massachusetts, and the National Institute of Building Sciences (NIBS) of Washington D.C.

As an educator, Mr. Coad served as a Lecturer in Mechanical Engineering for 12 years at Washington University in St. Louis. For 17 years he was an Affiliate Professor at Washington University, teaching graduate courses in Mechanical Engineering and serving as a thesis advisor in building environmental systems design.

Mr. Coad is a member of the Consulting Engineer's Council, the American Society of Mechanical Engineers (ASME) and a Fellow in the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE). His positions in ASHRAE have included terms as President (2001–2002), Vice President, Treasurer, and member of the Society's Board of Directors. He has also served on numerous Technical Committees and Task Groups, on the Nominating Committee, the Presidential Committee on Energy Resource Evaluation, Panel 12 Standard 90–75, Finance Committee, Energy Council, Technology Council, Members Council, Publishing Council, Research & Technical Committee, Education Committee, and the Continuing Education Committee. (Often, he has served as Chairman or Vice Chairman of the above committees and councils). He served in all offices of the St. Louis Chapter of ASHRAE, (President, 1971–72).

Mr. Coad received the Society's Distinguished Service Award in 1980, the Crosby Field Award for the best paper published by ASHRAE in 1985, the Louise & Bill Holladay Distinguished Fellow Award in 1989, the award for Best Journal Article (1991), ASHRAE's highest award for technical achievement, the F. Paul Anderson Award in 1996, the Exceptional Service Award in 2001, and the Andrew T. Boggs Service Award in 2002.

Mr. Coad is an Honorary Member of Pi Tau Sigma (Mechanical Engineering Honorary Society), a (1992) recipient of the Washington University Alumni Achievement Award, and the (2001) recipient of the Donald Julius Groen Prize of the British Institute of Mechanical Engineers (ImechE). He has published several Symposium Papers and has authored numerous articles on Engineering Philosophy and Building Environmental Systems (including, for 15 years, a monthly column entitled "Fundamentals to Frontiers" in *HPAC Engineering Magazine*).

William Coad authored "Energy Engineering and Management for Building Systems," published by Van Nostrand Reinhold, and is a co-author of "Principles of Heating, Ventilating, and Air Conditioning" published by ASHRAE. He is a member of the Editorial Advisory Board of *HPAC Engineering Magazine.* He has served on the St. Louis Professional Code Committee, and the Missouri State Building Code Steering Committee. Mr. Coad has been Chairman of the Building Technology Advisory Committee to the Missouri Energy Agency, a member of the Building and Grounds Committee of the Washington University Board of Trustees, the Board of Directors of St. Elizabeth Academy in St. Louis, and the Energy Conservation Committee of the American Consulting Engineer's Council.

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WILLIAM J. COAD, PRESIDENT
wjcoad@coadengineering.com

June 19, 2009

Via email: jane.wise@mail.house.gove

U.S. Representative Brian Baird
c/o Ms. Janie Wise
2321 Rayburn House Office Building
Washington, DC 20515

RE: Subcommittee on Energy and Environment
High Performance Buildings
April 28, 2009

Dear Ms. Wise:

I would like to thank Representative Baird for the opportunity to review the Stenographic Minutes of the above hearing.

I have one statement regarding my testimony that is incorrect and misleading, although I very well may have said it under the pressure of the moment. The statement is the first 2 words on line 378 on page 21. The words "run out" should have been "peak". If you cannot change the minutes, a footnote or parenthetical correction would be appreciated.

If you have any questions or comments concerning this request, please call me.

Sincerely,

William J. Coad

WJC:mfz

PROFESSIONAL ENGINEERS PLANNING • DIAGNOSTICS • ANALYSIS • CONSULTING
MECHANICAL • HVAC • IAQ • PLUMBING • FIRE PROTECTION • ELECTRICAL • DESIGN INTEGRATION

Chairman BAIRD. We will have plenty for you, Mr. Coad.

Mr. COAD. Sorry I ran over time.

Chairman BAIRD. That is fine. You know, you folks have invested your entire lives in this and then we are foolish enough to ask you only five minutes, but we will get more. I just have to commend your association. To have someone in your role named Coad and your new President named Green, you guys are in marketing, not just engineering and then we have got Ehrhardt here to lead the way as well.

Mr. Cicio, thank you very much and we look forward to your comments.

STATEMENT OF MR. PAUL N. CICIO, PRESIDENT, INDUSTRIAL ENERGY CONSUMERS OF AMERICA

Mr. CICIO. Chairman Baird, Ranking Member Inglis, my name is Paul Cicio and I am the President of the Industrial Energy Consumers of America. Thank you for the opportunity to testify on the Department of Energy Industrial Technologies Program. The Industrial Energy Consumers of America is a trade association of leading manufacturing companies with more than $510 billion in annual revenues. We employ 850,000 employees across the country, and we are an organization created to promote the interests of manufacturing companies for which the availability, the use and cost of energy, and power and feedstock play a significant role in our ability to complete globally.

The manufacturing sector is a vital sector to the welfare of the country. We provide the largest contribution to GDP at 12 percent, over 60 percent of the exports. We employ 14 million people and nearly of the quarter of the world's manufacturing output.

Mr. Chairman, the speed at which the world around us is changing is accelerating and we face enormous challenges competing for domestic and offshore markets and unfortunately it looks like we are losing ground. From 2000 to 2008, imports are up 29 percent and manufacturing employment fell 22 percent, a loss of 3.8 million jobs, and that does not count 2009. Of great concern is that new manufacturing investment in the United States as a percent of GDP has been on a decline since the late 1990s. At the same time, significant new capital investment, often with the latest technology, has made companies in developing countries top in class competitors. Many of these companies are State owned and are subsidized. Our competitors are third world countries with first-rate manufacturing technology.

Of new competitive concern is the upcoming requirement to reduce greenhouse gas emissions that could add substantial cost that our competitors in developing countries will not bear. This brings me to my point. There has never been a time in our history where new technology and best practices are needed more to increase manufacturing competitiveness, reduce energy consumption, reduce greenhouse gas emissions.

The Industrial Technologies Program mission to improve national energy security, climate, environment and economic competitiveness by transforming the way U.S. industry uses energy is needed more than ever before. As noted, U.S. manufacturing is losing competitiveness. Our manufacturing processes are operating at their technical limits, which should urgently place a priority on these private-public partnerships for research and development. In talking to various companies and trade associations in advance of this hearing, I feel confident to report to you that this program is on sound ground. It is well run and it is creating value for the industrial sector. The only criticism that is consistent among everyone is that it is woefully underfunded. The R&D program by sector, the R&D crosscutting technologies, the best practices, the industrial assessment centers, and the Save Energy Now Program are all effective and they are desirable.

The fiscal year 2008 funding of $64 million and the fiscal year 2009 funding of $62 million is completely insufficient to meet the competitiveness challenges. For perspective, $62 million is an amount less than one ten-thousandth the amount spent on the stimulus package. Surely we can afford to invest more than $62 million.

In contrast, developing countries are placing a high value on manufacturing and they are investing in it. They understand that it creates good-paying jobs and needed exports. For example, our stimulus package has negligible spending directed towards manufacturing while China's stimulus package places manufacturing at the heart of their investment in their economic recovery.

In closing, Mr. Chairman, given the enormous and growing challenges that we face, we no longer can take the manufacturing sector for granted. It is important for this body to understand the enormous value that this sector brings and that it is time for investing to take it seriously. Thank you.

[The prepared statement of Mr. Cicio follows:]

PREPARED STATEMENT OF PAUL N. CICIO

Chairman Baird, Ranking Member Inglis, my name is Paul Cicio and I am the president of the Industrial Energy Consumers of America. Thank you for the opportunity to testify before you on the Department of Energy, Industrial Technologies Program.

The Industrial Energy Consumers of America is an association of leading manufacturing companies with $510 billion in annual sales and with more than 850,000 employees nationwide. It is an organization created to promote the interests of manufacturing companies for which the availability, use and cost of energy, power or feedstock play a significant role in their ability to compete in domestic and world markets. IECA membership represents a diverse set of industries including: plastics, cement, paper, food processing, brick, chemicals, fertilizer, insulation, steel, glass, industrial gases, pharmaceutical, aluminum and brewing.

The manufacturing sector is vital to the economic and security welfare of this country. We provide the largest contribution to GDP at 12 percent, over 60 percent of the exports; employ over 14 million people and nearly a quarter of the worlds manufacturing output.

Mr. Chairman, the speed at which the world around us is changing is accelerating and we face enormous challenges competing for domestic and offshore markets. Unfortunately, it looks like we are losing ground.

From 2000 to 2008 imports are up 29 percent and manufacturing employment fell 22 percent, a loss of 3.8 million high paying jobs. Of great concern is that manufacturing investment in the U.S. as a percent of GDP has been on a decline since the late 1990s. At the same time, significant new capital investment, often with the latest technology has made companies in developing countries top in class competitors. Many of these companies are State owned and are subsidized.

A new competitive concern and/or opportunity is the upcoming requirements to reduce GHG emissions. This could add substantial costs that our competitors in developing countries will not have to bear.

This brings me to my point. There has never been a time in our history where new technology and best practices is needed more to increase manufacturing competitiveness, reduce energy consumption and GHG emissions than like today.

The Industrial Technologies Program (ITP) mission to improve national energy security, climate, environment and economic competitiveness by transforming the way U.S. industry uses energy is needed more than ever. As noted, U.S. manufacturing seems to be losing competitiveness. Our manufacturing processes are operating at their technical limits which should urgently place a priority on private public partnerships in research and development like this program.

In talking to various companies and trade associations in advance of this hearing, I feel confident to report to you that the program is on sound ground, well run and creating value for the industrial sector. The only criticism is the lack of federal funding.

The R&D programs by sector, the R&D crosscutting technologies, best practices, the Industrial Assessment Centers and the Save Energy Now Program are all effective and desirable.

The FY 2008 funding of $64 million and the FY 2009 of $62 million is completely insufficient to meet the competitiveness challenges. In comparison, from 1998 to 2001 well over $120 million was spent annually.

Mr. Chairman, given the enormous and growing challenges that we face, we can longer take the manufacturing sector for granted. It is important for this body to understand the enormous value that this sector brings and that it is time to take investing in this sector seriously by vastly expanding this program.

Thank you.

BIOGRAPHY FOR PAUL N. CICIO

Paul N. Cicio has been the President of the Industrial Energy Consumers of America (IECA) since its founding six years ago. IECA is a non-profit trade association created to promote the interests of manufacturing companies for which the availability, use and cost of energy, power or feedstock play a significant role in their ability to compete in domestic and world markets. Membership represents a diverse set of energy intensive industries including: plastics, cement, aluminum, paper, food processing, brick, chemicals, fertilizer, rubber, steel, glass, industrial gases, pharmaceutical and brewing.

Mr. Cicio is a well known consumer advocate for the industrial sector on issues related to energy and the environment and is recognized for his efforts within national and international circles. He has testified seven times before the U.S. House of Representatives; three times before the U.S. Senate; and twice before the Federal Energy Regulatory Commission on issues regarding natural gas supply; natural gas market oversight; climate policy and energy efficiency. He has also intervened at the Commodity Futures Trading Commission.

In 2008, the Chairman of the Commodity Futures Trading Commission appointed Mr. Cicio to the newly created Energy Markets Advisory Committee (EMAC) representing industrial energy consumers.

In 2006 and again in 2008, the Secretary of the Interior appointed Mr. Cicio to the U.S. Department of Interior Outer Continental Shelf Policy Advisory Committee. In 2007, the Secretary of Energy appointed him to the National Coal Council, an advisory council to the Secretary. In both appointments, Mr. Cicio became the first energy consumer advocate.

Mr. Cicio moved to Washington DC from Houston, Texas in 1991. Since that time he has served in several leadership positions within a host of trade associations that include the National Association of Manufacturers, the American Chemistry Council, the Electricity Consumers Resource Council and the International Federation of Industrial Energy Consumers. Leadership positions in European trade associations include the International Chamber of Commerce; the Business and Industry Advisory Committee to the DECD; and the International Federation of Industrial Energy Consumers–World.

Previous to IECA, Mr. Cicio was employed by The Dow Chemical Company where he held a number of diverse responsibilities including: hydrocarbons and energy global issues management and Federal Government affairs, hydrocarbons and energy senior commercial manager, marketing manager, district sales manager, product sales manager. He retired from Dow Chemical with almost 30 years of service.

Mr. Cicio graduated from Youngstown State University with a BS in Business Administration and Economics.

Chairman BAIRD. Thank you, Mr. Cicio.

Dr. Ehrhardt-Martinez.

STATEMENT OF DR. KAREN EHRHARDT–MARTINEZ, RESEARCH ASSOCIATE, AMERICAN COUNCIL FOR AN ENERGY–EFFICIENT ECONOMY (ACEEE)

Dr. EHRHARDT-MARTINEZ. Thank you. My name is Karen Ehrhardt-Martinez and I am a research associate with the American Council for an Energy-Efficient Economy, and I am also the Chairman of the 2009 Behavior Energy and Climate Change conference, which will be held here in D.C. in November, and I have to add that I am a resident of Bowie, Maryland.

My testimony responds to a request to provide information about the role of social and behavioral sciences in reducing energy consumption in buildings and how these sciences could be included in the DOE's research programs. As discussed in detail in my written testimony, insights from the social and behavioral sciences really do offer an important opportunity to enable a significantly greater level of energy savings in buildings as well as other energy sectors. They can help maximize potential technology-based savings. They can improve decision-making and reveal social, behavioral and cultural means of motivating and facilitating smart energy behaviors.

Let me start by saying that behavior-oriented programs and research can help us understand, explain and address two of the most persistent gaps that continue to limit energy savings and energy efficiency. The first gap is the energy efficiency gap, or the gap between the potential cost-effective energy efficiency investments on one hand and the investments that are actually made on the other. The second gap is what I call the attitude behavior gap, and this gap divides favorable attitudes on the one hand from what might be best characterized as less than favorable behaviors on the other.

The energy efficiency gap is large. According to several ACEEE studies, this first gap represents lost energy savings of roughly 30 percent or more. Similarly, studies of prevailing attitudes and behaviors suggest that while people are often aware of the economic and environmental benefits of investing in energy-efficient technologies and behaviors, a variety of social, cultural and economic factors actually frequently intervene so as to severely limit the amount of follow-through that actually occurs, whether by individuals, households or businesses. A great example "gap" is provided by some recent Gallup Poll research that reveals that while roughly 85 percent of Americans have actually reported that they should be spending thousands of dollars to increase the energy efficiency of their homes, in reality, only a very small percentage actually are acting on these concerns in any way significant way.

So what is going on? That is what social and behavior research can really help us to understand. We need to improve our understanding and application of social and behavioral and even cultural factors that can help us deliver more of the potential energy savings that are available through new and existing technologies. We also need to use this information to reduce social and cultural barriers and to motivate people to take the actions that they readily recognize as important to achieving energy savings. My written testimony provides many examples of how social science insights have been able to narrow these gaps.

Next I would like to talk about what I call designing a new looking glass, a new way to imagine human behavior and why it matters. While our culture generally likes to think of people as rational actors, social scientists tend to work with a more complete understanding of human behavior. Unfortunately, traditional approaches of achieving energy savings and energy efficiency use what I call a distorted looking glass. They use what is most commonly referred to as a techno-economic framework, and this approach is primarily focused on a rational actor model that seeks to increase energy efficiency and increase energy savings exclusively through technological and economic means. Unfortunately from this purview, reducing energy consumption is as simple as designing a more energy-efficient product and then ensuring the product is economical and its replacement is cost-effective. The logic in that regard is sound but only as far as it goes. Programs built around this logic assume that people typically act in economically rational ways. Unfortunately, real-world experience suggests otherwise. In fact, research suggests that in the residential sector, people seldom act accordingly to the rational economic actor model, and our understanding of the decision-making processes in business and industry also tend to fall short. As such, the performance of energy and efficiency programs requires that we gain and apply an improved understanding of what actually motivates energy-smart behaviors.

Two mechanisms I suggest could help develop a better looking glass and more effective programs. One is a substantial increase in the involvement of social and behavioral scientists in the variety of processes, and the second is the development and application of a behavioral toolkit that effectively identifies key concerns and behavioral insights that have proven effective in addressing behavioral change.

Finally, I would like to conclude by mentioning the need for a broad integration of social and behavioral science throughout DOE's work. It is important to recognize the significance of behavior-related approaches as an essential piece of a multi-part strategy for addressing energy issues and climate change efforts. As noted in a recent *New York Times* article, the principal drivers of our current energy and climate challenges are human choices, behaviors and lifestyles. As such, the success of our efforts depends on our ability to give these issues more prominence through behavior-smart policies, through an improved understanding of the ways in which people both shape and are shaped by their physical environment, by a recognition of the opportunities and constraints associated with existing social structures, cultural norms and values and other sociocultural considerations, and finally, a recognition of interpersonal and psychological factors associated with motivating and constraining behavioral change. By moving in this direction, we can make important strides in closing both the energy efficiency gap and the gap between consumer attitudes and behaviors. In short, mobilizing our population to adopt energy-smart behaviors and technologies will require the insights provided by social and behavioral scientists and these insights need to become a larger part of the efforts of the U.S. Department of Energy. Thank you.

[The prepared statement of Dr. Ehrhardt-Martinez follows:]

PREPARED STATEMENT OF KAREN EHRHARDT-MARTINEZ

Summary

This testimony responds to an invitation from the House Energy and Environment Subcommittee of the Committee on Science and Technology to inform Committee Members about the role of the Department of Energy's research programs in:

- developing technologies and standards to enable deployment of net-zero energy buildings,
- support sustainability in domestic industries, and
- highlight R&D areas which need continued attention to achieve the goals of the DOE net-zero energy buildings program and beyond.

This testimony specifically addresses the need for increased research support to investigate and apply insights from the social and behavioral sciences. As discussed

in this testimony, insights from the social and behavioral sciences offer an important opportunity to enable a significantly greater level of energy savings in buildings, industry, the residential sector, and transportation. More specifically, social science insights can help maximize potential technology-based savings; improve decision-making; and reveal social, behavioral, and cultural means of motivating and facilitating smart energy behaviors.

Without the development and application of insights from the social and behavioral sciences, energy efficiency programs and policies will be constrained by the persistence of two important gaps:

- the gap between the potential energy savings of existing technologies and the actual energy savings achieved, and
- the gap between the good intentions of individuals, businesses, and institutions and the less-than-adequate translation of those intentions into smart energy behaviors.

According to several ACEEE studies of the unrealized energy efficiency potential associated with existing technologies, the first gap represents lost energy savings of 30 percent or more with current technologies. Similarly, studies of prevailing attitudes and behaviors suggest that while people are often aware of the economic and environmental benefits of investing in energy-efficient technologies and behaviors, a variety of social, cultural, and economic factors frequently intervene so as to severely limit the number of individuals, households, and businesses that actually follow through on their intended actions. A better understanding and application of social and behavioral factors could deliver more of the potential energy savings available through new and existing technologies. They could also help reduce existing social and cultural barriers and motivate people to take the actions that they readily recognize as important to achieving energy savings and stabilizing (and then reducing) carbon emissions.

Unfortunately, traditional approaches to energy efficiency typically apply what is most commonly referred to as a techno-economic framework. This approach is primarily focused on achieving energy efficiency through technological and economic means. From this purview, reducing energy consumption is as simple as designing a more energy-efficient product (furnace, television, refrigerator, computer, motor, etc.) and then ensuring that the products are economical and their replacement is cost-effective. The logic is sound—as far as it goes. Programs built around this logic assume that people who are given the choice to invest in a product that is more energy efficient, with little risk and a short payback period, should adopt the superior technology. Unfortunately, however, real world experience tells a different story. In fact, research suggests that people seldom act according to the rational economic actor model. As such, we need a better means of understanding what actually motivates energy-smart behaviors, otherwise many government programs are likely to continue to under-perform. Fortunately, the development and application of a behavioral toolkit could go a long way toward substantially improving upon the more traditional approaches to energy efficiency and result in greater energy productivity and energy savings.

Of equal importance, however, is the need to recognize the potential scope of energy savings associated with social and behavioral initiatives. Such initiatives offer the potential of large energy savings. In fact, two recent studies (Gardner and Stern, 2008; Laitner et al., 2009) suggest that the potential behavior-related energy savings in the residential sector alone represent roughly 25 percent of current residential sector energy consumption. By applying insights from the social and behavioral sciences to improve our understanding of decision-making, organizational behavior, and the influence of social and cultural norms in business and industrial processes, greater energy savings could also be achieved in the commercial and industrial sectors.

Finally, it is important to recognize the significance of behavior-related approaches as an essential piece of energy and climate change efforts. In fact, the principal drivers of our current energy and climate challenges are human choices, behaviors, and lifestyles. As such, they must also be an essential part of any attempt to address these challenges, if we hope to be successful in our efforts. In other words, human and organizational behavior is a critical component of both cause and solution. The DOE's efforts would undoubtedly benefit greatly from a more systematic and widespread incorporation of social and behavioral insights. However, funding for these types of initiatives is woefully inadequate and needs to be greatly expanded in order to realize the full magnitude of potential behavior-related energy savings. Such an effort would go a long way toward closing the gaps that currently exist between: potential and actual energy savings on the one hand and between attitudes and behaviors on the other. In short, mobilizing our population to adopt energy-smart behaviors and technologies will require the insights provided by social and behavioral scientists. These insights need to become a larger part of the efforts at the U.S. Department of Energy.

Such an approach should provide widespread and accelerated research, experimentation, and application of behavior-related initiatives as well as policy initiatives that recognize the well-documented limitations of the techno-economic model and the need to integrate behavioral considerations broadly into existing programs and policies.

Introduction

My name is Karen Ehrhardt-Martinez. I am a Research Associate in the Economic and Social Analysis Program at the American Council for an Energy-Efficient Economy (ACEEE), a nonprofit organization dedicated to increasing energy efficiency as a means of promoting economic prosperity, energy security, and environmental protection. I am here today at the invitation of the House Science and Technology Subcommittee on Energy and Environment to discuss the role of the Department of Energy's research programs in developing technologies and standards to enable deployment of net-zero energy buildings and, in particular, to highlight R&D areas which need continued attention to achieve the goals of the DOE net-zero energy buildings program and beyond.

I would like thank you for the opportunity to testify here today and I applaud the Committee for its interest in identifying R&D areas that need continued attention to achieve the goals of the DOE's programs.

There is no question that the DOE Building Technologies Program has achieved significant energy savings through its unique combination of efforts, including (but not limited to) their work on developing standards for appliances and commercial equipment, and establishing building energy codes, and more recent efforts at achieving marketable net-zero energy commercial buildings by 2025. Nevertheless, today's buildings continue to consume more energy than any other sector of the U.S. economy—more than transportation and more than industry. And the potential building-related energy savings continue to be large. Whether we are talking about improving the energy efficiency of existing buildings or new construction, the efforts of the DOE Building Technologies Program offer the opportunity of substantial energy savings.

An important part of what makes the Building Technologies Program work so well is their active partnership with the private sector, State and local governments, national laboratories, and universities, and their work to not only improve the efficiency of buildings but also the equipment, components, and systems within them. These efforts include developing more energy-efficient technologies associated with building envelopes, equipment, lighting, and windows, as well as the use of advanced sensors and controls and other high-tech means of managing energy use (DOE, 2008).

The primary driver of the Program's activities is the DOE's zero energy building research initiative.[1] Importantly, the goal of achieving zero energy buildings necessarily requires extreme energy efficiency in all aspects of building design and construction, equipment choice, and building and equipment operation. Unless all of these areas are adequately addressed, the concept of zero energy buildings is unlikely to be achieved in practice.

While the strengths of the existing program are many, there are unfortunately also some weaknesses. And as is common to most programs at DOE, there is an substantially insufficient amount of attention paid to the human dimensions of energy consumption and energy efficiency. This shortcoming is associated with a long history of technology-centric programs that have failed to achieve their technological potential in terms of energy savings. A more effective approach must recognize the importance of the human element and work with social and behavioral scientists to effectively address it through behavior-oriented programs.

The Two Gaps: Efficiency Potential, Attitudes, and Behaviors

Among the potential benefits of behavior-oriented programs and research is the promise it holds for explaining, understanding, and addressing the two most important gaps that persist in maximizing energy efficiency and reducing energy consumption. More specifically, behavior-based programs can help identify solutions for closing: (1) the energy efficiency gap (the gap between the potential, cost-effective, energy efficiency investments and those investments actually made); and (2) the at-

[1] Zero energy buildings produce as much energy as they use over the course of a year.

titude-behavior gap (the gap between favorable attitudes toward energy efficiency and less favorable behaviors).

According to several ACEEE studies of the unrealized energy efficiency potential associated with existing technologies, the first gap represents lost energy savings of 30 percent or more with current technologies. Similarly, studies of prevailing attitudes and behaviors suggest that while people are often aware of the economic and environmental benefits of investing in energy-efficient technologies and behaviors, a variety of social, cultural, and economic factors frequently intervene so as to severely limit the number of individuals, households, and businesses that actually follow through on their intended actions, resulting in additional efficiency losses. For roughly 30 years, numerous researchers have attempted to identify the causes behind the energy efficiency gap (although primarily from an economic perspective) attributing the gap to various market barriers, transaction costs, and (in part) to consumer attitudes and preferences (Sanstad et al., 2006; Stern and Aronson, 1984). Among social scientists there has been a parallel effort to explain the gap between favorable environmental attitudes and less favorable behaviors (Dunlap, 2008). An example of this second gap can be illustrated using recent Gallup poll research that indicates that while more than three-quarters (77 percent) of Americans personally worry (either a fair amount or a great deal) about the availability and affordability of energy and 85 percent report that they "should be spending thousands of dollars to increase the energy efficiency of their homes," less than two percent of the population is actually acting on these concerns in any significant way. Despite the high level of concern about energy and global climate change, people aren't taking advantage of the potential for cost-effective energy savings.

Rational Economic Actors and the Need for a Behavioral Toolkit

Most efforts to date have approached the challenge of maximizing potential energy savings exclusively through a techno-economic framework of change (Parnell and Popovic Larsen, 2005). Since 1970, both theoretical and practical models of energy-related behavior have focused on reducing energy use as a function of developing the right technologies, making them available at the right price and then promoting them to consumers by espousing their "rational" economic benefits.[2] Underlying the techno-economic model are the assumptions that growth in energy consumption is best solved through the application of new technologies and that energy consumption and technology adoption behaviors are best understood in terms of a set of economic calculations involving the price of energy, the cost of technologies, and the level of disposable income. In this context, people are portrayed as rational economic decision-makers who will behave in predictable ways when confronted with changes in energy prices within a given market setting. Moreover, the model also suggests that the prevalence of energy-efficient behaviors and choices may be enhanced most effectively through the introduction of carefully crafted economic incentives and disincentives (Archer et al., 1987). Finally, the model suggests that consumers, when presented with information about the economically-desirable package, will act to increase their net benefit.

According to the techno-economic model, the primary barriers to the transfer of energy-efficient technologies are 1) the lack of more efficient technologies, 2) the lack of sufficient economic incentives, and/or 3) the lack of timely, sufficient, or even accurate and complete information. While these factors are undoubtedly important, and while a cursory evaluation suggests that programs using this approach have achieved some success, their success has been significantly limited as a result of the narrow focus on the techno-economic model and the flawed assumptions on which it is based (Parnell and Popovic Larsen, 2005).

Not surprisingly, the assumption that individuals are economically-rational actors has been regularly called into question. For example, in a study of solar technology adoption, Archer et al. (1987, p. 78) found that, "information indispensable to even gross cost calculations was, in fact, absent" in people's assessments. Similarly, in a study of vehicle purchase decisions, Turentine and Kurani (2006) found that "even the most financially skilled" consumers did not use payback calculations as part of their vehicle purchase decision-making. Archer et al. (1987) concluded that "this result appears to *contradict* a central tenet of the rational model"—namely, the economic rationality of the decision-making process. Similarly, in a study of consumer intentions to conserve energy, Feldman (1987, p. 39) finds that, "avoided costs and implicit discount rates are probably not useful concepts for describing the behavior

[2] Note: One especially interesting observation is that although most people easily recognize that social and behavioral approaches to energy savings are more complex than traditional technology-based approaches, behavior-based approaches have consistently received substantially less funding.

of the general public . . ." and concludes that it is dangerous to assume that energy consumers operate as rational investors. Moreover, Stern and Aronson (1984, p. 61) argue that "there is a problem with the very notion of users as investors" because people generally don't conceptualize energy and energy-using equipment only as investments. For example, when people purchase a car, they are concerned with a variety of characteristics including performance, reliability, safety, styling, status, resale value and fuel-efficiency, but the primary emphasis may be on any one of these factors. As an example, evaluations of utility-sponsored incentive programs promoting home retrofits have shown that even when utilities offered rebates that covered as much as 93 percent of the retrofit costs, only five percent of people actually decided in favor of having the retrofits done.

The persistent and overly narrow focus on economic considerations often results in the oversimplification of the decision-making process and the exclusion of social, psychological and other variables that have proven essential in understanding individual and organizational behavior. In fact, social and behavioral research consistently shows that people and organizations are both overtly and subconsciously influenced by a variety of non-economic variables including their values, beliefs, and attitudes, as well as prevailing social norms, group norms and interpersonal dynamics. As such, the need for increased behavioral research is real and the potential energy savings are significant.

In order to unlock these potential savings, research on energy-efficient technologies and practices would clearly benefit greatly from the adoption of a behavioral toolkit. Such a toolkit would include the use of insights from a variety of social and behavioral fields including sociology, psychology, anthropology, demography, public policy, behavioral economics, marketing, and communications. Notably, these types of insights are increasingly being shared among those people working in these fields of study. In fact their efforts to develop more extensive networks of collaboration have recently been catalyzed through the development of an annual conference on Behavior, Energy and Climate Change (BECC). This year will mark the third annual BECC Conference that will bring together more than 700 policy-makers, social scientists, and researchers, as well as representatives of government agencies, utilities, cities, businesses and non-profits to focus on understanding human behavior and decision-making in order to improve energy efficiency research, policy design and program effectiveness and to accelerate our transition to a low-carbon economy. Importantly, this year's conference will be held in Washington, D.C., allowing for the broad participation and involvement of national policy-makers, Hill staff, DOE and EPA staff, and representatives of the many national labs. This is a unique opportunity to catalyze DOE's work in this area. This year's BECC Conference will be held at the Marriott Wardman Park Hotel on November 15–18, 2009.[3] An overview of prior conference insights in provided by Ehrhardt-Martinez (2008).

The Behavior Continuum and the Size of Potential Behavior-Related Savings

An amazing variety of behavioral influences have contributed to the historical gains in energy efficiency that have already been achieved, but to what degree can a more concerted effort to integrate behavioral insights achieve even greater returns in terms of additional energy savings? This section (1) provides an example of the dramatic behavior-related energy savings achieved in Juneau, Alaska; (2) describes the range of relevant, energy-smart behaviors that comprise what we call the Behavior Energy Response Continuum; and (3) discusses the range of potential savings associated with energy-smart behaviors—behaviors that both drive new innovations and that change the patterns of technology adoption and energy service demands.

Powering Down in Juneau, Alaska

What can we learn from actions taking during energy emergencies? The experiences of the city and residents of Juneau, Alaska can teach us how large and how quickly energy savings can be achieved through behavioral change when people get serious about the task at hand. In April 2008, an avalanche damaged a major electrical power line near Juneau, cutting power to the city's 30,000 residents. Following the avalanche, the city was forced to rely on a bank of diesel-powered generators to supply its power. Within two weeks, Juneau had cut its energy consumption by about 20 percent, and by the end of May electricity use was down 40 percent (Berkeley Lab News Center, 2008).

The massive and coordinated effort to cut electricity consumption included quick energy audits of the city's low-income housing and local businesses, a public cam-

[3] More information is available on the BECC Conference web site at *www.BECCconference.org*

paign to engage people in the cause, an effort to identify and unplug items that needlessly draw power even when turned off, a campaign to replace incandescent bulbs with compact fluorescents, and identification of unnecessary municipal electricity use. In addition, the local utility provided regular feedback to the public, charting the city's progress in reducing energy use (Berkeley Lab News Center, 2008).

These efforts were geared toward making energy conservation more than just socially acceptable—instead they attempted "to suggest that conservation was expected." The essential message was that in order to be a good citizen, you needed to conserve energy (Berkeley Lab News Center, 2008).

The lesson? A city of 30,000 people was able to cut electricity consumption by 40 percent in approximately six weeks. So, what might be possible society-wide given the right motivation, the right programs, and the right incentives? Even five months after the power lines were restored, the city's electricity consumption remained eight percent below consumption levels for the prior year (NPR, 2008). A variety of similar examples of dramatic, behavior-based energy savings have been documented by Alan Meier in his book, *Saving Energy in a Hurry* (Meier, 2005). While these examples are useful for illustrating the scope of potential behavior-related savings, the exceptional circumstances are likely to influence consumers' general willingness to participate in energy saving behaviors. Nevertheless, the examples do suggest that more concerted programs could significantly increase energy savings.

The Behavior Continuum

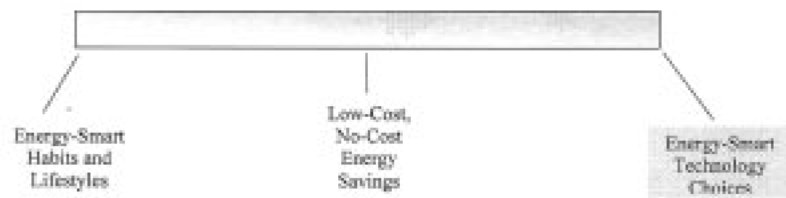
The real debate isn't about whether behavior has contributed to the dramatic reductions in energy consumption growth rates in the U.S. Instead it is about the need to recognize behavior as an important but often overlooked resource for achieving large-scale reductions in energy consumption and carbon emissions. Unfortunately, some energy professionals continue to suggest that while behavior-oriented programs may provide a useful way to help deploy smart technologies, they are best thought of as boutique or niche strategies which are most suitably employed to enhance an otherwise technology-focused deployment of more energy-productive investments. Nevertheless, research on this topic suggests that sizable energy savings and efficiency gains are likely to be achieved by addressing the human dimensions of energy consumption, energy efficiency and energy conservation.

In fact, past analyses by the American Council for an Energy-Efficient Economy (ACEEE), and by well-known researchers like Gerald Gardner, Paul Stern, and others suggest that understanding and shaping behaviors can provide a significant savings. (See Gardner and Stern et al., 2008; and Laitner et al., 2009.) Indeed, recent, albeit preliminary, assessments by ACEEE researchers indicate that "the behavioral resource" might provide as much as a 25 percent efficiency gain (possibly more) above normal productivity improvements. Similarly, utilities and energy research organizations are increasingly working to integrate behavior-change programs and practices into their larger portfolio of activities with the goal of reducing costly energy production and consumption and carbon emissions.

As such, the Behavior Continuum was designed to illustrate the range and potential impact of changed habits, lifestyles and technology-based behaviors in terms of the potential energy savings within the United States. Although the recent implementation of the Behavior Continuum has been focused on identifying and assessing energy-smart behaviors in the residential sector (including personal transportation uses within the control of households), future assessment will also include behavior-related energy saving in the commercial and industrial sectors as well.

The Behavior Energy Response Continuum is a means of estimating the energy savings that could be achieved if new energy-wise habits (i.e., building and equipment operation practices and maintenance) became the norm, and if new energy-wise lifestyles and choices were encouraged by smart policies oriented toward reducing energy consumption. The Behavior Continuum ranges from habits and lifestyles on one end, to technology choices on the other. The middle of the Continuum includes a variety of infrequent, low-cost and no-cost behaviors that can reduce energy consumption including weather-stripping and caulking and insulating ducts or ensuring adequate space between the refrigerator and the wall (Ehrhardt-Martinez et al., 2009). See Figure 1 below.

Figure 1: Behavior Energy Response Continuum



In terms of the residential sector alone, preliminary research at the national level suggests that changed behaviors offer potential reductions of 20–25 percent of current levels of residential energy consumption over perhaps a five- to eight-year period within the United States.

Moreover, in a recent application of the Behavior Energy Response Continuum for the State of Wisconsin, the potential impact of behavior-oriented programs (focused on addressing individual habits, lifestyles, and technology choices) indicated a potential doubling of the projected residential sector energy savings opportunities (Ehrhardt-Martinez et al., 2009). More specifically, the Wisconsin estimates (based on Wisconsin-specific energy data) indicated that behavior-oriented programs held the potential of reducing residential energy consumption in Wisconsin by as much as 18 percent by 2012, or 38 trillion Btus. As such, a more comprehensive behavior program could result in savings that are more than twice as large as those associated with standard, technology-oriented approaches by generating a broader range of energy-smart behaviors, by eliciting a greater level of responsiveness among "traditional program" participants, and by driving a greater level of spill-over among non-participants throughout Wisconsin.

The use of the behavior continuum is one means of identifying the numerous types of behavior-related energy savings opportunities and developing a more comprehensive estimate of potential behavior-related energy saving. Importantly, the Behavior Continuum and the results from the associated analysis challenge traditional approaches to energy efficiency programs that tend to marginalize behavior-oriented programs by characterizing them as boutique or niche strategies that can only round out a technology-based deployment of more energy-productive investments. The application of the Behavior Continuum suggests the contrary; that behavior-related programs offer potential energy savings on a surprisingly large scale—one that rivals a pure technology based perspective in terms of expected efficiency gains.

Levels of Intervention and Recommendations

Even with all this good news about the potential for using social and behavioral insights for generating larger reductions in energy use, it is important to recognize that these savings will not occur without consciously and deliberately incorporating social and behavioral change as an explicit initiative within D.O.E. programs.

Such an initiative would ideally apply relevant behavioral insights through a variety of intervention levels including:

- behavior-smart policies,
- an improved understanding of the ways in which people both shape and are shaped by their physical environment,
- a recognition of the opportunities and constraints associated with existing social structures, cultural norms and values, and other socio-cultural considerations,
- a recognition of interpersonal and psychological factors associated with motivating and constraining behavioral change.

At the policy level, for example, behavioral interventions could help design more effective policies by taking advantage of the current cognitive dispositions that have been shown to be prevalent across the population. Many of these approaches are explored in the field of behavioral economics. For example, when faced with making a decision about which building features or equipment to include in various builders packages, the structure of those decisions is likely to play an important role in the ultimate decision made by the consumer. By structuring the decision such that consumers need to opt-out as oppose to opt-in to the choice of energy efficient designs and equipment, a much larger proportion of new home buyers are likely to incorporate energy efficient features in their new homes. The work of Carrie Armel (at the Precourt Energy Efficiency Center at Stanford University), Cass Sunstein (Thaler and Sunstein, 2008) and other researchers suggest that people tend to have a lot of inertia when it comes to decision-making. Armel uses the example of automobile drivers faced with the decision of donating their organs. Participation in such programs tends to be about 20 percent in countries where the default option is NOT donating (therefore participants are required to opt-in) compared to a participation rate of 80 to 90 percent in countries where the default option is to participate (therefore participants are required to opt-out). See Thaler and Sunstein (2008) for additional examples.

In terms of the built environment and buildings in particular, social and behavioral insights can play an important role in determining and emphasizing the many non-energy benefits of energy-efficient designs and equipment. For example, natural daylighting and greenery have been shown to increase productivity, while equipment designed from the users perspective (with the help of social and anthropological insights) have been shown to reduce operator error, increase the proper usage, and maximize energy savings. According to Armel (2008), there is an enormous body of literature in cognitive science speaking to issues of how we can improve users' performance, yet often this knowledge fails to be incorporated into design.

Socio-cultural and interpersonal interventions recognize the importance of social institutions and culture, norms, and networks in the shaping of individual and organizational behaviors. And there are an increasing number of examples of energy programs that are successfully incorporating some of these socio-cultural insights into their efforts to increase the adoption and diffusion of energy-efficient technologies. Some examples include Project Porchlight which uses several different social insights to encourage the adoption of compact fluorescent light bulbs in Canada, and the ENERGY STAR program's Change a Light Campaign. Interestingly, both of these programs use social networks, commitment, norms, and feedback to promote the adoption of energy-efficient light bulbs. And both have been structured using the principles of community-based social marketing which readily overlap with elements of an approach rooted in a concern for social, rather than economic, rationality. (See Ehrhardt-Martinez et al., 2009).

The ENERGY STAR Change a Light Campaign, led by the U.S. EPA, requires participants to pledge to change at least one light bulb in their house with one that has earned the ENERGY STAR. Individuals and organizations can participate by logging on to the ENERGY STAR web site[4] and specifying how many light bulbs they plan to change. Individuals can also become "pledge drivers" by committing to get their community or organization involved in the campaign and committing to promoting the change of at least 100 light bulbs. Participants provide their name, zip code and organizational affiliation, allowing pledge drivers and EPA staff to track their progress and access established social networks to promote change and establish new social norms. The progress of each organization is tracked online-observable for all to see. The public tracking prompts passive competition among pledge drivers and presents an opportunity to recognize top performers. Moreover, the web site offers special resources for teachers, retailers and government leaders to work with students, consumers, and communities.

Project Porchlight is a similar initiative run by a Canadian non-profit organization called One Change based in Ottawa, Ontario. The campaign works with Hydro Ottawa, the City of Ottawa, volunteers and other partners to effect social and environmental change. The original goal of the campaign was to get 200,000 households in Ottawa to change at least one inefficient incandescent light bulb to one energy-efficient CFL by providing residents with a free light bulb. By using existing networks, the project encourages local action in neighborhoods and within groups by working with group members who deliver light bulbs door to door. Light bulb recipients make a commitment to their neighbors that they will install the light bulb (preferably in a prominent place) as a symbol of their commitment to the effort; an action which also provides a first step in shaping their identity as someone who is willing to take action to reduce their environmental impact (One Change, 2008). Early in 2008, the project successfully surpassed their revised goal of delivering more than one million energy-efficient bulbs.

According to McKenzie-Mohr and Smith (2007), direct appeals that ask people to commit to take a specific action achieve higher levels of behavior change. If a person agrees to take a specific action, they are likely to follow through on it, especially

[4] *http://www.energystar.gov/index.cfm?fuseaction=cal.showPledge*

if the commitment has been made publicly. They state that because human beings have a need to appear consistent, we are likely to agree to future similar requests for our commitment as well. This holds true even if the next request is larger, occurs after much time has passed, and comes from a different group than that of the initial request. Agreeing to the first request is actually thought to alter how one sees oneself, and in an enduring way.

Social and behavioral insights can also be used to change behaviors associated with habits and lifestyles. For example, several studies have explored the role of social norms in determining environmentally responsible behaviors. In 1990, Cialdini et al. investigated the effect of norms on individuals' decisions to despoil the environment. In the study, "participants were given the opportunity to litter in either a previously clean or fully littered environment after first witnessing a confederate who either dropped trash into the environment or simply walked through it." Cialdini et al. hypothesized that: 1) participants would be more likely to litter in the already littered environment than into a clean one; 2) participants who witnessed the confederate drop trash into a fully littered environment would be the most likely to litter there themselves because their attention would be drawn to the pro-littering descriptive norm; and 3) participants who saw the confederate drop trash into a clean environment would be least likely to litter there, because their attention would be drawn to evidence of an anti-littering descriptive norm. In fact, the study found that 32 percent of the participants littered in the littered environment without the confederate while 54 percent of participants littered in the same environment when the confederate did litter. The third hypothesis was also supported by the finding that only 14 percent of participants littered in the clean environment when the confederate did not litter, while a mere six percent of participants littered in the same environment when the confederate littered.

In a more recent study of energy conservation, Schultz et al. (2007) investigated "respondents' views of their reasons for conserving energy at home as well as reports of their actual residential energy saving activities such as installing energy-efficient appliances and light bulbs, adjusting thermostats, and turning off lights." A study of the relationship between participants' stated reasons for saving energy and their energy saving actions indicated that conservation behaviors were most strongly correlated with the perception that other people were participating. According to Schultz, "this belief that others were conserving correlated twice as highly with reported energy saving efforts than did any of the reasons that had been rated as more important personal motivators." This work has recently been taken one step further through a number of innovative program designs being implemented through some electric utilities. In a recent review of Positive Energy's work in this area, the application of social norms and other behavioral insights was found to be effective in generating a two to three percent reduction in energy consumption during a nine-month implementation period.

Social and behavioral insights can both enable technology-based energy savings and provide additional savings through the development of energy-wise habits, decisions and lifestyles. Importantly, these types of approaches offer low-cost options for achieving dramatic energy savings. Unfortunately they are largely missing from existing DOE initiatives.

As stated in the introduction to this testimony, the primary driver of the Building Technologies Program activities is the D.O.E. zero energy building research initiative.[5] In order to meet the initiative's goal of achieving zero energy buildings, every effort will need to be made to achieve the extreme energy efficiency goals in building design and construction, equipment choice, and building and equipment operation. Social and behavioral research and insights will be a critical component in meeting these goals. As such, it is imperative that:

- D.O.E.'s work more adequately address the human elements that are integral to achieving their energy-efficiency goals,
- support and learn from the work of social and behavioral scientists,
- develop a social and behavioral initiative as part of their own work, and
- provide financial support in order to expand on existing research in this field of study.

The long history of technology-centric programs has failed to substantially narrow the gap between the energy saving potential of existing cost-effective technologies and actual levels of energy savings. Social and behavioral insights can help close that gap if we're willing to invest in them.

[5] Zero energy buildings produce as much energy as they use over the course of a year.

Conclusions

The full array of evidence provided in this testimony suggests that more research and development is needed to explore, develop and apply social and behavioral insights and interventions. Similarly, evidence provided herein also suggests that such insights and initiatives offer the possibility of a significantly improved effectiveness of D.O.E.'s building technologies initiatives as well as increased energy savings.

Behavior-related approaches represent an essential component of energy and climate change efforts. In fact, the principal drivers of our current energy and climate challenges are human choices, behaviors, and lifestyles. As such, they must also be an essential part of any attempt to address these challenges, if we hope to be successful in our efforts. In other words, human and organizational behavior are a critical component of both the causes of, and solutions to, our energy and climate problems.

While the DOE's initiatives will undoubtedly benefit greatly from a more systematic and widespread incorporation of social and behavioral insights, this will not happen without increased funding for associated research and development.

Such an effort would go a long way toward closing the gaps that currently exist between: potential and actual energy savings on the one hand and between favorable attitudes and less-favorable behaviors on the other. In short, mobilizing our population to adopt energy smart behaviors and technologies will require the insights provided by social and behavioral scientists. These insights need to become a larger part of the efforts at the U.S. Department of Energy.

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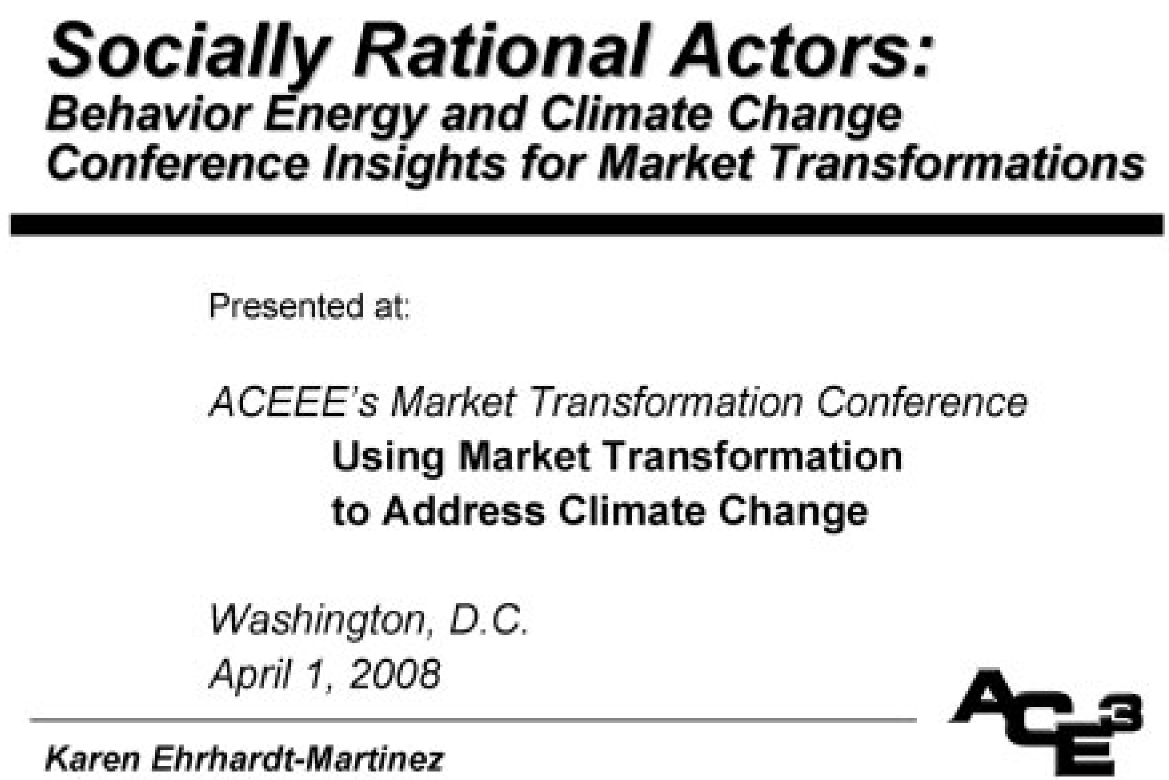
Socially Rational Actors:
Behavior Energy and Climate Change
Conference Insights for Market Transformations
Presented at:
ACEEE's Market Transformation Conference
Using Market Transformation
to Address Climate Change
Washington, D.C.
April 1, 2008
Karen Ehrhardt-Martinez
ACE3

The 2007 BECC Conference

Goals:

- Increase our understanding of decision-making and behavior for both individuals and organizations, and
- Facilitate the application of that knowledge to accelerate our transition to an energy-efficient and low-carbon future.

Topics:

- Policies and programs
- Individuals, households, businesses, government and orgs.
- Opinions, knowledge, habits/practices/lifestyles, technologies

Karen Ehrhardt-Martinez

ACE3

Guiding Questions

What insights have we gained from the BECC Conference?

- Make Energy and Efficiency Visible
- Understand Individuals/Consumers Better
- Strengthen Trade Allies Linkages
- Maximize Program Effectiveness

Karen Ehrhardt-Martinez

Making Energy and Efficiency More Visible

- Your Average Kilowatts of Electricity per Month/Year?
- National and Regional Averages?

Karen Ehrhardt-Martinez

Making Energy and Efficiency More Visible

Table 5: U.S. Average Monthly Residential Electricity Consumption by Region, 2006

Census Division Region	Number of Consumers	Average Monthly Consumption (kWh)
New England	6,056,160	640
Middle Atlantic	15,392,413	698
East North Central	19,472,313	798
West North Central	8,846,054	940
South Atlantic	24,899,810	1,137
East South Central	7,791,650	1,255
West South Central	13,860,466	1,165
Mountain	8,518,567	885
Pacific Contiguous	16,970,544	703
Pacific Noncontiguous	663,094	666
U.S. Total	122,471,071	920

Average Annual Electricity Consumption = 10,664 kWh

Karen Ehrhardt-Martinez

Source: EIA

Making Energy and Efficiency More Visible

Historically, we have moved from:

- Visible to invisible forms of energy
- Limited use to ubiquitous demand for energy services.
- A focus on expanding energy resources to increasing energy efficiency and reducing our carbon footprint.

Karen Ehrhardt-Martinez

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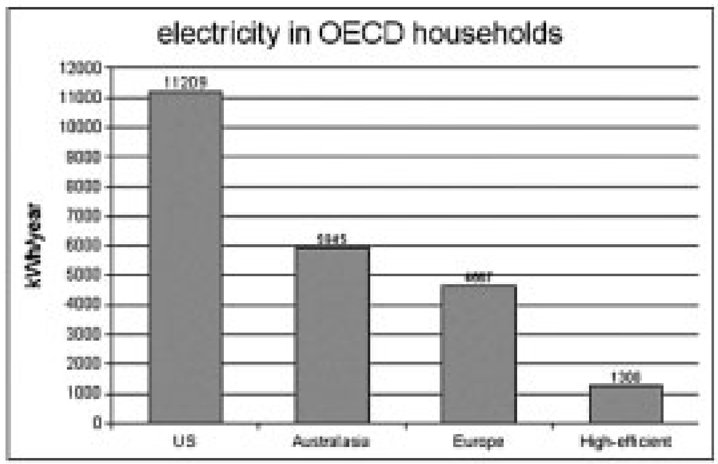
Making Energy and Efficiency More Visible



Karen Ehrhardt-Martinez

Making Energy and Efficiency More Visible

Earth Hour

Saturday, March 29th, 8pm

- Turn off lights and non-essential electronics.
- Cut Sydney's electric consumption between 2.1% and 10.2% (for the hour) in 2007
- 2.2 million people (57% of Sydney's residents) took part in 2007

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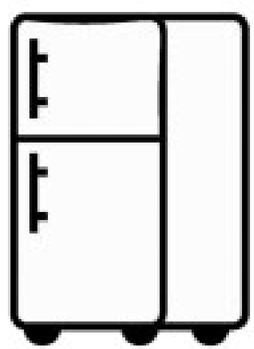
ACE3

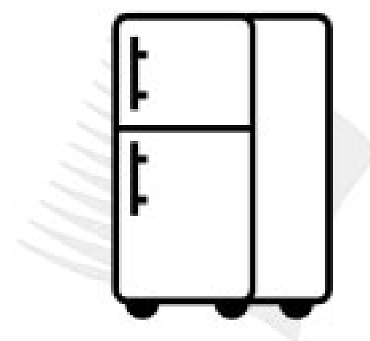
Understand Individual/Household Decision-Making and Behavior

Economically Rational Decision-Making 101

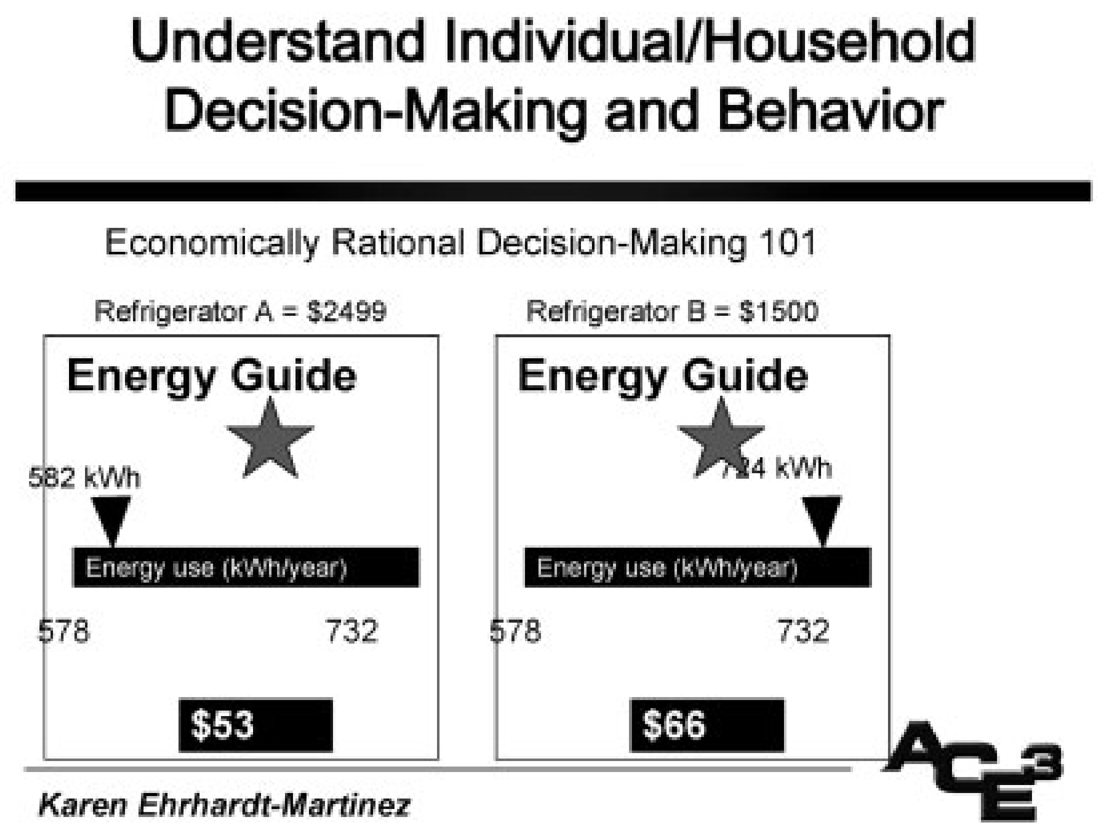
Refrigerator A = $2499



Refrigerator B = $1500



Karen Ehrhardt-Martinez


Understand Individual/Household
Decision-Making and Behavior
Economically Rational Decision-Making 101
Refrigerator A = $2499
Refrigerator B = $1500
Energy Guide
582 kWh
Energy use (kWh/year)
578
732
$53
Energy Guide
Energy use (kWh/year)
578
732
$66
Karen Ehrhardt-Martinez

Understand Individual/Household Decision-Making and Behavior

Calculate the Life Cycle Cost and Payback.
Which refrigerator should you buy?

Refrigerator	A	B	A - B
Purchase Price	$2,499	$1,500	$999
Size (Cubic Feet)	26	26	$0
Annual Use	582	724	-$142
Energy Star Compliant	Yes	Yes	
Total Elec Cost	[redacted]		
Total Life Cycle Cost			

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Understand Individual/Household Decision-Making and Behavior

Calculate the Life Cycle Cost and Payback.
Which refrigerator should you buy?

Refrigerator	A	B	A - B
Purchase Price	$2,499	$1,500	$999
Size (Cubic Feet)	26	26	$0
Annual Use	582	724	-$142
Energy Star Compliant	Yes	Yes	
Total Elec Cost	$ 616	$ 766	-$150
Total Life Cycle Cost	$ 3,115	$ 2,266	$849

Karen Ehrhardt-Martinez

Understand Individual/Household Decision-Making and Behavior

What accounts for variation in household energy consumption?

- Features of infrastructure and technology.
- Non-physical factors (3:1 variation)
  - Demographics
  - Lifestyles
  - Habits
  - Values, Beliefs, Norms and Perceptions

Karen Ehrhardt-Martinez

ACE3

Understand Individual/Household Decision-Making and Behavior

Where are the potential savings?

- Potential CO_2 Savings from Residential Efficiency Improvements > 25%
  - Upgrade attic insulation (7%)
  - More efficient HVAC (5%)
  - Replace incandescents with CFLs (4%)
  - More efficient windows (3.7%)
  - Caulk and weatherstrip (2.5%)
- But behavior includes purchasing, maintenance, and daily living.

Karen Ehrhardt-Martinez

Understand Individual/Household Decision-Making and Behavior

Are we economically rational actors?

- People are poor calculators

- We don't always/often act in economically rational ways
- Our habits, choices, and preferences are often shaped by social influences and the people around us

Karen Ehrhardt-Martinez

Understand Individual/Household Decision-Making and Behavior

Socially Rational Actors

- Individuals are influenced by other people
  - Social learning and modeling
  - Social marketing
  - Social norms
  - Social status
  - Identity framing
  - Social networks

Karen Ehrhardt-Martinez

ACE3

Understand Individual/Household Decision-Making and Behavior

Socially Rational Actors

- Ideas from the BECC Conference
  - Public Health and Health Promotion
  - Social Norms, Feedback and Persuasion Theory
  - Social Networks, Diffusion, and Commitment
  - Social Marketing

Karen Ehrhardt-Martinez

Other BECC Lessons

Information and Feedback

- Carbon labels, footprint analysis and smart meters

Trade Allies

- Efficiency as a prominent choice option

Program Effectiveness

- Process evaluation and program feedback

Karen Ehrhardt-Martinez

Research Paths

1. Data Collection and Data Availability
2. Lifestyle and Social Diversity
3. Social Context and Social Rationality
4. Embodied Energy and Consumption Choices
5. Symbolism, Identity and Rebound
6. Energy: Visibility and Ubiquity
7. Trade Allies and Choice Points
8. Behavior in Business and Industry
9. Accelerating Technological Solutions

Karen Ehrhardt-Martinez

CPUC White Papers

1. Energy efficiency potential of behavior
2. Measurement and evaluation of energy savings and non-energy impacts from energy efficiency behaviors
3. Process evaluation's insights on energy efficiency program implementation
4. Behavioral assumptions underlying energy efficiency programs

Karen Ehrhardt-Martinez

ACE3

CPUC White Papers

5. Market segmentation and energy efficiency program design.
6. Experimental design for energy efficiency programs
7. Motivating policymakers, program administrators, and program implementers to pursue behavioral change strategies.
8. Encouraging greater innovation in the production of energy-efficient technologies and services.

Karen Ehrhardt-Martinez

The Next BECC Conference

November 16-19, 2008

Sacramento, CA

Speakers will be selected:

By competitive abstract review

and by invitation

Karen Ehrhardt-Martinez

ACEEE

BIOGRAPHY FOR KAREN EHRHARDT-MARTINEZ

Karen Ehrhardt-Martinez is a Research Associate with the American Council for an Energy-Efficient Economy (ACEEE). With more than 15 years of experience in academic and applied research, Karen currently works in the Economic and Social Analysis Program at ACEEE were she is responsible for leading the organization's efforts on the social and behavioral dimensions of energy efficiency and environmental change. Karen is currently serving as the Conference Chairman for the 2009 Behavior, Energy and Climate Change Conference to be held November 15th–18th in Washington, D.C. Karen has a Ph.D. and M.A. in Sociology from The Ohio State University and a Bachelor's degree in International Studies.

Chairman BAIRD. Thank you very much, Doctor.
Dr. McQuade.

STATEMENT OF DR. J. MICHAEL MCQUADE, SENIOR VICE PRESIDENT, SCIENCE AND TECHNOLOGY, UNITED TECHNOLOGIES CORPORATION

Dr. MCQUADE. Good morning, Mr. Chairman, Ranking Member Inglis and Members of the Committee. Thank you for the opportunity to be here today. I am Michael McQuade, Senior Vice President for Science and Technology from United Technologies Corporation. I am pleased to share my thoughts about the need and opportunity to invest in basic research in building system science to dramatically reduce the energy consumed and carbon emitted by buildings.

We are very pleased with President Obama's commitment to a robust R&D agenda as expressed in his remarks yesterday at the National Academy of Sciences. We believe that the investments in building system science described here align directly with his vision and can be aggressively accomplished within the DOE portfolio of ARPA–E, EERE and the Office of Science.

We believe it is vital to pursue basic research in mathematical and computational capabilities to optimize the design, construction, commissioning and operation of complex buildings, in systems, sciences and whole-building approaches and in multi-institutional national laboratory, academia and industrial partnerships to prototype and demonstrate this science and technology in real buildings across multiple real applications. Investments in the range of $50 million per year for five years will lead to deployable science, technology and products that will ensure that the full potential of energy savings are captured over the useful life of buildings. This is a critical initiative to reducing energy consumption, decrease greenhouse gas emissions and improve this country's energy security.

United Technologies is a $55 billion global aerospace and building infrastructure technology-driven company. As one of the leading suppliers to the built environment, we are keenly aware of, and interested in, the role that buildings play in energy and climate. As we have said multiple times today, buildings consume about 40 percent of the energy used in the United States and are responsible for nearly 40 percent of the greenhouse gas emissions. To put this in perspective, a 50 percent reduction in building energy consumption in the United States is equivalent to removing the carbon emissions from every car and light truck on the road today in the United States. These are very big numbers and they represent very big opportunities.

UTC is a co-chair of the 14-company World Business Council for Sustainable Development Project on Energy Efficiency in Buildings. Yesterday this project released the first results from a landmark study on actions needed for reducing building energy consumption and the resulting carbon emissions. Among the key findings is that a transformation of the building industry is essential and achievable if we are to reach the nearly 80 percent reduction in carbon emissions called for by the Intergovernmental Panel on Climate Change. This study documents that significant progress can be made against this goal with cost-effective deployment of energy-efficient components based on known technologies at market-acceptable investment costs. However, if we are to reach the full 80 percent reduction goal, we need new science that treats buildings as complex systems of interactive components coupled to their occupants and to their external environment.

A recent DOE study cited six examples of high-performance buildings whose design intent was to deliver as much as 80 percent more efficient energy use than standard buildings. Through sub-optimal integration during the construction and operation phase, these buildings actually delivered less than half this desired performance. UTC recommends that DOE continue its vital public-private partnerships to address energy-efficient building components, and at the same time it is essential to increase the research, development and deployment of the science needed to understand and optimize buildings as whole systems. With a deeper scientific base enabled by mathematics, computational science and control sciences, it is possible to combine energy-efficient components into intelligent and even more efficient systems so that whole buildings perform as designed and sustain that performance during a lifetime of operation.

UTC is a major supplier of energy-efficient products, but we also are engaged in early-stage research in optimizing building systems. For example, UTC is part of a collaboration of national laboratory, academia and industry partners working to demonstrate advanced control and information systems on the campus of the University of California Merced's campus. This program, partially sponsored by the DOE's EERE office, is showing that through the use of advanced building control algorithms, an additional 10 to 15 percent energy consumption reduction in the campus cooling delivery system and up to a 20 percent additional energy savings for campus building HVAC systems can be achieved.

We believe that a vigorous investment in the range of $50 million per year for five years will deliver significant new science that can be deployed into public and private built environments. This technology will serve as the basis for products that the private sector will develop to make highly efficient energy-efficient buildings the norm in the commercial marketplace.

Energy efficiency and carbon reduction are critical strategies for climate control and energy security. The building sector represents a larger opportunity for greenhouse gas emission reductions than either the transportation or industry sectors. An enhanced national research strategy in building sciences coupled with the already strong DOE program in energy-efficient components for buildings will provide the foundation for industry to deploy market-driven solutions to reduce building energy. We look forward to working with Congress and the DOE to advance this critical national need.

Thank you for the opportunity to be here today.

[The prepared statement of Dr. McQuade follows:]

PREPARED STATEMENT OF J. MICHAEL MCQUADE

Summary

The building sector consumes about 40 percent of the energy used in the United States and is responsible for nearly 40 percent of greenhouse gas (GHG) emissions.

In addressing GHG reductions in the building sector the Department of Energy (DOE), in collaboration with the private sector, should continue to develop and deploy energy efficient building components (lighting, heating, ventilation, air conditioning and other elements). At the same time, there is an important push for research and development in science and technology to understand and optimize a whole building via a "systems" approach that ensures that efficiency gains are properly designed and also sustained during building operation.

UTC is one of the largest capital suppliers to the building industry worldwide. As such, the development of both sustainable and energy efficient products is of critical importance to UTC, its suppliers and the markets and customers that it serves. UTC takes an active industry role in addressing building energy usage. Key findings of the three-year World Business Council for Sustainable Development (WBCSD) project on Energy Efficiency in Buildings (EEB), for which UTC is a co-chair, are that transformation of the building industry is essential to achieving the 77 percent reduction of carbon emissions called for by the Intergovernmental Panel on Climate Change (IPCC). The transformation of the building sector to reach the carbon emissions goal can occur only through a combination of public policies, technological innovation and informed customer choices. These reductions require:

- Mandated federal building codes that recast regulation for increased transparency on energy use; and
- Ensuring buildings operate as designed by developing and using smart technology to enable and assure continued energy saving behaviors.

Among the key recommendations are:

- Creation and enforcement of building energy efficiency codes and labeling standards
- Incentivizing energy-efficient investments
- Encouraging integrated design approaches and innovations
- Funding energy savings technology development programs
- Developing workforce capacity for energy saving
- Mobilizing for an energy-aware culture

The current design, construction, commissioning and operation phases of the delivery process for buildings allows for efficiency decay that often fails to deliver optimal energy savings. Achieving approximately 80 percent energy reduction in buildings requires new research and development (R&D) investments in a systems approach to design and operations.

Two types of R&D investments are needed to attack the sources of energy efficiency decay: (1) investments in computational capabilities with specific attention to modeling, analysis, simulation and control of buildings and (2) targeted programs to combine fundamental science & technology with market impact to address specific market verticals in a Defense Advanced Research Projects Agency (DARPA) style model of projects.

The R&D initiatives to enhance building efficiency and functionality are only one element of a comprehensive national strategy to achieve net zero energy buildings. Other elements should include: the use of Energy Savings Performance Contracts (ESPC); mandated and regular energy audits; implementation of a national performance-based retrofit program; the establishment of a national energy efficiency standard; support for demonstrations and deployment of emerging technologies and products; education and workforce training; development of a building technology roadmap; and financial incentives.

Introduction

As the House Science and Technology Committee considers R&D needs for high-performance buildings, United Technologies Corporation (UTC) offers recommendations on cost effective, innovative and environmentally friendly ways to address energy efficiency using a whole building or a "systems" approach.

UTC ranks #37 on the latest Fortune 500 listing and is one of 30 members of the Dow Jones Industrials. Our 2008 revenues were $58.7 billion. UTC products include: Carrier heating, air conditioning and refrigeration; Otis elevators and escalators; Pratt & Whitney aircraft engines; Sikorsky helicopter; Hamilton Sundstrand aerospace systems and industrial products; UTC Fire & Security systems; and UTC Power fuel cells. We are a company of innovators and pioneers. Elisha Otis invented the safety elevator that made multi-story buildings usable; Willis Carrier invented modern air conditioning—just to mention two examples. So, as one of the largest suppliers to the global building industry and a leader in energy reduction, both in our own operations and through energy efficient innovations in our products and services, UTC brings a credible voice to the policy debate.

UTC takes an active industry role in addressing building energy usage. As a cochair of the three-year long World Business Council for Sustainable Development (WBCSD) project on Energy Efficiency in Buildings (EEB), along with thirteen other major multinational corporations representing various aspects of building design, construction, delivery and operations, UTC is working to identify the barriers, levers, and necessary actions to achieve market transformation and a much needed pathway to net zero energy buildings (NZEB)—those buildings that, over a period of a year, consume no energy. Among other important findings is the fact that professionals in the building industry have widely *underestimated* the impact of buildings on carbon emissions (by a factor of two) while significantly *overestimating* the cost of sustainable construction (by a factor of three). This knowledge gap is just one of several barriers to market transformation of the building sector.

The EEB report released on April 27, 2009 finds that transformation of the building industry to achieve the IPCC 77 percent reduction of carbon emissions would require:

- Mandated building energy codes that recast regulation for increased transparency on energy use; and
- Ensuring buildings operate as designed by developing and using smart technology to enable and assure continued energy saving behaviors.

The EEB report recommendations can be summarized as:

- Create and enforce building energy efficiency codes and labeling standards
    - Extend current codes and tighten over time
    - Display energy performance labels
    - Conduct energy inspections and audits on a regular basis (not one time). This supports the continuous commissioning process now gaining favor among advanced energy users.
- Incentivize energy-efficient investments
    - Establish tax incentives, subsidies and creative financial models to lower first-cost and technology adoption hurdles
- Encourage integrated design approaches and innovations
    - Improve contractual terms to promote integrated design teams
    - Incentivize integrated team formation
- Fund energy savings technology development programs
    - Accelerate rates of efficiency improvement for energy technologies
    - Improve building control systems to fully exploit energy saving opportunities
- Develop workforce capacity for energy saving
    - Create and prioritize training and vocational programs
    - Develop "system integrator" profession
- Mobilize for an energy-aware culture
    - Promote behavior change and improve understanding across the sector
    - Businesses and governments lead by acting on their building portfolios

Examples of UTC Energy Efficient Building Technologies

Increasing efficiency in buildings boosts productivity through the reduction of energy costs. Developing better products that improve energy efficiency offers new market opportunities. In 2006, George David, at that time the CEO and Chairman of UTC, spoke at the WBCSD meeting in Beijing:

> *"The lessons I bring from UTC are that we can always reduce costs and increase productivity and performance. The same is true for environmental impacts and potentially to an even greater degree because companies generally haven't worked at these as hard as they have at costs and corporate profitability. Remember that more than 90 percent of the energy coming out of the ground is wasted and doesn't end as useful. This is the measure of what's in front of us and why we should be excited."*

In addition to our collaborative efforts within the WBCSD, UTC is also engaged in developing energy efficient products for buildings including:

- Otis' Gen2 elevators with regenerative drives: Up to 75 percent more energy efficient than comparable equipment a decade ago, the Gen2 sends its excess power back to the building's electrical grid.
- Carrier's Evergreen tri-rotor screw chiller: The world's most efficient water-cooled chiller delivers 40 percent higher efficiency than current ASHRAE 90.1 efficiency standards.
- Carrier and UTC Power's combined heat and power (CHP) products: These products put "waste heat" from prime movers, such as fuel cells and micro-turbines, to productive use by driving heating, ventilation and air conditioning equipment, boosting efficiency from around 33 percent based on the individual components to nearly 80 percent in the total integrated system. Locating the system at the point of use allows the building to productively use the waste heat and avoid transmission line losses. The on-site attribute is a key component of optimizing the system's performance.

A number of investments have been made at UTC and a number of federal and State programs that can be utilized to move to increased energy efficiency in buildings. The UTC experience in deploying and supporting energy efficient products to the global building sector and providing a range of energy services has convinced us that a systems approach will result in even greater gains.

Understanding Energy Losses in the Delivery Process: Targeting R&D

Achieving energy savings through increasing building efficiency gains represents a tremendous opportunity. The building sector consumes about 40 percent of the energy used in the United States and is responsible for nearly 40 percent of greenhouse gas emissions. For comparison, the entire transport sector represents only 28 percent of energy use. A 50 percent reduction in buildings' energy usage would be equivalent to taking every passenger vehicle and small truck in the United States off the road. A 70 percent reduction in buildings' energy usage is equivalent to eliminating the energy consumption of the entire U.S. transportation sector. These levels of energy reduction in buildings are achievable but the United States today lacks the market drivers as well as the underlying science and technology infrastructure (including scientific and engineering workforce) to broadly realize these levels of efficiency improvements in cost-effective ways. Setting a targeted and aggressive R&D agenda is necessary to position the United States effectively and a well-executed R&D agenda is critical to increasing the competitive position of the United States.

The building sector is made up of multiple stakeholders and decision-makers, including State & local government regulators, builders, architects, service and repair companies, owners, realtors, product manufacturers and energy suppliers. The delivery process for buildings can be divided into design, construction, and maintenance phases. It is important to highlight how energy efficiency losses occur in this process.[1]

Owners, architects and architecture & engineering firms set the building design and consider their usage, aesthetics and the energy consumption. The design stage has the highest leverage in the overall delivery process by selecting the architecture and constraining the overall design space. The selection of design elements can significantly enhance—or limit—the ultimate performance depending on how these elements interact. For example, increasing daylighting can influence the amount of lighting that is needed which in turn affects the overall heating and cooling load.

[1] Throughout each of these stages, the influence of federal, State, and local regulation should be acknowledged. Current design and construction protocols, implemented through myriad building and other codes and regulations, can have an enormous impact on building energy performance.

These interactions can alter the energy consumption in beneficial or detrimental ways.

The next stage of delivery is construction. Here, components are considered against cost and schedule targets, and typically do not capture the integrated elements of design that are key to efficient energy performance of the whole building.

The last stage, or two stages, relate to the so-called commissioning and post-occupancy, or operations phase of the building. Commissioning should start during design and not just at the tail end of construction. The point to highlight here is that the design intent must be verified and the operations must ensure persistence of design intent.

As a result the current delivery process has energy efficiency losses at four points, outlined below, which represent major barriers to achieving the energy performance transformation required in the broad building stock:

1. **Design:** Inadequate design exploration and the efficacy of the tools that can be deployed for critical trade studies;
2. **Construction:** Inadequate coupling of design intent to value engineering needed to maintain the energy performance intended by design;
3. **Commissioning:** Ensuring that the construction process and installation have been faithful to the design intent with respect to whole building energy performance and not just functional tests at a component level;
4. **Operations:** Ensuring persistence of the design intent as components age and the building changes usage due to movement of tenants and different occupant needs and as operators override the intended operating sequences.

It is critical to understand where energy efficiency is lost to be able to target R&D.

R&D Elements For A Systems Approach

A systems approach can reduce the energy efficiency losses by identifying and controlling the interactions among building subsystems. In this way it is possible to drive down energy consumption dramatically and to ensure that these energy savings persist. It is critical, though, to understand that the substantial science and technology base to reliably and in a cost effective manner realize such savings in the market simply does not exist today.

Two basic flaws in the current design and operation of buildings contribute to poor energy performance. First, the design and construction of commercial buildings do not utilize metrics or tools to identify and quantify critical interactions, or "coupling," between subsystems. Computational tools are not used initially in the design phase nor are these couplings tracked during the changing construction process. Second, the coupling between subsystems are neither monitored nor controlled to avoid the erosion of performance in operation of the building.

The reality of today's methodology and tools is that attempting to couple subsystems—even using higher performance (efficient) components than are routinely used today—does not regularly deliver the levels of efficiency gains needed and, in some cases, produces negative effects from improper integration. Case studies show that even new buildings that are constructed with state-of-the-art "energy efficient" technologies can fail to achieve desired levels of efficiency due to the detrimental coupling of modified subsystems. A study of high-performance buildings by the National Renewable Energy Laboratory (NREL) demonstrated that even with a range of advanced component technology (ground source heat pumps, an under floor air distribution system, daylighting, and high-performance windows), when the systems were not properly integrated, the building measured a 44 percent reduction ratio versus 80 percent when all components were fully integrated. Unfortunately, the NREL results are not atypical and represent a significant barrier to wide scale adoption of high-performance integrated building systems.

The systems approach considers a building as a complex dynamic system that has considerable uncertainty in both operating parameters and the operating environment. Indeed, the Brown report[2] states:

> *A complex system is a collection of multiple processes, entities or nested subsystems where the overall system is difficult to understand and analyze because of the following properties:*

[2] D.L. Brown, J. Bell, D. Estep, W. Gropp, B. Hendrickson, S. Keller-McNulty, D. Keyes, J.T. Oden, L. Petzold, and M. Wright. Applied Mathematics: A Report by an Independent Panel from the Applied Mathematics Research Community. Technical report, Lawrence Livermore National Laboratory, 2008.

- *The system components do not necessarily have mathematically similar structures and may involve different scales in time or space;*
- *The number of components may be large, sometimes enormous;*
- *Components can be connected in a variety of different ways, most often nonlinearly and/or via a network. Furthermore, local and system-wide phenomena may depend on each other in complicated ways;*
- *The behavior of the overall system can be difficult to predict from the behavior of individual components. Moreover, the overall system behavior may evolve along qualitatively different pathways that may display great sensitivity to small perturbations at any stage.*

Such systems are often described as "multi-component systems," or when the components are physics based, "multi-physics systems." When the components involve multiple spatial or temporal scales, the adjective "multi-scale" can be used as well.

The challenges for buildings reflect precisely those stated for complex systems: to predict the overall behavior, which depends critically on the coupling of the subsystems, and the uncertainties in the built environment.

The coupling of components is difficult to achieve and requires the development and use of new science and engineering approaches to avoid the detrimental coupling discussed in the NREL work mentioned above. New science, design methodologies and tools will then be used to capture the complex couplings, enable the deployment of technologies that can take advantage of the natural dynamics of the building (e.g., natural ventilation, free cooling, and thermal storage).

More specifically, what is needed for targeted R&D relative to the picture of energy efficiency losses and the benefits of a systems approach for complex dynamical systems. In our view several specific R&D elements at the science & technology level should be established. We believe these recommendations are necessary in order to meet the challenge laid out by Secretary of Energy, Dr. Steven Chu, in his March 2009 testimony before the U.S. House of Representatives Committee on Science and Technology wherein he states:

We need to do more transformational research at DOE to bring a range of clean energy technologies to the point where the private sector can pick them up, including: Computer design tools for commercial and residential buildings that enable reductions in energy consumption of up to 80 percent with investments that will pay for themselves in less than 10 years; and . . ..

Computational R&D Thrusts

The foundational elements UTC believes will support this vision are computational support for design, optimization and control. Attention to modeling, analysis, simulation and control is also advisable along the following directions:

- **Systems Engineering and Design Methodologies**
  - Rigorous and scalable process and tool environment for building project requirements management & system architecture exploration
  - Integrated mechanical and control design methodology and simulation environment
  - Architectural exploration tools with rigorous capture of performance uncertainties
- **Optimization and Control of Multi-scale Dynamics**
  - Analytical techniques for system decomposition, analysis and uncertainty propagation in heterogeneous, networked, multi-scale building systems
  - Optimization and simulation techniques for multi-scale computations
  - Nonlinear dynamical systems theory tools to exploit natural dynamics
- **Robust Control and Decision Support Algorithms**
  - Control and Commissioning Systems
  - Supervisory and de-centralized control theory and algorithms
  - Estimation and machine learning techniques to synthesize actionable information from heterogeneous, asynchronous and uncertain data streams
  - Automated fault detection and diagnostic (FDD) capabilities using building automation systems

The focus here is on computational capabilities. Hardware testbeds should be used to validate models and capture the relevant physics for sub-scale experiments to provide environments where subsystem interactions can be captured in a controlled environment, and help identify gaps in existing components. There should be a range of testbeds which move from sub-scale to full scale systems. The testbeds are also a critical element to enable teaming between academic, National Laboratories and industry and to facilitate adoption of new technologies by end-users.

It is worth emphasizing that these areas of R&D targets are not unfamiliar to other industries.[3] In the aerospace and automotive sectors, performance requirements have driven both investments in underlying science and technology along the lines of computational support for design, optimization and control along the lines listed above.

UTC has partnered with numerous federal and State agencies to further technology and standards development. In particular the United Technologies Research Center led, proposed and executed a National Institute of Standards and Technology (NIST) Advanced Technology Program project, "Integrated Building Energy and Control Systems (IBECS)," that focused on system-level modeling and simulation environments as a means of understanding and reducing building energy consumption. UTC is developing advanced control and information systems to improve energy efficiency in buildings using a systems approach to building modeling and operation in collaboration with Lawrence Berkeley National Laboratory, the University of California at Berkeley, and the University of California at Santa Barbara, and seeks to demonstrate those technologies on the University of California at Merced's campus. This program, co-sponsored by DOE's Energy Efficiency & Renewable Energy, the California Energy Commission, and UTC, represents an example of multidisciplinary teams composed of industry, academia and National Laboratories. The program's work is also an example of full scale demonstrations that must be carried out to enable risk reduction of new technologies in building energy performance but that utilize foundational science and technology.

In addition to the development of science & technology, a number of UTC business units participate in standards bodies. Work in inter-operability with the BACnet[4] standard has been led by Automated Logic Corporation (ALC) while engagement with the ASHRAE 90.1 standard has been strongly engaged by Architectural Energy Corporation (AEC), both of which are units of Carrier.

R&D Thrusts to Fuse Foundational Science & Technology with Market Transformation

The building industry in the area of energy consumption lags behind other industries in the use of computation, theory and information technology. Also, while the automotive and aerospace industries serve as a starting point in what is needed for the science and technology base, much work needs to be done to understand the relevant physics, capture the physics into appropriate modeling tools, and develop computational and analysis algorithms. Furthermore, additional work is necessary to tailor research to the needs of buildings and to enable a work force that can effectively use the new methodology and tool set. These efforts transcend any one company and are therefore appropriate for DOE investments.

Computational infrastructure is critical to remove points where energy efficiency is potentially lost and to enabling cost effective scaling of new design processes such as the Integrated Project Delivery approach for concurrent engineering advocated by the industry.[5] This R&D thrust by itself, though, is not enough to achieve transformational change. We believe that DARPA style investments, such as those that could be accomplished within the Office of Science in the newly created ARPA–E organization, are also necessary. We believe that large, multi-institutional, focused teams with specific milestones and aggressive metrics are necessary to advance energy performance enhancement solutions. One area that could utilize such investments is the design and operation of retrofits. In this area investments are needed that develop and utilize science and technology but also include prototyping and technology demonstration at scale.

In the area of retrofitting, R&D targets should include similar elements to those recommended above for the computational development but should target specific

[3] See for example the PITAC report "Computational Science: Ensuring America's Competitiveness," June 2005.

[4] BACnet is a data communication protocol for building automation and control networks. BACnet was developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to create a protocol that would allow building systems from different manufacturers to inter-operate.

[5] *Integrated Project Delivery: A Guide, The American Institute of Architects,* 2007.

technologies and increase the performance of targeted market verticals. Elements of such an R&D program should include the following:

- Building performance assessment
  - — Need: Process and tools for rapid failure mode assessment, sensing, model calibration, and analysis of the lack of building performance.
  - — Response: Mathematical tools, measurement systems, scalable algorithms and application (for example focusing on DOD, GSA, and university campuses).
- Design of systems for effective and robust retrofits
  - — Need: Process and tools for trade studies and optimization of multi-scale dynamic systems (focusing especially on emerging technologies: active facades, natural ventilation, passive heating and cooling technologies).
  - — Response: Tools (integrated within BIM) and application.
- Robust and persistent implementation
  - — Need: Modular platforms (equipment and controls) and decision support (for rapid implementation and performance persistence).
  - — Response: Scalable, simple-to-use toolset, DOD/GSA/campus implementation.

In summary there should be two types of R&D investments to attack the sources of energy efficiency loss. One is investments in computational infrastructure. The other is large, targeted programs to attack specific issues and market verticals and to couple the science & technology with demonstrations.

We believe that a heavier focus on fundamentals in the R&D portfolio than has occurred in the recent DOE history is required to move the needle on energy consumption in buildings. We believe that the two specific thrusts above are needed in addition to tighter coordination between elements of DOE, specifically, the computational resources within the Office of Science and the building domain expertise and demonstrations currently within the Energy Efficiency and Renewable Energy office.

Policy Recommendations: Comprehensive National Strategy

The House Science and Technology Committee must address the potential future contributions that can be made from supporting and overseeing basic and applied scientific research, development, demonstration, commercial application of advanced energy technologies, and energy efficiency. But this is just one piece of the jigsaw puzzle.

In the short-term, Congress should take immediate steps to encourage and enhance building efficiency. Specifically, Congress should enact legislation that promotes investment in energy efficiency in the buildings sector, for example The *American Recovery and Reinvestment Act of 2009* provided tax incentives to spur investment in energy efficiency, funding for energy efficiency and green buildings and support for various science and technology programs.

Congress should continue to focus on energy efficiency in buildings as it considers comprehensive energy and climate change policy through a number of relatively short-term measures including:

- Use of Energy Savings Performance Contracts (ESPC) that will multiply the job creation potential of recovery funds used for energy efficiency projects, and will ensure those funds are used in a transparent and verifiable manner.
- Establishment of a national performance based standard for building retrofits that measures success in energy efficiency based on actual measured savings after a retrofit is complete.
- Energy audits for existing buildings should be required to ensure that existing property is operating at the highest level of efficiency. All commercial buildings should commit to ongoing (i.e., at least every three years) energy surveys to measure and monitor energy use, and to identify opportunities for improvement.
- Those who invest in reducing energy consumption and demonstrate validated results should be eligible for accelerated deprecation schedules or other financial incentives.
- Establishment of a national energy efficiency standard either as a stand alone requirement or included as a compliance mechanism as part of a national re-

newable electricity standard to encourage low emission, high efficiency base load energy resources.

- A systems approach to tying these technologies together in commercial buildings and removing regulatory barriers to implementing near- and long-term cost-effective net zero energy building approaches.

In the longer-term, UTC believes that in order for investments to fully realize the benefits of whole building design and operation, the DOE and other agencies must address a number of science and technology issues including:

- **Recommendation I: Measurement and Transparency.**

  The Federal Government, especially the Department of Energy and the National Institute of Standards and Technology, should consider establishing measurement science for building energy performance and devising common measurement standards and metrics to ensure that building energy performance can be effectively evaluated by the marketplace. Such evaluation should include the measurement of energy efficiency at the whole building level both in the design stage, using computational methodologies, as well as in the commissioning and operations stages.

- **Recommendation II: Technology and Organization.**

  The Federal Government should create specific research programs implemented through private-public partnerships to maximize the effectiveness of technology development and transition. Research and technology investments must be made in systems: the creation of system engineering practices and associated design processes and tools. The newly established Advanced Research Projects Agency–Energy (ARPA–E) is supported by UTC and the recommendation is to create an office within ARPA–E whose investments would solely focus on systems methodologies, tools and technologies for building energy efficiency. Projects in the ARPA–E portfolio should be conducted on a multi-year basis with joint university-National Laboratory-industry teams.

- **Recommendation III: Computational Methodology and Tools.**

  The Federal Government should initiate programs that build foundational infrastructure in modeling, simulation, analysis and controls focused on building systems. The portfolio should include elements that address (a) capturing fundamental physics, (b) developing simulation algorithms and computational infrastructure tailored to building physics and (c) developing analysis tailored to the specific dynamics of the built environment. Automated fault detection and diagnostics would be included in this set of tools.

- **Recommendation IV: Facilities.**

  The Federal Government should encourage public-private partnerships with incentives to promote facilities that help users validate and test the performance of hardware and software in a real, integrated building environment to reduce risk and enable wide-scale commercialization, particularly for "systems" technologies and solutions. Demonstration projects to engage key stakeholders in the buildings industry will reduce risk for deployment to the entire building stock. The DOE Energy Efficiency and Renewable Energy program portfolio should be augmented with systems technology and methods should be matured through relevant demonstration programs that are planned and executed with joint multi-disciplinary university-National Laboratory-industry teams.

- **Recommendation V: Talent.**

  The Federal Government should invest in education and training carried out to define the new knowledge and skills required by the methods, systems, and tools for deploying and maintaining systems. University and government buildings and facilities should be used as case studies and demonstration sites for advanced monitoring, control, simulation models, prototypes, component, and systems research. There must be engagement with all components of post secondary education including professional and vocational training with community colleges and other organizations for building design, construction, commissioning, energy analysis, energy accounting, and operations to ensure a talent base that can design, install and maintain building systems.

Thank you for the opportunity to submit this testimony to the Committee. I would be delighted to respond to any follow up questions regarding this testimony or the recommendations contained within.

BIOGRAPHY FOR J. MICHAEL MCQUADE

J. Michael McQuade is Senior Vice President for Science & Technology at United Technologies Corporation. His responsibilities include providing strategic oversight and guidance for research, engineering and development activities throughout the business units of the Corporation and at the United Technologies Research Center. He also provides leadership to UTC Power, UTC's business unit responsible for the research, design, commercialization and after-market support of stationary and transportation fuel cells.

McQuade has held senior positions with technology development and business oversight at 3M, Imation and Eastman Kodak. Prior to joining UTC in 2006 he served as Vice President of 3M's Medical Division. Previously, he was President of Eastman Kodak's Health Imaging Business. Earlier, McQuade held technology and business leadership positions at Imation Corporation after its spin-off from 3M in 1996. His early career at 3M was focused on research and development of high-end acquisition, processing and display systems for health care, industrial imaging and remote sensing. He has broad experience managing basic technologies and the conversion of early stage research into business growth.

McQuade holds doctorate, Master of Science and Bachelor of Science degrees in physics from Carnegie Mellon University. He obtained his Ph.D. in experimental high-energy physics for research on hadronic charm quark production performed at the Fermi National Accelerator Laboratory.

McQuade is a member of the American Physical Society and is a member of the Boards of Directors of the Connecticut Science Center, the Connecticut Technology Council and the advisory boards of the Schools of Engineering at Yale University, the University of California at Berkeley, the University of Connecticut and the Institute for Energy Efficiency at the University of California at Santa Barbara. He is also a member of the Board of Trustees for the Center for Excellence in Education and Board of Directors of Project HOPE.

United Technologies Corp., based in Hartford, Conn., is a diversified company providing high technology products and services to the aerospace and building industries worldwide. Its businesses include Pratt & Whitney aircraft engines, Sikorsky helicopters, Hamilton Sundstrand commercial and military airplane and space-based systems, Carrier heating, air conditioning and refrigeration equipment, Otis elevators and escalators, Chubb and Kidde security and fire detection and prevention systems, and the world leading fuel cell products from UTC Power.

DISCUSSION

Chairman BAIRD. Thank you very much. I thank all the panelists for very, very informative and stimulating input. We will now proceed with questioning. The procedure basically is that each of us asks about five minutes' worth of questions and then we alternate sides. We have been joined as well by Ms. Edwards. You are right to be proud of your Representative. She is a fantastic Member of this Congress. Ms. Giffords was here a moment ago, Mr. Matheson and Mr. Tonko as well, all very active, committed Members of the Committee, very interested in this. We are grateful for their presence as well and we will proceed then with questions.

AN INTEGRATED APPROACH TO ENERGY EFFICIENCY

What strikes me as I listen to you folks is that clearly the 40 percent figure is a very, very prominent part of our energy equation. It seems to me that all of you have a fundamental role to play. To what extent—we have got this great gathering of experts here on this committee. To what extent do you actually work together in the real world? And by that, I mean to what extent does DOE work with each of you, to what extent does, for example, UT work with the social behavioral side, does social behavioral side work with the code side, with the industrial—talk to us a little bit about that.

Can you do more? Do you do enough? How can we facilitate that? Mr. Coad.

Mr. COAD. Mr. Chairman, getting on Dr. Ehrhardt's subject, I believe that energy and the proper use of energy is an ethic. I think we have to find some way to get the public, the people to adopt the ethic. Energy efficiency isn't—this isn't rocket science. This is very simple. When you walk out of the room, you turn off the light. When you are not using the building, you put it on an idle mode and you don't leave it running 24 hours a day because you are only occupying it for eight. So I think we work together. I learn a lot from being around people like we have on the panel and this subcommittee. We are continually learning. Energy efficiency is not rocket science.

Chairman BAIRD. But we still need this integrated approach.

Mr. COAD. It has to be integrated right on through but it is not rocket science, and when we talk about efficiency, we are talking about doing things more efficiently but doing the same work, keeping the same productivity up. That is what the high-performance is all about.

Chairman BAIRD. I have advocated, and some of my colleagues tire of me saying this but after various trips around the world and seeing what is happening to rain forests, icecaps, coral reefs, my own belief is, we ought to make a national commitment to a 20 percent reduction in energy in 20 weeks, not by 2020 but 20 weeks, and I think we have evidence that it can done if there were an ethic and if we used behavioral sciences and if we integrated with the technology, and by the way, as some of you said, that is not true necessarily. We do have to use the gee whiz new technologies, maybe solar, photovoltaic paint, et cetera, things of that sort, but we could do this behaviorally without additional costs and an enormous savings very promptly.

Dr. Ehrhardt-Martinez, talk to us a little bit about the social scientists can integrate with some of the other testimony we have heard today.

Dr. EHRHARDT-MARTINEZ. Well, I think, you know, to a certain degree it does happen. The problem is that to a large degree it doesn't happen in a systematic way or a widespread way, and particularly I think there is a lot to be gained within the DOE programs for a more concerted effort to really include the social sciences at all stages and throughout all of the programs that they work on. You know, it has been—if you look at all of the funding that has gone to climate change research, two percent or less has gone to the social and behavioral sciences. It is a minuscule amount, but yet, as I said in my testimony, you know, there really—you know, if we really—it really is a human problem. I mean, it is a human-created problem, and if we really want to understand how to address this problem, we really need to incorporate the social and behavioral sciences to unlock, you know, the knowledge that exists and apply it to these questions about why is there these two persisting gaps between what the technology can provide in terms of energy savings and what is really provided. It is a human equation.

Chairman BAIRD. Let us ask Mr. Chalk then a little bit. What Dr. Ehrhardt-Martinez has said I obviously agree with and I think we have abundant evidence to it. Mr. Coad pointed out there is an ethic, it is a behavioral element. Given that, to what extent does DOE involve human behavioral sciences, whether it is economics, psychology, sociology, et cetera, even anthropology in some cases maybe, to these various programs that it oversees on building industrial efficiency?

Mr. CHALK. Well, specifically, this is an important area. In fact, we are in the process of hiring somebody with a behavioral science background. But to answer your earlier question about how we work, I mean, Mr. Cicio mentioned he is pleased with our industrial program, which is another 33 percent——

Chairman BAIRD. Did you pay him to say that?

Mr. CHALK.—of the primary energy. So we are talking about 70 percent of the primary energy here today with industrial plus the building efficiency. The other thing that we have done in establishing our Commercial Buildings Initiative is worked with code organizations, worked with companies like UTC on the technology but also built alliances across the whole value chain, working with the realtors, working with the building owners, and the building owners are typically not the people that occupy the buildings in the commercial space so sometimes the building might be designed for another purpose than the occupants are using it for or they decide to run two shifts instead of one shift. So this gap that you have between design intent and actual use of the building is very, very critical, so we try to work with the whole value chain, if you will, of retail associations and alliances. We have a national accounts program that brings in big box developers and things like that. So we try to work with the whole value chain until we get everybody's input when we approach this from a systems standpoint.

Chairman BAIRD. I want to acknowledge, Mr. Cicio, one brief point about the realtors. One of my colleagues suggested or actually a realtor back home, one of the prime opportunities for doing residential retrofits on energy efficiency is at the point of sale. So once the selling party has vacated the home and the purchasing party hasn't moved in, that is when you hit and we ought to have some way to target our incentives right at that moment because you don't disrupt everybody's life. That is when you really ought to—and we ought to be able to roll it right into the mortgage, and if we are going to do some tax incentives put that tax incentive right on at the point of the transfer of the home or the business because that is when you are most able to do that kind of work.

Mr. Cicio, you wanted to comment and then I will recognize my colleagues.

Mr. CICIO. Yes. The cross-hair where we as manufacturers cross over and work with the building people, we are suppliers so when we improve the quality of the products, the diversities of the products, whether it is for lighting or for simple things like double-pane windows or glass insulation, we are the providers of those materials for them. Where the ITP program comes in is, it provides new technologies, breakthrough technologies that help provide these new needed materials, but also important is to help keep costs low because obviously you have heard from Mr. Coad, it is about cost and it is about economic return that helps drive energy efficiency.

Chairman BAIRD. So you are both consumers of energy in the process of the manufacturing but producers of the new equipment that is going to help us solve the problem?

Mr. CICIO. Absolutely.

Chairman BAIRD. Mr. Inglis.

EXECUTING BEST PRACTICES IN THE PUBLIC

Mr. INGLIS. Thank you, Mr. Chairman. You know, I was talking to a physician recently about health care and he says we all know what we need to do, we need to eat well, we need to exercise, we need to sleep plenty, we need to drink plenty of water, it is just we don't do it. And in the case of energy usage, we all know what we need to do, right? It is just we don't do it. So tell me how it is that we are going to do it. I am hoping that one of you gives the secret answer. There is a secret answer. So let us see if you know it. Yes, Dr. McQuade.

Dr. MCQUADE. Thank you very much. If I may, I think it is a very true statement. I think in the energy efficiency building study that was released yesterday, the sort of we know what we should do and the economics of doing it come together for something in the range of 40 to 50 percent of the reduction that can be achieved. So today's technology, five-year paybacks, market incentives to achieve that can really be accomplished. I think to go beyond that to achieve the sort of hyper-performance we want in buildings, the 80 percent reduction is going to require a combination of new technologies and new systems, and I would say that thinking about the things I testified today about building systems, those combined with human factors and behavioral sciences really to create buildings, think about commercial buildings that actually tune and optimize themselves. So it is one thing, for example, to require or ask someone behaviorally to turn the lights off when they leave the room, it is another thing to install motion sensors to turn the lights off automatically. So we think there is a key role that can be played by both the technology side and the human factor side to achieve that. So back to your question, I think a significant portion of the technology base we have today can give us substantial reduction in building energy consumption, 40 to 50 percent. To go beyond that to achieve these really strong numbers is going to require the kind of things that you heard today in terms of both technology investment and human behavior investment.

Mr. INGLIS. Mr. Cicio.

Mr. CICIO. Congressman Inglis, for the manufacturing sector, it is we are different, I would differ with you. The manufacturing sector's greenhouse gas emissions are only 2.6 percent above 1990 levels while the commercial, the residential, the transportation and the power sector greenhouse gas emissions are up on average about 30 percent, and the reason that we have—for two reasons we have improved energy efficiency, it is a cost, and without reducing energy costs, we lose competitiveness. So we are the only sector. We have always had the price signal to force down energy consumption. So we would differ in perspective of the others but can we do more, yes, and we have lots of different ideas on that but technology is at the core of these things.

Mr. INGLIS. Take my house, for example. The reason it doesn't have a solar panel on the roof is because electricity is just so cheap. I mean, it is not—the economics don't work out for me to put even a simple solar hot water heater, which isn't that something like 30 percent of my home's electricity or some amazing number? And I have lived in South Carolina and we have a beautiful southern exposure and we don't have a solar hot water heater. But it is because the economics don't work out, right? Ben Franklin, "what we obtain too cheaply we esteem too lightly," and so if I obtain electricity so cheaply, I sure do esteem it lightly. Is that right, Dr. Ehrhardt-Martinez?

Dr. EHRHARDT-MARTINEZ. I think that is definitely part of the answer. I guess I would respond by asking you, you know, if in fact you were able to establish something like smart grid technologies and you were able to feed your electricity production from your solar panels back into the electric system, how would that change the equation and change your decision-making process?

Mr. INGLIS. I think it clearly would. It would change the economics. Because the secret answer I was looking for is, it is about economics here. It is about making it so that this works out for me to put that solar hot water heater on my roof to make it so I want to have that technology, and if I decide I want it because I am sort of aware of the price signal, I will change my behavior. Is that right?

Dr. EHRHARDT-MARTINEZ. Well, I would just add to that, I would say that that is necessary but not sufficient. I think that there are other factors that come into play. You know, just because it is economical doesn't mean everybody is going to go out and do it, and I think that we need to recognize that there are a variety of other things, barriers, you know, sociocultural barriers, a variety of things that also shape, you know, people's decision-making process and their habits and whatnot, and it is important to keep those in mind as well. So, yes, it is one of the components but there are other things going on as well.

Mr. INGLIS. So I have a bigger view of economics than you do maybe but it is basically this, that, you know, as Tom Friedman has written, we found out what it is. It is $4 a gallon changes behavior on gasoline because apparently one of the reasons that GM killed the electric car is people didn't want to plug in their car, they said. But in the midst of $4-a-gallon gasoline, ask people in town meetings, would you mind plugging in your car, there was nobody who resisted plugging in their car at $4 a gallon. And so it sort of changes us, doesn't it, when we realize gee, we must change. And so just a short commercial with the Chairman's indulgence. That is why if we do something better than cap-and-trade, a revenue-neutral carbon tax, where you reduce taxes elsewhere so people have money in their pocket to buy some of these fabulous technologies and they have the price signal, they will do it. And of course, I am sure there are some other barriers to be overcome but necessity is the mother of invention, especially when it comes to rising energy costs, and it would cause me to change my behavior. I would be buying one of those solar hot water heaters for my roof.

Thank you, Mr. Chairman. I am out of time.

Chairman BAIRD. I always appreciate the commercial announcement for the alternative which by coincidence I happen to support.

Ms. Edwards is recognized next for five minutes.

Ms. EDWARDS. Thank you, Mr. Chairman, and I think I will start out with a question for someone from Bowie, Maryland, Dr. Ehrhardt-Martinez. Thank you all for your testimony today.

CONSUMER EDUCATION AND BEHAVIOR

I am curious about this behavior question because I know in my own home, I know plenty of things that I could do to reduce my energy use in the home and to consume better, and I have only done a couple of those things, and I often describe myself as heating and cooling only my cat for all of the space, and I think a lot of folks are like that and so I wonder what realistically we can do from a public policy perspective to push changes in behavior. I will just give you an example, that a lot of our policy relies on things like tax credits and so if you are, you know, in a working family, middle class family, you know, to make the tradeoff between college tuition or daily expenses and changing your energy consumption in your house in exchange for a tax credit that is going to come later on, makes that a very complicated decision and so I wonder if you could talk from a policy perspective of things that we could do to actually incentivize changes in consumer behavior.

Dr. EHRHARDT-MARTINEZ. Okay. That is a tough question. I think that it is important to keep in mind that a lot of these investments in energy efficiency are, you know, cost effective in that they do pay for themselves over time so I think that, you know, that is where we need to begin is to make sure that people are aware of that and then to come up with mechanisms to help them overcome barriers whether it is financial barriers or other types of barriers for the people who are interested in actually pursuing those types of changes. But we also have to recognize that there are—you know, that the world is full of different kinds of people and that different people face different barriers and live different lifestyles and, you know, live in different conditions and have different resources at their disposal and so I think it is also important to recognize that while there are some people who like you are aware of, you know, what needs to be done and perhaps need simply certain incentives in order to do it, there are other people that maybe need, you know, more information. And then it is also about how we provide that information and how we go about providing programs as to whether or not those programs are more or less likely to be effective. So, for example, there is research on—there is a very long history of research on home retrofits and, you know, why some programs—and there is a huge amount of variation in terms of how successful those programs have been in actually getting consumers to have their homes retrofitted and generate energy savings as a result, and one of the insights from that research has been that, you know, the huge variation is more a function of how the programs are being implemented than they are of—I mean, so you can have the same program that has the same incentive structure but the way in which the program is implemented and the way that information is, you know, distributed to people and things of that nature have, you know, just a dramatic effect on the proportion of people that actually participate in that program and are able to reap the rewards.

Ms. EDWARDS. Thank you very much. And then my last question for Mr. Chalk has to do with building efficiencies and the way that buildings get described as being efficient. I know as kind of a, you know, slightly outside—it is very confusing. I had folks in my office just a week or so ago and they were describing that they met some sort of environmental standard for their building, and I had no clue what they were talking about. I don't really understand the standards. I think there is a wide variation in the ways in which people can describe their buildings and the efficiencies of those buildings and I think that we need to clear that up so that builders and developers have some sort of and consumers comparing apples to apples.

Mr. CHALK. Yes, we have a label much like buying an appliance. It is an energy guide label. It tells you how much electricity a refrigerator uses. So we have developed with the building community a label that says this house is rated at this energy use and you will pay approximately this much in average utility bills for all your loads whether it is thermal or electric.

Ms. EDWARDS. But what about commercial buildings?

Mr. CHALK. For commercial buildings, we are just beginning the Commercial Buildings Initiative and there in reference to your previous question it is very difficult because the owner of the building who pays for the construction is not the one that pays the energy bills so we need to work with both groups then to decide how to incentivize, what are the right policy mechanisms that need to be evaluated to incentivize greater energy efficiency. But back to the home. When you buy a house, you have to have a termite inspection. If you also had to see the energy use of that house, then that would also be something very valuable and that is what we working on so we would have greater adoption in there so that consumers are informed as they go and buy a house, you know, maybe they can afford the mortgage, which is the first cost of the house, but the utility bill is typically not included in that, in the mortgage, so we need folks to realize what their energy bill is going to be as they purchase the house.

Ms. EDWARDS. I think my time has expired. Thank you, Mr. Chairman.

Chairman BAIRD. Dr. Ehlers.

Mr. EHLERS. Thank you, Mr. Chairman, and thanks to the panel for being here. This is one of my favorite topics even though I spent 35 years on it so far but it never ceases to amaze me how difficult it is to get people to change their behavior, so I am very pleased you have Dr. Ehrhardt-Martinez here to enlighten us on that. I think one of the biggest factors, and I am speaking now as a physicist, the public just doesn't understand energy. They don't know what it is and how it can happen, and a number of times I have given speeches talking about how I wish energy were purple because if people could see the energy, they would behave differently. If they drove up to the house in the winter and saw purple oozing through the walls and purple rivulets around the doors and windows, they would say good grief, I have got to tighten up this house, and similarly with other activities. As it is, the only concrete evidence the average citizen sees about energy costs is the price at the gas pump and utility bill at the end of the month, and that is not enough. There have to be other ways.

Mr. Chalk, this is not intended to criticize you because I think the Energy Department is starting to change dramatically but it was very frustrating to me in my 15 years here to see so little being done by the Department of Energy to assist in this problem. In fact, the only real program I am aware of during the early years I was here was the EPA where they had their Green Lights Program, went around to various businesses, pointed out how they could save money if they put different lighting in, and if you show a businessperson that there is a payback time of about eight months, they put in a new lighting system, and the EPA did a fantastic job of that. My only criticism is that the Department of Energy, knowing the issue, should have done it long before. I think we have to hit all of these things and it is not easy. For example, I was upset with a poorly insulated attic in a house we bought so I determined to insulate it properly, and in a cold climate, part of that means you fill up every hole, you know, rafters, beams and so forth because when the electricians come through they just bore a hole through, put the wire through and that only occupies about a third of the size of the hole so that hole is leaking all the time up into the attic. I could not for any reasonable price get someone to come in and really do the insulation correctly so I did it myself. Our utility bill or gas bill, I should say, since we use gas for heat, was reduced by one-third, and because I didn't count my labor, that meant in a space of about a year I paid off the entire project. Now, that is a really good return on investment, but until we educate or require all those working on insulation to really understand what insulation does—and it has been so frustrating to me over the years to find how many people in the business don't really understand it. And I loved the example of where someone was building homes in a tract and somebody came by and noticed that they put formaldehyde insulation on the outside of the concrete shell but they stopped at ground level. They said why did you do that; well, we don't need it up here, it is just you need it down below to protect from all that cold in the ground. And they had no recognition that even though concrete has a very high heat capacity, in other words, it can store a lot of energy, it is also a very good conductor of heat so 48 inches of concrete is equivalent of 1 inch of formaldehyde foam insulation. If you don't know that, you are going to build a house the way he did. If he knew that, he would have built it in a much more energy-efficient way. So I think education is very important.

Now, the country is going to get much worse. We are always talking here about carbon footprints and everyone in the Congress is worried about that. That is not the real point. The real point Mr. Coad alluded to. He said we are going to run out of oil by 2010. Actually that is not right. That is when the production peaks, the Hubbert curve. So then it is half gone. But it does mean that it is going to be continually more expensive as we go on, and if the public responds only to money, then we are in bad shape because we are going to be quite a ways down the peak before they start doing the things. I really think it has to be a combination of the work you do, the combination that we should be doing in the Congress to make sure the public is well educated but through tax credits persuade them to do something which is just marginally effective. Thank you.

Chairman BAIRD. Excellent comments, Dr. Ehlers.

Mr. Matheson would be next and then followed by Mr. Tonko.

Mr. MATHESON. I am happy to go, Mr. Chairman.

RETROFITTING

Mr. Chalk, just a quick question. What do you—what would you need to have a successful retrofit program at DOE? I know funding is going to be one answer but I am looking for other things in addition to funding that you think you need that would help make that happen.

Mr. CHALK. A combination of things, and the retrofits are very important because as we talked about earlier, we can do 30, 40 percent on a cost-neutral basis now for new construction. Retrofits are much harder. Ms. Edwards was talking about there are other priorities for homeowners and so forth. So what we need, we have the R&D and we have been investing much more in commercial buildings research. What we need to do though is, we have been emphasizing and optimizing individual components like the HVAC, lighting, windows and so forth. We need to do more in integrating those components. There are tradeoffs. So, you know, when the climate changes outside, the windows are talking to the lights which are talking to—communicating with the HVAC system so that all of these things are working together for total optimization of the building and it is tied to the occupants whether they are there or not and to what type of activity. So systems control and integration of all these components from an R&D standpoint is the top priority, that with the right policy and finance because it is always the first cost that is the barrier. So if there are incentives for longer-term financing, that would be very helpful because these technologies do pay back but they may not pay back for eight, ten years. But that is okay. The building is typically in the inventory for more than 50, so I think we can do this. And the last piece is really workforce training that has been mentioned to make sure that people know how to install correctly, and as part of our weatherization program where we weatherize low-income housing, we offer training assistance so that people are doing that correctly and we have inspectors and so forth. So the combination of R&D, the right policies and financing as well as a strong deployment effort where we can demonstrate these technologies to folks where we actually—and one of the issues with the codes is, when you start out with a code it is really the design intent. We are not doing enough to follow up the actual measurement verification of energy use. We need to do that, disseminate that information and then combine that with workforce training, not just for the installers but also the building operators so they know how to change as the activity changes within the building, that they are continuously optimizing. So we almost need a brain or a CPU for the building, would be ideal, a dashboard, so that people could—otherwise they are just paying retroactively or a month behind what they used last month. They don't see real-time energy use going to lights when there is maybe nobody occupying or, you know, maybe there is a piece of equipment that is malfunctioning and the energy level shoots up. So those types of things need to be put in everyday practice and then I think having those things for the building operator will allow them to most efficiently operate their building and decrease their cost.

Mr. MATHESON. I appreciate that.

Mr. Coad, am I pronouncing your name correctly?

Mr. COAD. Yes.

GREEN BUILDING STANDARDS

Mr. MATHESON. In your assessments report, you point out that there is what you call a race to respond, a consumer demand for green products. Do you think the capacity exists within the building standards industry to effectively address the need for new standards for all of these green products and keep up what are undoubtedly going to be more and more products coming into this expanding marketplace?

Mr. COAD. Yes. The High-Performance Building Council at NIBS in their first—well, in their organizational year, they had, like, 80 different organizations who wrote standards assemble together for that year and they did an extensive study of all the standards that were available and they are now working on filling all the holes and they are working with Mr. Carnahan's group to try to get that whole thing organized. It is a massive undertaking but we have all the information out there and we are finding out where the holes are, and as soon as we find that out we are going to start trying to get various standards-adopting organizations to start plugging those holes. As I mentioned before, this is not—we make this thing too complicated. It is not that complicated. And from an economics perspective, and I am going to say something that nobody is going to believe me: it costs less money to provide a more energy-efficient product, it doesn't cost more money. It costs less money because it all relates to money and power. Power is how big something is and energy is how long you run it, and if it is smaller you pay less for it and you use less energy while you are doing it. That is an absolute fact. That is an engineering problem, and the man on the street can't solve it but the design engineers can solve it. You give me any machine you want and if I work at it long enough, I can always figure out how to make it smaller and use less energy. It is just a matter of motivation. We have the technology. And if we don't do the efficiency first, then we will never be able to solve the problem with alternate fuels. We want to adopt a slogan, efficiency first. That is the first order of business.

Mr. MATHESON. Thanks, Mr. Coad.

Mr. EHLERS. Will the gentleman yield?

Mr. MATHESON. I am happy to yield, yes.

Mr. EHLERS. Just one quick comment on that. We saw what happened after the 1973 energy crisis. What I think really soured a lot of the public on this since they didn't understand it was all the shysters who got in the market selling all sorts of products which they promised would save tremendous amounts of energy. Most of them were not worth anything at all. And so I just want to put in a plug, and I know you are working on this but I will put in a plug to have really good standards so the public doesn't get fooled because they have no way of measuring energy. They have to be assured that when they buy something that it actually is going to work and is going to help.

Mr. COAD. I agree with you 100 percent.

Mr. EHLERS. Thank you. I yield back.

Chairman BAIRD. Ms. Giffords.

Ms. GIFFORDS. Thank you, Mr. Chairman. I thought Mr. Carnahan was on our subcommittee. You should join our subcommittee. It is a good one. Thank you for visiting.

Chairman BAIRD. We will get to Mr. Carnahan. We are not being rude to Mr. Carnahan. We generally proceed in the order of arrival but Mr. Carnahan is joining us as a guest today so he is last. He bats cleanup for us today.

Ms. Giffords.

EFFICIENCY IN THE FEDERAL GOVERNMENT

Ms. GIFFORDS. Mr. Chairman, thank you for holding this hearing and for our panelists' incredible discussion. My first question is for Mr. Chalk. I am very interested in what DOE can do to help promote adoption of best practices in building design and also retrofits throughout the Federal Government. I thought it was pretty astounding that 80 percent of the energy used by the Federal Government is used by the Department of Defense. I serve on the House Armed Services Committee and I am particularly interested in how we can help the military to adopt best practices in energy efficiency and renewable energy and operations and installations. So can you please tell me how the DOE is working to help promote building efficiency within GSA and also the DOD? Is there anything happening within DOD that might also help inform research at the DOE and what efforts are available for cross-pollination?

Mr. CHALK. We have a program within Energy Efficiency and Renewable Energy called the Federal Energy Management Program, which is responsible for overseeing energy across the Federal Government, help get agencies the tools they need to save energy, and one of the best mechanisms we have for that are things called ESPC contracts, which are energy savings performance contracts where, you know, typically if you want to modernize your building or make it more energy efficient, you have to have up-front appropriations to do that. What this ESPC mechanism allows is private contractors to come in, they specialize in energy efficiency. They will put all the up-front money to switch out the lights from incandescent to fluorescent or, you know, upgrade insulation, HVAC systems, chillers and so forth. They will put all the up-front capital to modernize the building and then they get paid through the actual savings in the utility bill. So that is typically the primary mechanism that the Department of Defense is using, and they are doing a very good job at this. And actually if you look across all federal agencies, the Department of Defense is one of the leaders in terms of actual energy saved and in terms of putting somebody in charge accountable for energy management. So they are very, very good example. And so what our program does is, it gives people the tools to do that.

Ms. GIFFORDS. One of the specific problems we have, I come from Tucson, Arizona, is the heat of the Southwest, and I know specifically, well, not just with our military installations but our other government buildings as well, we have a real problem in keeping our buildings cool during the hot weather. So I am curious about the unique research challenges for the green building program. Is it insulation? What are the real possibilities that we can develop when you are talking about a climate that gets to be 115, 120 degrees?

Mr. CHALK. Well, the first thing to do is no air infiltration, and so it is about the building envelope, how well you are insulating it, making sure you don't have thermal bridges and conductivity. But then I think the breakthrough could be in new cooling technology and we are looking at several different approaches at the Department of Energy because cooling technology has advanced greatly. Heat pump technology and so forth is much more efficient than it was even 10, 15 years ago, so if you have a heat pump that is 15 years old, you can do a lot better today than that. But we can go beyond that to new technology for cooling and I think that is an area of emphasis going forward for our program, especially in the commercial buildings area.

IMPLEMENTING DEMONSTRATION PROJECTS

Ms. GIFFORDS. And finally, Mr. Chairman, for all the witnesses, one of my great concerns that I have, and we sit through a lot of these committee hearings, whether we talk to NREL or the high-performance green building consortiums and others and the work that is being done is very impressive, but I think that we need to move beyond pilot programs, pilot projects and demonstration projects to actually put what is being done in little specific areas out for the entire building industry. So if a couple people could please comment on how we go from these little projects to really implementing more national programs?

Mr. CHALK. I will comment just briefly. As we build these alliances in the commercial buildings area, we are building a database so every building that has demonstrated will go into the database, how it is used, what its energy use is, and we will take data on those buildings so this would be education out there to other architects, other developers so they can see what has been demonstrated at a much larger scale that goes beyond the research and development.

Dr. EHRHARDT-MARTINEZ. I would just like to add to that, I think that it is really clear that, you know, the whole question of distribution of technology and the diffusion of technology again is very much rooted in understanding human decision-making and, you know, when and why people decide to adopt these technologies and so again I think that the social and behavioral sciences need to play an important part in that process.

Chairman BAIRD. I think Mr. Coad had a comment he wanted to add.

Mr. COAD. I am the air conditioning guy. I can't not answer that question. The first thing you do when you are in Tucson and you are building a building is that you don't build a building the same way you would build it if it were in San Francisco. You don't build a building out of all glass with an enormous cooling load. You build a building so it has less of a cooling load. You use less glass and you use better insulation and then your cooling system will be smaller, it will cost you less money and it will use less energy. So the engineering and the architecture is, I mean, that is where it all begins in buildings. When you are building a new building, you reduce the load just by configuring the building of the right materials and so forth and then you are going to reduce the cost and the energy from then on. Thank you, Mr. Chairman.

Ms. GIFFORDS. And Mr. Chairman, just a comment. There was a federal courthouse built in Phoenix a couple of years ago, a glass building that is probably the most energy-inefficient building ever constructed where the guards that sit down at the entrance in the summer have fans blowing on them, in the winter have little space heaters. I mean, it is a huge atrium that has been constructed. And again, you know, it is a federal building, beautiful by design but incredibly inefficient and certainly is going in the wrong direction.

Mr. COAD. I certainly agree with you. I am very familiar with the building and you are right.

Chairman BAIRD. Those buildings tend to be water inefficient as well, as some of them cool by spraying water into the air in a desert. It makes an awful lot of sense. As you know, Ms. Giffords, the Chairman of the Transportation and Infrastructure Committee, Mr. Oberstar, has been a passionate advocate of green buildings for the Federal Government and in fact the stimulus package had a substantial element in that but it is only right that the Federal Government lead the way and we need to find more and more opportunities. I thank you for the line of questioning.

Mr. Tonko, as many of you know, has a long history in energy from his work in New York State. Mr. Tonko, thank you.

GREEN INFRASTRUCTURE FUNDING

Mr. TONKO. Thank you, Mr. Chairman. As was indicated, I had past experience most recently prior to this job as president and CEO of NYSERDA, the New York State Energy Research and Development Authority, very much pronounced activities in energy efficiency and retrofitting R&D investments. So my question would be following on Mr. Matheson where you talked about the successful retrofitting of programs through DOE. So Mr. Chalk, the next question I would have of that is, are we adequately funded within the building technologies program to be aggressive with the building infrastructure across this country? Are we at a level that is reasonable?

Mr. CHALK. Right now we have adequate funding, but I would also add to that that building efficiency is one of Secretary Chu's top priorities, so I think you will see more and more a priority placed on this, as everybody has said here, the significance of the energy consumption, greenhouse gases and water use.

Mr. TONKO. So does that imply that we will just grow that program with the human infrastructure needed at DOE?

Mr. CHALK. I think across the Federal Government we will see so much more emphasis on building efficiency: within the Department of Energy, within GSA, within EPA and so forth.

Mr. TONKO. I mentioned NYSERDA. The New York City office of NYSERDA is a net-zero office, and based on the *Energy Independence Act of 2007,* we are targeting 2025, I believe, as aiming to provide the net-zero outcome to a full-scale approach. Don't we need to be much more aggressive about that targeted year?

Mr. CHALK. I think that there are quotas associated with certain years in the Act. Right now with our funding levels we are on track by 2025 to meet that and what we talk about—so it is net zero now. But we talk about is affordable, you know, widespread market adoption so we are talking about when the commercial space about having a payback for that within five years. That is still a challenge, affordability, the cost of the technologies and we are going to get more elaborate building controls because we can get more efficiency. That is the emphasis of our R&D and we are still a ways from achieving those goals for a five-year payback.

Mr. TONKO. In regard to the R&D, are we supportive enough with the prototype stage? I know that we seem to be aggressive about funding prototypes and then a number of nations pick up on our R&D at that first stage and then we don't follow through with the deployment into the practical and commercial stages. Do we need to be more aggressive in the follow-up of prototype investment?

Mr. CHALK. Yes, the Department actually does very little—pays for very little demonstration. We pay for the R&D. We work with the code organizations so that new construction or major retrofits are more efficient and we actually don't demonstrate a whole lot. Our partners actually do the demonstrations.

Mr. TONKO. So maybe to other members of the panel, is there any reason to believe that we need to be ratcheting up the investments made in the post-prototype stages?

Dr. MCQUADE. If I may, sir, I think there are two aspects to the question, so the easy answer is yes because taking the large investment that DOE is making and turning those into deployable solutions is not happening fast enough.

Mr. TONKO. I think it is a real weakness in the energy culture of this country, so what would you recommend we do and where do we focus and target that?

Dr. MCQUADE. Yes, I think there is a second part of it, and I will refer to Mr. Chalk's comments on where research and development is spent. In some sense, I will use the word "easy." It is easy to do a one-off building and make it energy efficient. Part of where the research has to be focused is making solutions that are easily deployable at scale so that every building is not unique. We need tools that are deployable across the design space. We need simulation and modeling capabilities of buildings so that every building doesn't have to start from ground zero as a new project that no one has ever approached before and I think there is a significant investment now and continuing investment at DOE in developing generic tools that can provide generic building operating systems and capability so that it is not just, 11let me do a demonstration project and deploy that," it is, "let me do a demonstration project and deploy that to multiple classes and kinds of buildings going forward."

Mr. TONKO. And that that adjustment you believe can come through DOE?

Dr. MCQUADE. Yes, I do.

Mr. TONKO. Okay. And if in fact our behavior here is driven by economics and if the economics are played with by those who supply us a fossil-based economy, is there a way to deal with counter-economics where we provide the right incentives or the punitive measures? It seems to me we can figure out an efficient environment, the cost of an energy-efficient environment. Should those who want to be gluttonous in their usage pay beyond that reasonable amount?

Dr. MCQUADE. I think that—so the easy answer to the question is that you need to recognize the energy cost in the solutions you make, and that today the reasons some of the economics don't play out over the long-term—we talked before about the need to get that sort of last 20 or 30 percent of building efficiency. Right now those come from solutions that are economically unviable, and through a whole series of mechanisms to increase energy costs or increase, you know, recognize carbon costs, you can change that economics. I start from a more basic assumption that says the way to change those economics long-term is to invest in the technology that is going to change that. That is a combination of public and private partnership investment. Reducing the cost of those technologies is the one constant that allows us to make more efficient buildings in the future and change that economic situation.

Mr. TONKO. What about aggressive energy code enforcement? I mean, how are we letting buildings as that described by my colleague a minute ago in the State of Arizona——

Chairman BAIRD. We are a bit over time. I want to make sure I recognize Mr. Carnahan. We will get back to you, I hope.

Mr. CARNAHAN. Thank you, Mr. Chairman, and thanks to all the panel for weighing in on this. I really think that this is an exciting time for this issue and a lot of things have aligned to get some big things done we haven't been able to in the past. This issue has been around for a long time, as Mr. Ehlers mentioned earlier, but I think working with the private sector, the government has a key role in setting standards, creating incentives to really motivate consumers to grow the market but, also even to set an example in terms of our federal building infrastructure, and just a couple of comments. I know that Mr. Chalk mentioned this but one of the unique things that we have heard mentioned is how we can build into whether it is residential or commercial mortgages these kind of incentives that take into account cost savings and operational cost of the building. Because right now we are missing some of those things and that will be an incentive for buyers that certainly want to buy those kind of buildings that are more efficient but also to incentivize that from the building and the lending perspective. So that is just one good example.

HIGH-PERFORMANCE BUILDING STANDARDS

A couple of questions I wanted to throw out here to the panel. There is certainly a need to define high-performance building standards which potentially could be above and beyond existing building codes, and if there was adequate funding, what would these sort of enhanced high-performance building models look like in terms of getting them out there for use among the public and in the building sector? Dr. Coad.

Mr. COAD. I sound like a broken record but it is efficiency first. A high-performance building must be a super-energy-efficient building. That is the primary focus. The next thing it has to be, and this is why it is high-performance, it has to perform just as well as far as satisfying the needs of the people that occupy the building and the needs for their comfort and their productivity. So that is really where we are heading with high-performance buildings and hopefully we are going to get there, and to address the other question, I think the private sector has to move the building technology forward based on these standards for high-performance buildings.

Dr. EHRHARDT-MARTINEZ. Could I add to that? I would also argue that we really need to include in standards some kind of provision that provides feedback to people with regard to their energy consumption because the point that was made earlier about the fact that people—I mean, people can't manage what they don't see, and you know, you are trying to manage your energy based on a bill that you get after the fact and the fact that you don't really see how the energy is being consumed in your home. You know, people are left really powerless, in a lot of ways, to change their behavior in ways that matter because they don't really see the effects of the changes that they make. And there is already research evidence that strongly suggests that just by providing these feedback mechanisms to people in their homes, that simple step empowers people to actually take on the challenge of changing their own behaviors without any other kinds of incentives, without any other kinds of—whether economic or non-economic types of incentives. So I think that that really has to be an important part of the equation.

LIFE CYCLE ENERGY PRICING

Mr. CARNAHAN. Thank you. And I am going to jump to one more question as my time is running out. One of the problems we have also seen is the separation of the acquisition and operational aspects of buildings and it is really a dichotomy that has been difficult to bridge but in terms of taking into account the full life cycle cost of buildings, can you all address that issue?

Dr. MCQUADE. If I may, just a couple of statistics. First of all, most modern commercial buildings today, more than 80 percent of the energy and carbon associated with those buildings are in operation. They are not first costs on the building. We think there is a very important role that is needed in establishing labeling mechanisms. I am talking about commercial buildings now as opposed to residential buildings, sort of uniform labeling mechanisms that allow people to know how buildings operate, not just as designed but over the life of those buildings, so whether those are periodic auditing programs that take into account real performance on buildings, people who are buying space in new buildings need to know how those buildings are functioning not as they were designed 10 years ago but as they function today and so we think there is a very strong role for setting those kind of labeling standards.

In terms of regulating performance, I offer you one statistic. In the United States over 100 years, we have accepted certain codes and capabilities that make our buildings safe, sprinkling systems, fire detection systems. Estimates are that those add about four percent total to the cost of buildings over what we have developed over time. The numbers we are talking about here for making buildings 70, 80 percent efficient likely add numbers of eight to ten percent. So it is a comparable scale to achieve a national strategy of reducing energy comparable to what we accept as a cost that our buildings should bear in the marketplace over time. So we are talking about numbers that are appropriate and conceivable in the kind of challenges and tradeoffs we have already made for something as important as the energy security of this country.

Chairman BAIRD. An outstanding line of questioning, and I think the issue there is also the net cost at the end of the day, and I appreciate Mr. Carnahan's reference to life cycle costs. I have been told that, for example, LEED standards are all about the energy efficiency of the building as an envelope but they don't look at the net life cycle cost of the materials that go into the building so hence wood, which is a much more energy-efficient product to create than concrete or steel generally, is not counted as extra credit and indeed may not be counted as a structural material at all in LEED, and certainly as someone from timber country, they believe, and I think with justification, that life net total life cycle costs ought to be factored in.

Mr. Carnahan also mentioned the issue of standards and that leads to a question I want to ask in deference to my friend and colleague, Mr. Wu, who heads the Subcommittee with jurisdiction over NIST. I wonder if any of you have had interaction with NIST as we look at standards and if we were to look towards developing a standard metric for how we evaluate codes or measure building technology and efficiency, what role does NIST have or should NIST have in concert perhaps with DOE? And I open that to the panel.

Mr. CHALK. Well, first I ought to speak on that. The relationship with DOE and NIST is very good. In fact, DOE funds NIST with about $1 million a year out of the DOE budget, and they help us do the appliance test procedures. They help us an awful lot on indoor air quality and ventilation and helping setting standards and best practices in that area, and in fact there is an overall interagency group that meets under OSTP that NIST and DOE co-chair and they meet quarterly, so we are at DOE working very closely with NIST on all of these issues and especially in our new Commercial Buildings Initiative.

Chairman BAIRD. Mr. Coad.

Mr. COAD. Mr. Chairman, NIST is represented on the High-Performance Building Council as is DOE.

Chairman BAIRD. So they work together with you?

Mr. COAD. Right. They are all part of the council.

Chairman BAIRD. Is that an effective partnership in your judgment? Are there things that NIST ought——

Mr. COAD. Very effective, yes.

Chairman BAIRD. So that has been working for you?

Mr. COAD. Yes.

Chairman BAIRD. Mr. Cicio, did you have any comment on NIST's role with your efforts?

Mr. CICIO. No, sir.

Chairman BAIRD. Dr. McQuade, did you have a comment on it?

Dr. MCQUADE. No comment.

MEANS OF INFORMING CONSUMERS

Chairman BAIRD. What do you think might be some of the impact of—you know, when we buy cereal, it says you have got vitamin A or D or whatever in it. When you buy a house, you almost, you know—Mr. Inglis and I were talking. One would think that as informed consumers one would ask what is the cost of the heat of this house or the air conditioning of this house if you are in Arizona. But to my knowledge there is no mandatory reporting of the net energy usage of homes or industrial buildings, again, recognizing the caveats about the user function. What would be the impact of informing people as part of the home purchase—you know, you fill out 100 damn documents—pardon me—darn documents, you know, you are filling these things out, you are signing them and you don't know what they are. But something that says look, pal, you are going to spend $400 a month over and above your mortgage cost just to heat or cool this place. What are the—would there be merit to that, to having to do that at point of purchase? Mr. Coad.

Mr. COAD. In commercial buildings, there is what we call commissioning and retro-commissioning to where you go in and you do like an audit each year on how the building is performing, and one of the things you check is the energy consumption. It would be very, very, very easy to require that a building be retro-commissioned before a person buys it. I would see nothing wrong with that at all. And it would seem like with leadership from the Congress or the States or somebody, these would be pretty simple instruments to implement for the sale of a home.

Chairman BAIRD. Well, when you look at how many homes are funded either through FHA or VHA, Freddie, Fannie, et cetera, it ought to be fairly easy to require something like that and then people could see. I think it makes an awful lot of sense.

Mr. COAD. And all the records are available through the utility companies now instantaneously.

Mr. CHALK. The Department has developed a scale, and I hesitate to hold it up because it is too small, but we have a scale from zero to 100 as part of our Builders Challenge, which is getting builders to build homes 30 percent more efficient. So they would score a 70 on that. As you go to zero, you would go towards net-zero-energy homes. So we have developed such a scale and it is not mandatory, of course, but some tool like this would definitely inform consumers and make that——

Chairman BAIRD. I think that is really good for new buildings. I am not smart enough to know the answer but my guess is 90 percent of home sales at least are existing structures, and so my hope would be that when you shop buildings, that homeowners would say—back to Mr. Inglis's point, do you make the investment or not? If homeowners had reliable, ready information about the energy efficiency of a home, it would be part of their comparison shopping, and if it were mandatory that that be given to people, now my investment pays—otherwise it rolls off the tongue, well, I have got low E double-pane windows and a new furnace and blah, blah, blah. That is real money on top of your mortgage expense, and the one house now, its monthly payment is much higher than the other house because the other house has made the investment, that is valuable with existing structures.

Mr. CHALK. Right now it is voluntary. We have a Home Performance with Energy Star, DOE and EPA, where people can go in and do the measurement and then tell you what efficiency measures to take care of, but it is a voluntary program. It is not mandatory.

Chairman BAIRD. Mr. Cicio.

Mr. CICIO. Mr. Chairman, I think you are absolutely on point. The combination of knowledge and then transparency empowers people to know the economics of choices, and just referencing the industrial sector, before we invest in a new electric motor, for example, we will know how many BTUs per kilowatt, we are going to know how energy efficient. It is part of the informed decision. And I think the residential sector needs that same informed knowledge.

Chairman BAIRD. Dr. Ehrhardt-Martinez.

Dr. EHRHARDT-MARTINEZ. Yeah, I would have to agree. I mean, there is a lot of evidence to suggest that labeling programs can be really effective and I think that integrating that kind of program in terms of, you know, whether it occurs you know, related to the inspection of a home or prior to that when the home is up for sale, I think that could be a really effective way of empowering, you know, home buyers to make wiser choices, and that is part of, I think, you know, an effort associated with the field of behavioral economics in terms of what they call choice architecture which can go a long way to helping people make smarter energy choices.

Chairman BAIRD. My guess would be it would have to—as a behavioral scientist and somebody that has bought some homes, my guess would be it needs to be listed on the MLS.

Dr. EHRHARDT-MARTINEZ. That would be the preference.

Chairman BAIRD. So cost of home, cost of heat, you know, on the transportation side. I think we ought to also frankly put in information about the net cost of getting to and from work because when people move way out to the 'burbs thinking they are saving an awful lot of money on their home and then have an hour-and-a-half commute in, that is a pretty false economy.

Dr. EHRHARDT-MARTINEZ. Right, and there are other—I mean, obviously with that particular example there are non-energy benefits associated with, you know, living closer as well in terms of time savings and whatnot.

Chairman BAIRD. But we don't quantify that in a way that is meaningful to purchasers.

Dr. EHRHARDT-MARTINEZ. Exactly.

Chairman BAIRD. Mr. Inglis.

ENCOURAGING EFFICIENCY AT THE VARIOUS LEVELS OF GOVERNMENT

Mr. INGLIS. Thank you, Mr. Chairman. We were just talking about the first house that my wife and I bought. We were warned in advance that it had resistant baseboard heaters but we didn't really pay attention to that until that first bill came, and then we were shocked what January in South Carolina does when you have got resistant heaters on baseboard. But also I went and watched the meter go around and that gave me an even quicker feedback loop about, you know, the thing looked like it was about to catch on fire as it spun. So the question I think for us in a lot of these kinds of initiative is, who is going—who does what? My view is that balancing the budget is a lot about answering that question is who does what. If you get it at the right level of government, then you get—you can actually go toward balancing the budget. And in this case, the question is, these great ideas we are talking about here that really do sound pretty exciting to me, are they best done at the federal level or are they best done through model codes that then are adopted by, say, Greenville and Spartanburg County, South Carolina, and enforced at Greenville and Spartanburg level? What do you all think about that?

Mr. CHALK. Well, the Department, I think, one of the assets it has is the R&D, the national laboratory, so I think the proper federal role is to sponsor a lot of the R&D and we are seeing that R&D, the fruits of that labor creep into building codes, and to address the earlier comments, through the Recovery Act, $3.1 billion was available to states for the State Energy Program, but to receive that money, governors of the states had to pledge to the Secretary that they would adopt the 2007 commercial code and the 2006 residential code in order to receive that money. So even though the standards are voluntary, I think we are seeing mechanisms to incentivize folks who are adopting those. And through a lot of our R&D, the successes there actually creep into the code and then hit the local level, so I think you are seeing a lot of that. I think that has been pretty effective working with the code organizations.

Chairman BAIRD. Mr. Coad, do you want to address that?

Mr. COAD. The voluntary consensus standards are pretty powerful devices and virtually all the states that have a building code have picked up ASHRAE standard 90 for commercial buildings and they also have a standard for residential buildings that is being promulgated. I think my personal feeling is that the proper role of the Federal Government is in leadership and education and incentivizing the states to do these things rather than having other departments of the Federal Government getting involved in something that really are local issues. But the consensus standards are out there and they are getting better all the time. And now we are starting to have other kind of activities like doing so much better than the standard because the standards aren't really as far as you can go and we can do better than the standards, so that is a lot of incentive in that direction. So they are being pretty effective on that but it is just that we are not—we haven't gotten real serious about it throughout the country. We need better leadership, I think, or more leadership to realize that this is a big problem.

Mr. CICIO. The local politics are often driven by builders whose primary—I don't want to over-generalize—is very cost conscious and have a history, I should say, of resisting any costs including energy efficiency costs. So while philosophically it sounds great to keep those decisions at the local level, maybe possibly the only way you really are going to get this done is through a federal mandate.

Dr. EHRHARDT-MARTINEZ. I would have to agree with that sentiment, although also provide the possibility of having a Federal

Government standard but also having a Federal Government program that would provide incentives to states and perhaps localities to, you know, exceed those standards so to provide other means of encouraging that kind of behavior at the local and State level.

Dr. MCQUADE. I would just add maybe slightly off the subject that in addition to the leadership role that we talked about before, there is a leadership role in the set of buildings that are managed by the government, the GSA portfolio and the DOD portfolio, and conversation about local versus national standards, being out in front with energy-efficient performance in federal buildings I think is a leadership role that the government has to take as a way to demonstrate the seriousness of the issue to people.

Mr. INGLIS. Very helpful. Thank you, Mr. Chairman.

Chairman BAIRD. We have about six more minutes left so I am going to ask our colleagues be brief. Mr. Tonko has a question and then Mr. Carnahan.

Mr. TONKO. Thank you, Mr. Chairman. I couldn't agree more with the sentiments about having a federal focus on a comprehensive energy plan. If we are going to pick and choose here, we will never accomplish the numbers we need. I would hope that at the local level we would have the information squad that would allow people to understand just what their actions mean and the actions they can take.

The only line of questioning I wanted to pursue that I didn't have time for earlier was on this whole buildings agenda. How is it that the Federal Government occupies a building that is energy inefficient? Was that building built by the Federal Government or is it just rented space?

Mr. COAD. Which building?

Mr. TONKO. The one in Arizona that my colleague was mentioning.

Mr. COAD. That was built by the Federal Government.

Mr. TONKO. So how is it that we don't have the coordination at a federal level to even do our own infrastructure energy efficient-wise?

Mr. COAD. I can't answer that.

Mr. TONKO. Who can?

Mr. CHALK. Right now through our Federal Energy Management Program, there is a conscious effort across the Federal Government to reduce water use, and increase energy efficiency by 30 percent by 2015.

Mr. TONKO. How old is the building that my colleague cited?

Mr. COAD. It is a reasonably new building.

Mr. TONKO. So how is it in the midst of an energy crisis we allowed a building like that to be built?

Mr. COAD. I would ask that question to——

Mr. TONKO. So we can start right at home with our own buildings and certainly if we are providing federal funds for any building construction, private sector and public, shouldn't we have an energy code maintenance, a requirement, and can we put in some sort of outside the public realm where there is no public dollars, can we put some sort of incentive in that addresses your mortgage or whatever just for being energy efficient? It seems as though there are aggressive actions that can be taken and there are com-missions of negligence in recent past history that need to be addressed by federal policy.

Mr. CHALK. I would say the federal buildings that would go up now would have to comply with the codes, and the codes just recently have become much more energy efficient than they were, say, 10 years ago. So I think progress is being made when new federal buildings are being built.

Mr. TONKO. Because of our gross neglect, I think we need to get very aggressive about energy efficiency, see it as our fuel of choice, give it our highest priority and move forward with a plan that finally addresses the demand side of the equation which has long been overdue.

Mr. COAD. Sir, I agree with you 100 percent.

Chairman BAIRD. Well said, Mr. Tonko.

Mr. Carnahan, no additional comments?

CLOSING

I think the take-home from this needs to be, many industries have made a real effort in terms of marketing basic numbers. I don't think if you ask the average American or Member of Congress, for that matter, what percentage of our energy consumption goes to the uses that we have talked about today. Most of us would probably be well off that mark, and if we are off that mark, then we are going to be off the mark in terms of targeting our interventions. And we have learned today the targeted interventions can be an—not can be, must be an essential part of solving our nation's energy independence, global warming, overheating and ocean acidification and our economic woes because the money that is saved is money you get to keep and so I applaud our witnesses for a very stimulating and most informative discussion. I wish every American could have tuned into this and all of our colleagues as well. I thank my colleagues and friends on the panel. Mr. Carnahan wanted a final remark and I recognize Mr. Carnahan.

Mr. CARNAHAN. Just one brief comment. I want to thank Chairman Baird for his leadership on this issue, and it has been one of my personal missions to be sure that when somebody gets up and talks about energy policy in this country, they don't leave out high-performance buildings because I have had three-fourths of the people I see stand up and talk about our energy policy and what we need to do as a country don't even mention it. So we have to be sure this is involved in this national conversation and I thank all the panel for what you are doing to make that happen. Thank you.

Chairman BAIRD. Excellent point, Mr. Carnahan, and I applaud your leadership. We talk about carbon sequestration and electronic vehicles and fusion energy, et cetera, and making our businesses and homes more efficient may be a whole lot more efficient and affordable in the shorter-term, and I applaud your leadership.

With that, the hearing stands adjourned. I thank our panelists and witnesses, excellent testimony, and my colleagues. I have to always say the record will remain open for two weeks for additional statements from the Members and for answers to any follow-up questions the Subcommittee may ask of the witnesses. The witnesses are excused. Thank you.

[Whereupon, at 11:59 a.m., the Subcommittee was adjourned.]

Appendix:

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Steven Chalk, Principal Deputy Assistant Secretary, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy

Questions submitted by Chairman Brian Baird

Q1. During the question and answer period of the hearing you said that DOE and National Institute of Standards and Technology (NIST) have a very good working relationship. Describe how DOE works with NIST on building code development. What specifically does DOE fund NIST to do? You also mentioned that you work with NIST on the new Commercial Buildings Initiative, what are you working with them on?

A1. The Department of Energy (DOE) collaborates with the National Institute of Standards and Technology (NIST) in several ways. For more than 12 years, DOE and NIST have co-chaired a series of buildings-related R&D subcommittees on the National Science and Technology Council, Committee on Technology. This co-chair collaboration includes development of R&D agendas, research, and other activities. NIST has also provided technical expertise in support of International Energy Agency work on building commissioning, and has made significant contributions in evaluating the usefulness of building commissioning. In addition, in accordance with section 324 of the *Energy Policy and Conservation Act* (EPCA), since the mid-1970's DOE has worked closely with NIST on the development and update of test procedures for consumer products and certain commercial and industrial equipment under the Energy Conservation Standards Program.

Q2. In your testimony you state that DOE is "actively engaged in the ASHRAE standards process by providing technical assistance to support the upgrade of standard 90.1." Please describe how you work with these voluntary consensus groups and what kind's research and development activities you are involved in that helps inform the process?

A2. The Department staff participates as a voting member on the Standing Standards Project Committee 90.1, recommends amendments to standard 90.1, and seeks adoption of technologically feasible, economically justified energy efficiency measures, as required by section 307(a) of the *Energy Conservation and Production Act* (EPCA). DOE shares its research and demonstration results from technology areas and high-performance building alliances, such as information from the Advanced Energy Design Guides. The design guides are jointly produced by DOE; the American Institute of Architects; the American Society of Heating, Refrigerating and Air-Conditioning Engineers; the Illuminating Engineering Society of North America; and the U.S. Green Building Council.

DOE also performs technical analysis and building energy modeling which it shares with the Standing Standards Project Committee 90.1 in its deliberations. This analysis and modeling has included development of new regression equations for use in setting envelope requirements, identification of new cost information, development of hourly load profiles for building prototypes, technical analysis of lighting issues dealing with lighting power densities, whole building simulation support necessary to supply the Envelope and Mechanical subcommittees with the results they need to develop changes, and modification of the requirements in the energy cost budget chapter and appendices to capture addenda such as new distribution transformer requirements and new variable speed chiller efficiencies. The Department's Pacific Northwest National Laboratory personnel chair the Lighting Subcommittee, and participate on several other subcommittees as members or consultants.

Q3. There are many specific R&D technologies and models identified in the National Science and Technology Council report on net-zero buildings issued last year. How does DOE prioritize what areas of research to pursue?

A3. The prioritization of technology topics for funding occurs at multiple organizational levels, and is driven by public policy goals established through authorizing legislation, and national policy documents and plans. For the Building Technologies Program (BTP), the research agenda is designed to achieve the technical and economic basis for marketable net-zero energy performance in residential construction by 2020, and in commercial construction by 2025.

Additional goals for implementation in the commercial market were established by the *Energy Independence and Security Act of 2007* (EISA). These goals include all new construction to be net-zero energy by 2030, 50 percent of commercial building stock to be net-zero by 2040, and 100 percent of commercial building stock to be net-zero by 2050. At this time there are no time-specific goals for the retrofit of existing housing stock analogous to the EISA goals for commercial buildings retrofits.

The technical research goals of developing net-zero energy buildings take into account costs to ensure broad applicability of research results to the market. For example, residential net-zero performance should have a net-zero cash flow on an annual basis to the homeowner, based on a 30-year fixed-rate mortgage and benchmark energy costs. Also, the BTP is working toward a five to seven year payback on the incremental cost of achieving net-zero energy performance in commercial buildings. The BTP conducts an annual multi-year planning process to update its research agenda based on a number of factors, including:

- Current and projected funding levels;
- Technical progress on funded work, informed by peer review and StageGate reviews;
- Technology roadmaps established and updated with stakeholders;
- Technology pathways (including risk assessment, barriers to development and adoption) developed analytically;
- External technology developments;
- Projected gaps in technical performance and/or cost of performance for whole-building systems-engineered net-zero energy performance;
- Market trends and analyses;
- Stakeholder input;
- Contingency plans for increased/decreased resources (e.g., having a developed list of unaddressed opportunities)
- Changes in Congressional authorizations, Administration policies and/or priorities (including OMB budget guidance, OSTP/NSTC guidance).

Each technology area (e.g., residential integration; commercial integration; solid state lighting; Heating, Ventilation and Air-Conditioning; Solar Heating and Cooling; thermal envelope and windows; and analysis tools) also develops an individual multi-year plan. These individual plans are then integrated in an annual workshop to ensure a coordinated set of activities are being pursued that can deliver on the long-term goals of the program. The integrated plan is published on the Internet and can be found at *http://www1.eere.energy.gov/buildings/mypp.html*. The multi-year plan, along with other analyses, drives the development of annual operating plans to execute appropriated budgets, and to drive budget proposals within the Department's Office of Energy Efficiency and Renewable Energy and at the Departmental level as well.

Q4. The Department of Energy as well as other agencies fund several different buildings consortiums. For example there is a High-Performance Green Building Consortium, a High-Performance Building Council and a Commercial Building Energy Alliance. How are these partnerships coordinated? How does DOE choose which to participate in?

A4. As required by the *Energy Independence and Security Act of 2007* (EISA), the Department formally recognized 11 high-performance green building consortia through a *Federal Register* Notice process, and competitively selected a single supporting consortium with which to consult in the implementation of the High-Performance Green Commercial Building Initiative (CBI). The CBI is designed to achieve net-zero energy performance in all commercial buildings by 2030 and in the entire commercial building stock by 2050. The formally recognized consortia have their contact information listed on the DOE web site and act as informal resources for the CBI. The supporting consortium, consisting of 150 organizations and stakeholders led by the National Association of State Energy Officials, is funded to coordinate input on CBI technical and planning topics, and to assist in communication and outreach with industry stakeholders, manufacturers and NGOs, among other activities.

The Department, through the CBI, engages the commercial buildings marketplace through Commercial Building Energy Alliances (Retail, Commercial Real Estate, Health Care, and two others in the planning stages) to encourage sharing of best practices, engage with manufacturers to identify common technology cost and performance needs, and to exchange experiences with new technologies, retrofit and new construction practices. In addition, research technical assistance is being provided to 23 major building portfolio owners and operators who commit to retrofitting a building at 30 percent better than the current ASHRAE 90.1 model energy code, and to design, build and operate a new building at 50 percent better than code. Targeted building technology, systems, tools and practices research needed to contribute to the long-term goals established by EISA, is informed by these activities.

The High-Performance Building Council was an ad hoc structure formed by the National Institute of Building Standards (NIBS) to produce a report required by Section 914 of the *Energy Policy Act of 2005.* The report was completed and delivered to Congress; it focused primarily on the needs for improved voluntary consensus standards for high-performance buildings. The Department provided funding to support this effort. The Department continues to work with the International Code Council and the American Society of Heating, Refrigeration and Air-conditioning Engineers to develop the next generation of model energy codes.

Q5. In your written testimony you talk about the work of the Residential Integration program, and testing the results on a community-scale. Have you been able to demonstrate community-scale systems, and if so, where? If not, are discussions underway to set up demonstrations of this size? How do you decide which technologies to demonstrate?

A5. The Department's Building America Program Stage-Gates is working to include: development of individual technologies and practices for integration into whole-house solutions; proof of performance in prototype research homes; and implementation in production housing construction practice, i.e., at the community scale. The research focuses on solutions for each of the five general climate zones in the U.S.: cold, hot-dry, hot-humid, mixed humid, and marine. The combination of technologies to be evaluated in a prototype home are selected using the Building Optimization model, which compares combinations of options based on performance and cost characteristics, with results representing the best cost-optimized potential solutions sets. It should be noted that solution sets include systems engineering improvements, such as advanced quality controls protocols, and advanced construction practices such as value engineered framing developed through research projects with builders.

Once a prototype house is built per the initial design, the team tests the prototype's systems for quality and energy use and makes necessary changes to the design to increase efficiency and cost effectiveness. The design must be tested and retested for total performance before it is ready for use in production or community-scale housing. Community-scale Stage-Gate criteria include a requirement that a minimum of 10 homes be constructed in at least five geographically dispersed locations within a climate zone. Usually the builder will construct the whole development using these designs. These developments typically have 150 to 300 homes. While the builders constructing these homes receive technical support, the program provides no funds for brick and mortar. Since the inception of the program, over 41,500 highly efficient research homes have been built. The locations and the number of homes at each location can be found on the Building America web site at *http://apps1.eere.energy.gov/buildings/building_america/cfm/project_locations.cfm*

Questions submitted by Representative Lynn C. Woolsey

Q1. DOE's Building Technologies Program has adopted a goal of developing net-zero energy buildings by 2025. In December 2007, the National Renewable Energy Lab (NREL) issued "Assessment of the Technical Potential for Achieving Net-Zero Energy Buildings in the Commercial Sector," a report to assess whether zero-energy buildings are achievable (attached). The study looks at how low building energy consumption can practically go. Our understanding is that this report was good, but because of the limitations in certain software, such as EnergyPlus, some significant energy saving options, were not able to be considered. Two questions:

Q1a. Does NREL/DOE have any updates to the 2007 study that refine and/or expand the study's conclusions?

A1a. Neither the National Renewable Energy Laboratory (NREL) nor the Department have updated the *"Assessment of the Technical Potential for Achieving Net-Zero Energy Buildings in the Commercial Sector"* study. However, in April 2009, NREL issued a companion study, *"Assessment of the Energy Impacts of Outside Air in the Commercial Sector,"* that expanded the original analysis to address relatively narrow questions surrounding the energy impacts of ventilation air needed for healthy indoor environments.

Q1b. Is NREL planning to update the study at anytime in the near future to take into account innovations in building technologies, new tools to evaluate building performance, and other such developments?

A1b. The *"Assessment of the Technical Potential for Achieving Net-Zero Energy Buildings in the Commercial Sector"* study uses data from the Energy Information Administration's (EIA) 2003 CBECS and ANSI/ASHRAE/IESNA Standard 90.1–2004 to model the commercial buildings sector. Once EIA releases its 2007 CBECS data and ASHRAE releases 90.1–2010, the Department will re-examine the need to update the study. The various software tools used in the study are steadily being improved to allow simulation of more technology options as their associated detailed characteristics become available for incorporation into the models. The Department is investing in the development of detailed performance characteristics of new and emerging technologies on a continuous basis.

Q2. How can we accelerate the development of software and other computational kinds of technologies to accelerate the design and construction of "green" buildings? Are there opportunities for cooperation with commercial software companies to improve the state-of-the-art in energy analysis? Is this an area where public-private partnerships can yield better results for everyone?

A2. While software and other computational technologies are essential tools in constructing high-performance buildings, the decisions designers make are only as good as the available data. In order to achieve its goal of market-ready net-zero energy buildings by 2025, DOE is actively seeking input data and accurate costs of different design options which only the private sector can provide.

DOE currently collaborates with four major private sector companies that create Building Information Modeling (BIM) systems (AutoDesk: AutoCAD, REVIT; Bentley: Microstation, Hevacomp, TAS; Graphisoft: ArchiCAD; and Google: SketchUp) to make energy simulations using DOE's tool, EnergyPlus, more accessible. This year, DOE began a series of educational workshops with Google and Bentley to explain how EnergyPlus can be used within their applications and how designs are validated in the real world.

In addition, university students have been creating new modules for EnergyPlus as part of graduate studies (without funding from DOE). As a result, in 2008 DOE brought more than 20 university professors together to discuss enhancing simulation training in universities. One way that DOE is embarking on such collaboration—in training and in extending the capabilities of EnergyPlus—is through the Higher Education Energy Alliance (HEEA). HEEA is one of five Commercial Building Energy Alliances that DOE is forming as part of its Net-Zero Energy Commercial Building Initiative (CBI), which aims to create market-ready net-zero energy buildings by 2025.

DOE believes such collaborations are essential to the successful and speedy development of energy simulation software required to design, build and operate high-performance green buildings. DOE will continue these highly productive partnerships and seek to expand its partnerships going forward.

ANSWERS TO POST-HEARING QUESTIONS

Responses by Karen Ehrhardt–Martinez, Research Associate, American Council for an Energy–Efficient Economy (ACEEE)

Questions submitted by Chairman Brian Baird

Q1. In your testimony you note that DOE building technology initiatives would benefit from a more systemic and widespread incorporation of social and behavioral insights. Within DOE, where and how should this information be incorporated? Do you think social and behavioral science should be supported by various initiatives or do you think there needs to be a coordinated social science program within EERE?

A1. A more systematic and widespread incorporation of social and behavioral insights within the building technology initiatives at DOE holds the promise of both deeper and faster energy savings. This effort should consist of a coordinated social science program that integrates social and behavioral insights throughout all of DOE's initiatives and that creates a people-centered approach to energy savings.

To date, DOE has been primarily focused on the development and dissemination of more energy-efficient technologies without giving sufficient attention to:

- the acceptability of those technologies,
- consumer choices and issues of technology adoption, or
- the ways in which people maintain or use new technologies and the energy implications of those choices, habits and lifestyles.

A people-centered approach would recognize that what people choose to do with any given technology or system of technologies is just as important as the characteristics of the technology itself in determining the amount of energy will be consumed or saved. As Internet guru, Clay Shirky stated "A revolution doesn't happen when society adopts new tools, it happens when society adopts new behaviors."

The Social Science initiative would ideally be housed within the Energy Efficiency and Renewable Energy Offices and would require the employment of sufficient senior level social scientists so as to provide expertise and training to other DOE staff and staff at the National Labs as well as to help build DOE's internal capacity in this area.

ANSWERS TO POST-HEARING QUESTIONS

Responses by J. Michael McQuade, Senior Vice President, Science and Technology, United Technologies Corporation

Questions submitted by Chairman Brian Baird

Q1. You pointed out that metrics need to be developed to achieve better-performing buildings through systems integration. What role do you think the Federal Government should play in the development of metrics or tools to identify and quantify critical interactions between systems?

A1. As noted in my testimony, there is a vigorous role for government-sponsored research into the methodology and tools needed to model, simulate and computationally control complex, integrated buildings. These tools, using leading edge and yet to be developed computer science, mathematics and physics-based modeling will allow us to understand how subsystems interact within a building and how buildings interact with their environment. These topics are major enablers to allow us to create the highly efficient buildings we discussed at the hearing.

Once these new buildings exist or existing buildings are retrofitted with upgraded capability, we believe there is a necessary role government should play in the establishment and deployment of "whole building" energy performance ratings and standards that incorporate these advancements. In addition, we believe these performance statistics should be publicly reported on a regular basis. Standards for energy-efficient components can be useful but standards for whole building energy performance are key to realizing energy-efficient buildings. The analogy here is that while we recognize the role engines play in automobile efficiency, we measure and apply mile-per-gallon standards to automobiles, not to their components, thus taking into account other technologies such as aerodynamic design, energy harvesting or adaptive engine control.

Q2. In your testimony, you note the importance of computational research and development in the design, optimization, and control of energy use in buildings. Are the current activities in these areas at DOE and NIST sufficient? Is there any way they can be improved? And within the Department of Energy, could the buildings program in the Office of Energy Efficiency and Renewable Energy make better use of the significant computational capabilities stewarded by the Office of Science?

A2. We do believe that the current programs at NIST and DOE have been helpful but that a full-fledged program of basic building energy sciences and tools development is needed beyond what these agencies have been charged with in the past. In particular, existing programs do not focus on the underlying thermal physics and dynamics of complex, interconnected systems and they do not have, as a goal, the creation of tools that can be applied by the building industry through the entire cycle from design to build to continuous operation.

We believe that a focused program should cover three areas. These areas are detailed in my written testimony. In summary they include:

- **Systems Engineering and Design Methodologies,** including rigorous and scalable process and tool environment for building project requirements management & system architecture exploration
- **Optimization and Control of Multi-scale Dynamics,** including analytical techniques for system decomposition, analysis and uncertainty propagation in heterogeneous, networked, multi-scale building systems and nonlinear dynamical systems theory tools to exploit natural dynamics
- **Robust Control and Decision Support Algorithms,** including control and commissioning systems and automated fault detection and diagnostic (FDD) capabilities using building automation systems

This kind of systems-level research does not yet exist within EERE. A vigorous program managed either by EERE or the newly forming ARPA–E would certainly make use of the computational tools and capabilities that exist within the DOE's Office of Science and especially its high-performance computing initiative.

The United States needs a comprehensive energy strategy to ensure we deliver to future generations a secure and livable world. Energy efficiency, doing more with less, must be at the heart of such a strategy, and reduction in energy consumption in our buildings can and must be a priority element. I applaud the work of the Committee in focusing on this issue and thank you again for the chance to testify on how we might move a national agenda forward. Please feel free to contact me if I may be of future assistance on this important topic.

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