Testimony Regarding

Reducing Energy Consumption in Buildings

Statement of

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Before the

United States Senate Committee on Energy and Natural Resources

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Chairman Bingaman, Ranking Member Murkowski and distinguished members of this Committee, it is an honor and privilege for me to be here to testify before you to provide recommendations for reducing energy consumption in buildings.

I am Arun Majumdar, Director of the Environmental Energy Technologies Division (EETD) at the US Department of Energy's Lawrence Berkeley National Laboratory, and Professor in the Departments of Mechanical Engineering and Materials Science and Engineering at the University of California, Berkeley. My field of expertise is the science and engineering of heating and cooling, which accounts for approximately 40-60 percent of the energy consumption in buildings. I am a member of the US National Academy of Engineering, and, over the years, I have served in an external advisory capacity for various federal agencies, including DOE Basic Energy Sciences. I am currently a member of the Advisory Committee of the National Science Foundation's Engineering Directorate.

My Division in LBL was created in 1973 in response to the energy crisis then and focused a substantial part of its efforts over these past 35 years on reducing energy consumption in commercial and residential buildings. It has contributed to various aspects of energy efficiency, such as building codes and appliance standards, creation of the building design software tools, technologies for internet-based demand response between buildings and the grid, electronic ballasts for fluorescent lamps, low-emittance and electrochromic windows, materials and coatings for cool roofs, and to many demonstration projects such as the New York Times Building in Manhattan and the San Francisco Federal Building. Furthermore, the Division has had major influence on the global buildings sector by educating, training and collaborating with people in federal and state agencies, private industry, non-profit organizations, philanthropic foundations, as well as in international governments and organizations. I will draw upon this experience in my testimony of how to reduce energy consumption in buildings in the future.

In August 2008, in response to the authorization of the Commercial Buildings Initiative (CBI) of the Energy Independence and Security Act (EISA) of 2007, DOE's Office of Energy Efficiency and Renewable Energy (EERE) launched a National Laboratory Collaborative on Buildings Technology (NLCBT), with the goal of coordinating the R&D activity of five national laboratories that have expertise in this field. I applaud EERE's efforts in bringing the national labs together. The NLCBT includes two members each from the EERE Buildings Technologies Program, as well as from Argonne National Lab, National Renewable Energy Lab, Lawrence Berkeley National Lab, Oak Ridge National Lab, and Pacific Northwest National Lab. Over the last six months, the NLCBT has worked closely to develop some common goals and approaches. I am one of the Berkeley Lab's representatives in NLCBT. While I have been influenced by the discussions, my testimony here reflects my views and those of Berkeley Labs and University of California, Berkeley.

I also want to bring to your attention the work recently completed by National Science and Technology Council's Committee on Technology. Their Building Technology Research and Development Subcommittee, representing 21 Federal agencies, released a report[1] on High-

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[1]"Federal Research and Development Agenda for Net-Zero Energy, High-Performance Green Building," Report of the Subcommittee on Buildings Technology Research and Development, Committee on Technology, National Science and Technology Council, October 2008.

Performance Green Buildings in October 2008. This document lays out a framework for R&D activities within the Federal government to achieve the aggressive net-zero energy goals set out within EPAct 2005 and EISA 2007. DOE's laboratories were a critical contributor to the development of this agenda.

1. Why Buildings and Why Now

We are living in a critical time. Energy security and climate change are two of *the* most important challenges of our lifetimes, and need urgent attention. The decisions we make and the paths we take now will determine the future health, security and well being of our Nation and the world. 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. I firmly believe that reducing energy consumption in buildings by a very substantial margin must be part of the solution. Otherwise, we are unlikely to adequately address the challenges of energy and climate change.

The U.S. building sector (residential and commercial):

- employs 8 million people; contributes to 10% of the U.S. GDP;
- consists of about 115 million households and 5 million commercial buildings;
- energy consumption is split roughly 50:50 between commercial and residential buildings
- consumes 72% of the electricity and 55% of natural gas, and 40% of the US primary energy (larger than either transportation or industry);
- per year, consumes 40 quads of primary energy, 2.7 trillion KW-hr, and accounts for 40% of CO_2 emissions or about 2300 MMT CO_2 equivalent.
- has a utility bill of about $400 billion per year while the construction sector is about $1,000 billion per year;
- By 2030, EIA estimates 16% growth in energy consumption, which will require additional 200 GW of electrical capacity

Most economic and technical analyses suggest that buildings offer one of the best opportunities, if not *the* best, to economically and rapidly reduce energy demand and limit green house gas (GHG) emissions. The buildings sector consumes (see box) the largest fraction of US primary energy (roughly 40 out of 100 quads) and is responsible for about 40% of the CO_2 emissions, which is more than either transportation or industry. The buildings sector also provides a significant fraction of the US GDP and employment, and hence it could play a critical role in stimulating the economy. The electricity transmission/distribution system largely exists for buildings, and buildings can provide some level of thermal and/or electrical storage to complement the grid, which will be even more important to address issues related to intermittency in renewable energy supply.

Looking ahead, the US will add about 1.5-2 billion square feet per year of new floor space[2] in commercial buildings. The US has about 115 million "households" today, that is likely to grow to 140 million by 2030 based on population growth estimates. If we maintain business-as-usual, Energy Information Administration (EIA) estimates[3] that by 2030 we will experience a 16 percent growth in buildings energy consumption. This amounts to approximately 200 GW of

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[2] In rough terms 2 billion square feet would be equal to 2000 Forrestal buildings or over 19,000 typical Home Depots.

[3] Annual Energy Outlook 2009 Early Release, Energy Information Administration; http://www.eia.doe.gov/oiaf/aeo/pdf/aeo2009_presentation.pdf

additional electricity capacity by 2030, which at a cost of about \$2-5/W capital expenditure[4], would require investments on the order of \$500-1000B over the next 20 years, or approximately \$25-50B/year.[5] While some investments in the supply side are necessary to keep up with demand, we cannot operate with a business-as-usual approach for the demand side: We must take some bold steps for significant reductions in energy consumption. Investments to reduce energy demand have been proven to be more cost-effective than increasing supply, as has been the experience in California.

While each building is unique, buildings often utilize similar materials and equipment, so that technologies developed for the buildings sector can be widely replicated, offering substantial leverage for these research efforts. Given the long lifetimes of residential and commercial buildings, often more than 50 years, technology development should include advances in materials, equipment, and strategies for retrofitting buildings for improved energy efficiency.

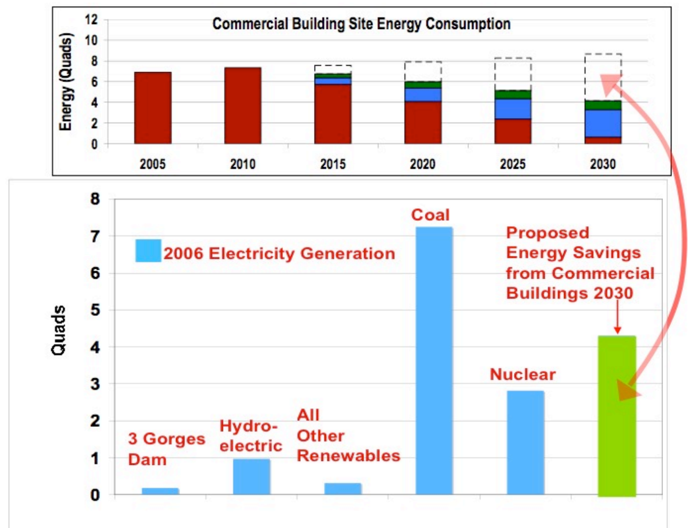

Fig. 1 (Top) Total reduction in site energy consumption in commercial buildings if by 2030 one can reduce consumption by 80% in new buildings and 50% in existing ones. (Bottom) Comparison of site energy savings in 2030 to electricity generation in 2006 from various sources.

The Federal Energy Independence and Security Act (EISA) of 2007 contains authorized legislation for a Zero-Net Energy Commercial Buildings Initiative, which calls for 80-90% reduction[6] in energy consumption for:

- All newly constructed commercial buildings by 2030
- 50% of the commercial building stock by 2040
- All commercial buildings by 2050

From here on, I will focus my comments on commercial buildings only.

Figure 1 shows that if by 2030, we achieve reductions in energy consumption of 80% in new construction and 50% in existing buildings, the site energy saved will be about 4 Quads (about 1200 billion kW-hr) per year. If this were to happen in 2006, it would have essentially

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[4] Cost estimates based on today's fuel prices are about \$2/W for pulverized coal, \$0.8/W for combined cycle gas turbine, \$1.8/W for wind, \$3/W for integrated gasification combined cycle, \$5/W nuclear

[5] For example, a recent industry study based on the EIA's 2030 projections, estimates that 214GW of new generating capacity at an investment cost \$697 billion will be required under a Reference Scenario. Transforming America's Power Industry: The Investment Challenge 2010-2030. Prepared by: The Brattle Group for The Edison Foundation. November 2008.

[6] Zero-net energy building reduces 80-90% energy consumption compared to benchmarks, and uses renewable energy to provide the remaining 10-20%.

eliminated the need for electricity from approximately half the coal-fired power plants. This would have saved 400 MMT-CO_2 emissions per year. The remaining load of 4 Quads could have been supplied by electricity produced by nuclear, hydroelectric and other renewable sources, and one could have reached a zero-carbon footprint for the commercial buildings sector. Yet, achieving these goals in a cost-effective, reliable, and scalable way will be very challenging. In new buildings, the potential energy savings with current technology are 40 to 60% compared to current code[7], but these are rarely achieved in practice and it is difficult to reach the EISA'07 goals for 2030 cost-effectively.

It is critical to continue current research, development, demonstration and deployment (RDD&D) activities in buildings, extending known technologies. In addition, the U.S. needs an aggressive and bold approach for advanced RDD&D to realize the full opportunity in the buildings sector to address the challenges of energy security and climate change.

2. Framework of a National Strategy

The goal of zero-net energy building (ZNEB) is bold and I believe the right one. The scale and magnitude of this challenge is daunting, but if successful, the US could witness significant increase in jobs, technological leadership with global impact, and a modernized infrastructure that has been largely underserved for the last 30 years.

Despite the scale of the problem and perhaps the best opportunity that it offers to reduce energy demand and carbon emissions, the budget for EERE's Buildings Technologies Program is on the order of \$100M/year, which includes only about \$12M/year for the Commercial Buildings Initiative. With these limited resources, the program has done a remarkable job in conducting some R&D, but has necessarily focused mostly on technology deployment through the creation of the Commercial Buildings Energy Alliances. While this is necessary and important, it is not sufficient.

Our past successes in building energy efficiency have taken 10-20 years to move from lab invention to mainstream market impacts as documented by NAS studies and other reports. We need to accelerate the process. It is critical that the Nation have a strong, long-term commitment to a balanced portfolio and a seamless pipeline of integrated RDD&D ranging from basic research to market transformation. This would require coordination, integration, alignment, and leveraging among several key thrusts, all of which require innovations:

i. science and technology;
ii. policy and finance;
iii. technology deployment and market transformation
iv. work force development through education and training.

Any one thrust alone cannot successfully address the challenge, but collectively they can.

The short-term goals ought to be focused on creating jobs, but without a long-term R&D base focused on science and technology, the US could be out-innovated by Asia and Europe, which in some cases are currently more advanced than the US. With a well-coordinated bold RDD&D program, the US has the intellectual capital and the capacity to be a global leader. EISA'07

[7] Note that current codes are for designed intent, and not based on actual performance. See Section 3(ii) for details.

authorizes $20M/yr for the Commercial Buildings Initiative in 2008, ramping up to $200M/yr between 2013-2018. It is unclear whether this level of investment is sufficient to address the challenge.

3. What are the Key Barriers, Gaps and Challenges

While the numbers are compelling for reducing energy consumption in buildings, in reality it has been difficult to reduce energy consumption in buildings because:

i. ***The Value of energy efficiency is uncertain and unappreciated***: Energy is usually a small (if any) part of building design, which focuses mostly on cost, aesthetics, comfort, and function. There is no clear market signal for reducing energy consumption. Since building energy performance is rarely measured (see ii below), and there are large uncertainties in designed performance, the value of energy efficiency is fraught with uncertainties, making it difficult to evaluate and to have financial transactions without legal implications.

ii. ***Actual performance does not often correlate to design intent***: Today's building codes are for *designed* energy performance, NOT for *measured* or actual energy performance (see Fig. 2 later). Code-compliant solutions are typically much worse than best practice; by definition they represent the worst, cheapest building that can be legally built and occupied. There are no requirements for performance measurement, and only about 5% of new buildings are ever commissioned–95% are operated without ever testing their systems upon completion of building construction.

iii. ***The Buildings industry is fragmented (see Appendix A-Chart 3)*****:** The buildings industry is fraught with functional gaps as well as management discontinuities that lead to ineffective coordination between operational islands. There is virtually no feedback loop from occupied buildings back to designers, beyond lawsuits, that might correct past mistakes.

iv. ***Lack of systems integration in building design and operation*****:** Building components (cement, steel, insulation, glass windows, coatings, sheet rock,…) and systems (lighting; heating, ventilation and air conditioning (HVAC); appliances) are developed by independent firms whose products are tested for individual performance independent of each other. While this must be encouraged and is necessary, it is insufficient. A whole building approach to design and operation, where these components are integrated in a way that they reduce energy consumption through cooperation, is rarely used, which commonly leads to significant system-level inefficiencies.

v. ***Lack of quantitative energy consumption evaluation***: Building operators often have neither the training nor the information handoff from builders they need to properly operate the building to meet performance expectations. Most operators are flying blind with three sets of uncorrelated data: (a) a time dependent snapshot of performance; (b) real-time complaint calls, and (c) an "after-the-fact" monthly utility bill. Most buildings don't have proper instrumentation or an Energy Information System to integrate, digest and display actionable performance data for the operator.

vi. ***Incentives for energy efficiency are not aligned***: In leased buildings, the building designers and developers specify components and decide how they are integrated in the design, primarily based on capital expenditure and not generally on energy efficiency. On the other hand, occupants' patterns of energy consumption determine how much energy is actually used, which is related to the operational expenses. The dichotomy of capital and operational cost between owner and user leads to split incentives, and makes it difficult to spread financial benefits or burdens due to efficient use of energy.

Since the Commercial Buildings Initiative is focused on achieving zero net energy in buildings, it is worth noting as an example, a recent study of some high-performance buildings. Frankel[8] recently conducted an analysis of 121 LEED[9] buildings (certified, silver, gold and platinum rated) that were in the low-to-mid range in energy use intensity (EUI in kBTU/sqft), and studied their actual versus design performances. Figure 2 plots the spread of measured EUI, and ratio of actual-to-design energy use as a function of design EUI. While this may not be a definitive study and perhaps does not contain a sufficiently large statistical sample, some trends and indications are worth noting:

a) While the average EUI of LEED rated buildings is lower than the national average, there is a large amount of scatter. Hence, LEED rating is useful on an average, but design intent does not generally correlate with actual performance in individual buildings.
b) For buildings with lower design EUI (i.e. towards zero net energy building), the discrepancy between the actual and designed EUI is larger, showing that it becomes more challenging to accurately predict performance as the performance goals are tightened.

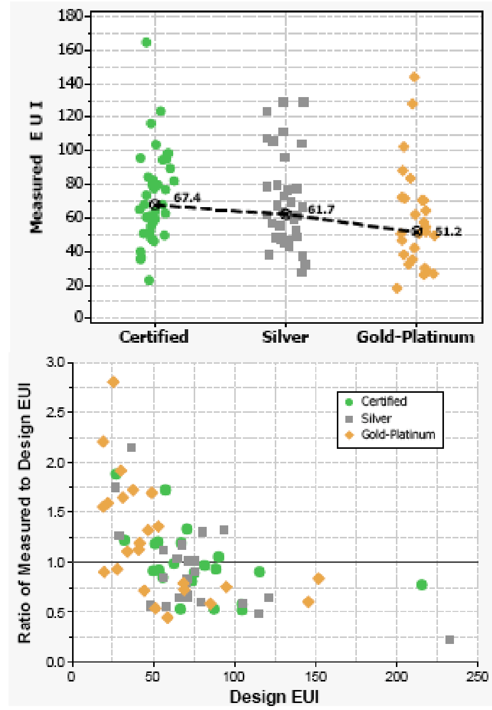


Fig. 2 (Top) Spread of measured energy use intensity (EUI in kBTU/sqft) of 121 LEED-rated buildings in the low-to-medium EUI range. (Bottom) Ratio of measured to design EUI versus design EUI for these buildings.

There are multiple reasons for why this is so and details can be found in Frankel's study. Clearly, further studies are required, but some of the gaps and challenges are well known in the buildings community and can be acted upon now.

4. Recommendations for Science and Technology

The US needs a comprehensive and balanced R&D program to achieve significant reductions in energy use in commercial buildings through innovations. To complement existing near- to mid-term technology development with longer-term development of transformative technologies, we need to integrate basic and applied R&D much more than has often been the case in the past. Today, building commissioning and simple retrofits may be cost-effective, but they reduce energy consumption on average by only 15-20%. On the other hand one can design and build new buildings that almost reach zero-net energy goals[10], but at a higher cost and not easily scaled

[8] M. Frankel, "The Energy Performance of LEED Buildings," presented at the *Summer Study on Energy Efficient Buildings, American Council of Energy Efficiency Economy*, Asilomar Conference Center, Pacific Grove, CA, August 17-22, 2008.

[9] Leadership in Energy and Environmental Design (LEED) is a Green Building rating system introduced by the US Green Building Council (http://www.usgbc.org/). LEED is a third-party certification program and the nationally accepted benchmark for the design, construction and operation of high performance green buildings.

[10] P. A. Torcellini, M. Deru, B. Griffith, N. Long, Shanti Pless, R. Judkoff, "Lessons learned from field evaluation of six high-performance buildings," Technical Report NREL/TP-550-37542, June 2006 (http://www.nrel.gov/docs/fy06osti/37542.pdf)

up to wide market introduction. The science and technology challenge is two fold: (a) how to reduce energy consumption to approach zero-net energy goals; and (ii) how to achieve this in a cost-effective, measurable and scalable manner. The innovations ought to focus not only on new technology but also towards dramatic reductions in risk and cost in existing technologies that would enable deep market penetration. Here are some potential elements.

i. ***Information Technology Infrastructure for Fundamental Data Gathering, Processing and Management.*** As suggested by Fig. 2, design intent and current simulation tools are insufficient to model and predict energy use in buildings. The US needs a significant program in collecting, analyzing, and displaying measured performance of all public buildings. Without these data, it would be very difficult to identify common inefficiencies, best practices, and best opportunities for smart retrofits. Furthermore, there is a need for tools to process and manage the data such that it is readily available and can easily be mined. *This addresses 3(i), 3(ii), and 3(v).*

ii. ***Whole System & Process Integration for Design and Operation of Smart Buildings***: To achieve the goals of zero-net energy buildings, optimizing individual components for energy efficiency, while necessary, is unlikely to be sufficient. We need a whole building approach that can treat the building as a system and minimize the energy consumption of the whole system while still optimizing comfort and other performance metrics. Furthermore, given the fragmentation of the buildings industry, sophisticated tools are required that help in integrating the process of building design, build and delivery, which promotes feedback and iteration. This needs:
   a. science-based approach that couples building science (thermodynamics, heat transfer, fluid mechanics, sensors, materials, components…) with architecture (structure, façade, comfort, aesthetics, …) and information science (communication, computations, control) that will lead to deeper understanding and pathways of how to integrate subsystems that will cooperate and collectively reduce energy consumption as a system.
   b. the above endeavor will form the foundations for tools for accurate simulation, analysis, optimization and data mining that can be used for both building design and operation
   c. continuous visualization, monitoring, reporting, diagnostics and demand-response of buildings – self-tuning buildings.

   This addresses 3(iii) and 3(iv).

iii. ***High-Performance Building Components and Sub-Systems:*** Inefficiencies in buildings can largely be attributed to thermal management as well as inefficient lighting. Hence, it is necessary (but not sufficient) to focus R&D effort on innovations in:
   a. <u>Building Fabric/Envelop Materials and Device Technology</u>: We need to identify new approaches for cost-effective super-insulations for both walls and windows. "Smart glass" or dynamic shading whose properties are dynamically controlled and adjusted to minimize cooling and maximize glare-free daylight are also necessary. Integration of phase change materials ("energy storage") into buildings must be investigated.
   b. <u>Mechanical Equipment, Controls, and Thermal Storage Technologies</u>: HVAC accounts for over 30% of the total commercial building energy consumption. A robust program could help develop the next generation of HVAC and controls suitable for use in buildings with loads approaching 10-20% of today's loads. New opportunities for further improving efficiencies include enhancing heat transfer using technologies such as micro-

channels and nano-scale surface treatments, or supplementing or substituting for vapor-compression cycles with thermoelectric, magnetocaloric, thermoacoustic, absorption, or other systems. Indeed, cooling technologies in the buildings, industry, and transportation sectors account for about 10% of primary national energy use and are a major driver of peak utility loads, among other impacts. Cooling technologies in use today also use hydrofluorocarbons as working fluids, which are strong greenhouse gases. Advances in this area could have broad application and significant benefits.

c. Electrical and Lighting Equipment Technology and Controls: Lighting accounts for about 12% of energy use in homes but often 30-50% in commercial buildings. While steady progress is being made with improved lamp efficacy with gas discharge and solid-state lighting sources, large savings can also come from robust, reliable, addressable and dimmable networked controls that allow light levels and distribution to be dynamically tuned to meet user needs over space and time. The next most important source of energy use is "miscellaneous electric loads" (MELS), such as computers, appliances etc. A robust effort is needed to find ways of minimizing and controlling these loads without inconveniencing occupants.

This addresses 3(iv).

iv. ***Integration of Buildings with Grid & Novel Energy Storage Concepts***: A goal of net-zero energy buildings requires both substantial increases in energy efficiency (up to 70 percent or more) with the balance provided by some form of renewable energy generation, either on-site (e.g., photovoltaic) or from off-site renewable generation. Research is needed to reduce the cost and enhance the performance of approaches to integrate renewable energy and energy storage systems. Research is also needed to capitalize on saving opportunities available from integrating intelligent buildings with the emerging smart grid. *This addresses 3(iv).*

v. ***Field Test Beds and Reconfigurable Test Facilities***: A wide diversity of real buildings ought to be used for collecting data and understanding common inefficiencies, best practices and best opportunities for reducing energy consumption. However, if one needs to incubate, debug and "crash-test" new technologies, they could potentially pose safety and occupational hazards to the occupants. Testing in facilities that are reconfigurable allows pinpointing of technical problems and rapid correction of design flaws, and also allows for "crash-testing" and debugging new technologies before they are rolled out in real buildings with occupants. They also provide much-needed measured evidence to builders and operators that proper systems integration can indeed significantly reduce energy consumption. Furthermore, such test facilities can also be used for education and training. *This addresses 3(i)-3(v).*

vi. ***Advanced Construction Methods:*** Often, poor on-site assembly result in buildings that adversely affect their energy use performance. New construction approaches are needed that are more effective at achieving energy efficiency and renewable energy integration. Advanced techniques also reduce construction wastes and enable utilization of newer materials with lower embedded energy and carbon emission consequences. *This addresses 3(iv).*

5. Recommendations for Policy and Finance

To achieve the zero-net energy goals given the barriers, gaps and challenges identified in Section 3, market forces alone are unlikely to enable market transformation. Innovations in policy must be used, but these need to be researched and evaluated for feasibility as well as impact on energy consumption, economics, law etc. Here are some elements – some of these are fundamental shifts from current policies, but these are necessary to achieve the bold goals outlined before.

i. ***National Building Standards Based on Measured Performance:*** This requires new policy to benchmark and label all commercial buildings based on measured performance. Measuring and disclosing real building energy performance consistently and reliably across the commercial building sector is essential to stimulate market awareness and demand for valuing and achieving improved energy performance levels. *This addresses 3(i) and 3(ii), and will be enabled by 4(i).*

ii. ***New financial instruments, valuation and performance-based compensation:*** There are many aspects of commercial buildings finance that could be altered to encourage investment in higher performance building solutions, such as: (a) grants, subsidies, tax credits, or other financial incentives to defray higher first costs associated with the design, construction, and operation of efficiency and renewables integration and subsequent measured performance; (b) including building actual performance parameters in real-estate valuation; (c) developing and promoting alternative leasing provisions that address split incentives—such as between owners and renters. *This addresses 3(v) and 3(vi), and is enabled by 4(i) and 4(ii).*

iii. ***Incentives for action—tax rebates and utility programs***: There is a wide and growing array of tax incentives and utility programs to promote energy efficiency more aggressively. The options proposed here build on this foundation to identify and implement a comprehensive, integrated set of financial and business incentives to supplement existing energy price signals that: (a) Develop and expand utility incentives; reward higher measured performance; (b) Decouple sales and revenues for utilities nation-wide; (c) Develop and expand tax credits for high performance buildings based on measured performance; (d) Develop programs for capital subsidies, grants, and loans; (e) Promote expedited permitting for high performance buildings. *This addresses 3(v) and 3(vi), and is enabled by 4(i) and 4(ii).*

iv. ***Incentives for Retrofits and Upgrades***: Since the lifetime of commercial buildings is generally more than 50 years, we must promote retrofitting and upgrading the existing building stock. Financial programs that could amortize the initial cost for upgrades over a time period could substantially minimize the financial burden for retrofits.

6. Recommendations for Technology Deployment and Market Transformation

In the commercial buildings area, there is a market transformation challenge that includes educating, incentivizing and assisting stakeholders involved in building design, construction and operation. The market is fragmented and incentives are not always aligned. While the proposed National Building Standards and affiliated financial incentives and disincentives might push the market towards common performance goals, other levers are also needed. Some examples are:

i. Standards generally provide the bare-minimum performance requirements for products in the market. Programs such as EnergyStar® can help pull the top of the market, which then helps identify and make possible the next generation of standards. These activities can be further expanded and strengthened.

ii. Conduct technology demonstrations and field performance evaluations for new technology

iii. Test products to ensure they meet manufacturers' claims and conduct independent assessments of technology cost and performance

iv. Create a best practices network domestically and internationally that will provide guidance for design and operation of new and existing buildings based on location and building type/use

v. Conduct studies of human behavioral responses to energy use and evaluate ways to better fit products and processes to natural responses

vi. Conduct studies of institutional responses to energy use and identify mechanisms that can more effectively assist implementation of cost-effective energy efficiency and renewable energy technologies into the buildings sector.

7. Recommendations for Education and Training

From my experience as a University professor interacting with undergraduate and graduate students both at Berkeley and other universities, I can safely say that the youth of this Nation are ready to roll up their sleeves and save the world. We are in one of the rare "moonshot" moments in history, where we have the opportunity to harness and galvanize the intellectual horsepower of the youth. We must grab this opportunity to attract the best minds and unleash them to address one of the biggest challenges of our lifetime and truly change the course of history. However, we need a framework for this purpose, part of which I have described in the previous sections. We also need adequate resources. Some of the recommendations I propose below go beyond the buildings program, and could be used in DOE and possibly other federal agencies:

i. Initiate a significant program of graduate student and post-doctoral fellowships as well as young investigator awards that will attract the best young minds to energy science and technology, and help create intellectual capital for the nation.

ii. Initiate a program to support joint curricula at universities or R&D centers that combines various aspects of science, engineering, architecture, business, public policy and law to collectively address the needs of the buildings industry, as well as for energy issues in other sectors of our economy.

iii. Combine research and education through the use of test facilities for education and training.

iv. Create education/training bootcamps that rapidly enable retraining for students and existing professionals

In the current marketplace, many stakeholders are unaware of proven existing methods, while others may have an interest in energy efficiency yet lack the ability to implement effective measures. Construction, commissioning and operations of more efficient buildings often require skill sets that are not yet widely available. The DOE program should include an expanded, robust training program for existing design professionals, contractors, commissioning agents, etc.

as well as developing accreditation and certification programs, higher education programs that foster high-performance, integrated design, and other activities.

8. Concluding Remarks and Overall Recommendations

Given the magnitude of energy use in buildings, the opportunity it offers for reducing carbon emissions, and the scale and urgency at which RDD&D needs to occur, the US needs a sustained and well-coordinated public-private partnership of adequate scale. Furthermore, it is important to create a balanced portfolio and an integrated seamless pipeline of RDD&D activities ranging from basic to applied R&D and finally to market transformation. Here are some recommendations to enable this:

i. Increase linkages between the Building Technologies Program in EERE with other programs within EERE and with other offices of DOE (e.g. Office of Science, Office of Electricity Delivery and Energy Reliability) so that the intellectual horsepower and knowledge-base within DOE can be leveraged and brought to bear on this challenge. Some of this has been done but more is possible. Identify linkages and leveraging between DOE and other federal agencies to coordinate RDD&D efforts.

ii. Use the geographical distribution, domain expertise, and availability of intellectual capital of the national laboratories to create on a competitive basis, multiple Regional Centers or Institutes of Excellence of adequate scale where researchers and practitioners from multiple national laboratories, industries, academia and other critical buildings-related organizations can collaborate and jointly address integrated RDD&D in the buildings sector. The Centers could complement each other in focus areas and collectively address the needs of the Nation in a comprehensive manner.

Thank you very much for giving me the opportunity to appear before you and testify.

Appendix A

Charts for Oral Testimony

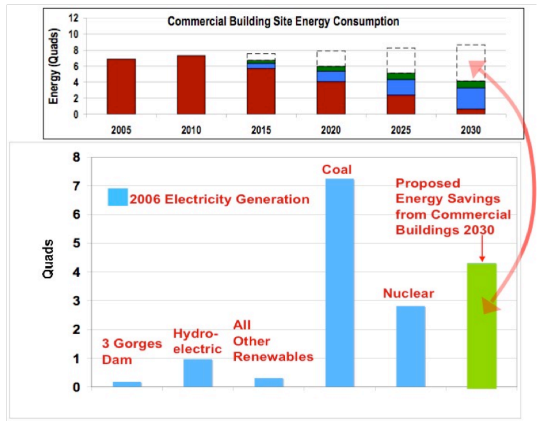
Zero Net Energy Commercial Buildings Initiative

Energy Independence and Security Act of 2007

Reduce energy consumpt on by 80-90%
- All newly constructed commercial buildings by 2030
- 50% of the commercial building stock by 2040
- All commercial buildings by 2050

- New: 80% reduction
- Existing: 50% reduction

The Opportunity



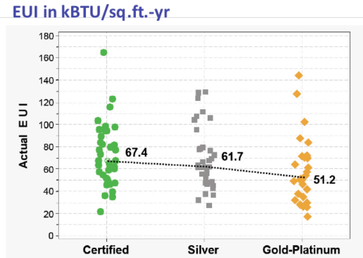
Analysis of 121 LEED-Rated Buildings

Low-to-Medium Energy Use Intensity Buildings

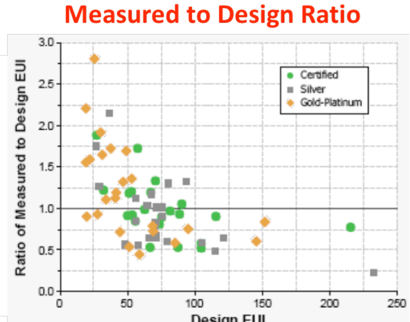
Building codes are for Design Performance, <u>NOT</u> based on Measured Performance.

The Spread

EUI in kBTU/sq.ft.-yr



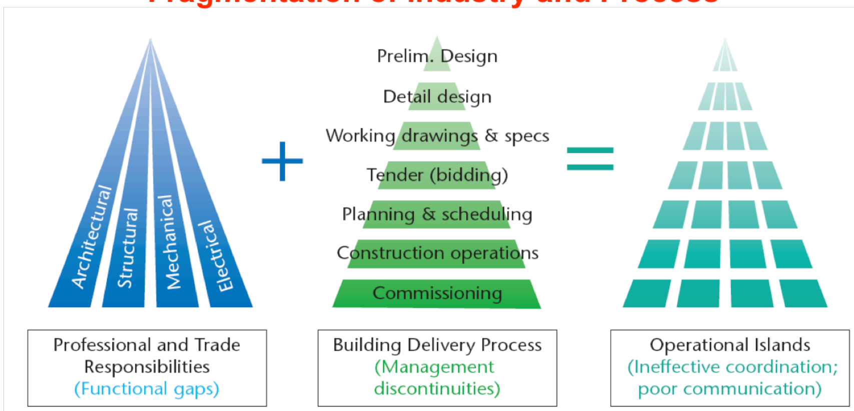
Measured to Design Ratio



Towards Zero-Net Energy

M. Frankel, "The Energy Performance of LEED Buildings," presented at the *Summer Study on Energy Efficient Buildings, American Council of Energy Efficiency Economy*, Asilomar Conference Center, Pacific Grove, CA, August 17-22, 2008.

Fragmentation of Industry and Process



Need to:
- Integrate process & communities
- Integrate building system
- Align incentives

Courtesy: World Business Council for Sustainable Development (WBCSD) Report on Energy Efficiency in Buildings, July 2008

Systems Approach to Whole Building Integration

Cooperation between Sub-Systems to Reduce Overall Energy Consumption