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Chairman Gordon and Members of the Committee, thank you for the invitation to discuss "Opportunities for Onsite Renewable Energy Integration." I appreciate the opportunity to testify today at this important hearing.

Many of you are probably aware that buildings account for 40% of energy use and emissions in the US. Without stepped-up renewable integration this trend is expected to outpace that of any sector. To curtail this, it is essential that buildings' energy use be significantly reduced. What I would like to outline today are significant challenges and obstacles which hinder the design community's ability to integrate innovative renewable energy technologies into the built environment.

Architects, engineers and planners are implicitly center stage in the design and building process. We actively engage and coordinate with building owners and occupants, as well as operations and maintenance staff to apply their goals to collectively forge environments which meet their current and future needs. At a minimum, compliance with building and energy codes is necessary, though the preference is to exceed those minimum standards. Buildings, as well as campuses and communities, are a dynamic interplay of complex cybernetic systems. It is through this interaction of society and technology that the ultimate outcome of how a building or environment performs is demonstrated. Often times, design consultants have not only the ability to influence the incorporation of renewable energy systems into the built environment, but also the social obligation to design high-performance buildings, ultimately reducing the demand the built environment has on our natural resources as well as our dependency on foreign resources. With that responsibility also comes accountability when buildings do not perform as originally intended.

At the onset of building design, the opportunities to produce "greener" buildings are rarely hindered by the ability to incorporate higher-performing technologies, but rather are often challenged by financial and political issues. Even when renewable energy systems are incorporated the positive net effect is sometimes compromised by the building location, user behavior, or by the overall building operational subsystems not effectively communicating amongst themselves and the occupants. All of these factors contribute to marginalize design intent and ultimately building performance. I would like to articulate those inherent issues and provide some insights into additional areas which could provide enhanced building performance benefits through further technological innovation and applied research.

Challenge: Financial/Political

One of the most obvious and frequent obstacles which impede the integration of renewables into the built environment remain political and financial. Though many States and the Federal government have chosen to lead by example, requiring new and renovated government buildings to meet stricter energy standards, there still remain many State and privately funded organizations which have fewer mandates and incentives to comply. As of September, 2010 there are seven US States which do not have simple energy standards or executive orders to develop or encourage high performing buildings beyond basic energy codes such as the 2004 or 2007 ASHRE 90.1. Likewise, only about half of the US States and Territories have tax credits, rebates, grants, or even local utility involvement to incentivize and offset the initial costs of incorporating renewable technologies. Even government-mandated policies like the *Federal Energy Management Plan* which is designed to encourage the use of on-site renewables on Federal projects, often establish conditional requirements tied to life-cycle cost analysis. Too often

the first cost decisions outweigh simple payback durations which lead to short-sighted fiduciary decisions outweighing long-term performance issues.

Today, many renewable technologies including solar, wind, and solar thermal are much more expensive to utilize and employ than conventional fossil-based utility sources, and many current building project stakeholders are quickly overlooking the long-term benefit. Without governmental mandates or forms of continued subsidy the equation is lopsided. The clear solution in this case includes measures which make renewables more affordable and cost competitive compared with traditional energy sources at the outset of a buildings conceptualization. This imbalance could be eased by continued advancements in their manufacturing costs and overall efficiency of performance, and further reinforced by continued Federal and State subsidies, as well as policy mandates requiring their integration.

Challenge: Technology and the Inability to Predict Unpredictable Human Behavior

As Americans forge ahead in their quest for more sustainable built environments, there are fewer technical limitations when conceptualizing better performing buildings. Downstream from the design concepts and design intents are some of the technical challenges which do not allow them to operate or perform to their best ability. One of those challenges is related to the interface between people and technology; essentially the behavior of its occupants.

On-site renewable energy sources are ultimately directly tied into complex building management systems. As a result, a higher dependence is placed on integrated building management and energy systems technologies. Real-time monitoring and optimization controls are constantly measuring and communicating information from vast mechanical, electrical, and information-based technology systems of a building to its operators and users with the anticipation that they will produce highly optimized and reliable results. Unfortunately, the measurement science of predicting the outcome is lacking, and hardware and software compatibility of these components and systems are not designed to interact with themselves or the end users.

To this end, two areas which would have compounding benefits from increased research are enhanced computational environmental and energy modeling tools and more open sourced building management systems architecture. Environmental and energy modeling technologies rarely can account for the human condition; that is, how users really behave in their environments when complex indoor-outdoor and mixed-mode strategies interact with more capricious factors such as day-light, natural ventilation, and building occupancy utilization. For example, we can make predictions that might account for a building occupant opening a window to let in a breeze, but it would be difficult to determine very specifically when he/she might do that, under what temperature conditions, or that on the same day, someone else might have turned on all the lights on a building floor during daylight hours on a sunny day.

Challenge: Lack of Integration Among Building Modeling Systems

What furthers this lack of predictable modeling is a deficiency in the inability of complex heating, cooling, ventilation, IT, and electrical systems of effectively and efficiently interacting amongst themselves when factoring in the human condition. This whole building systems and occupant science could be enhanced by creating more open-source measurement and verification technologies which are designed to interact and predict with whole building systems complexities. And as we look toward achieving net zero milestones, these enhanced technology needs should also incorporate emissions measurements of their source energy.

From a more direct technological standpoint, some additional areas in which research could further enhance efficiencies and overall building performance include:

1. On-site renewable systems which specifically address dense urban environments including solar, wind, solar thermal
   As a majority of commercial and office buildings are located in urban environments often times it is difficult not only to harness renewable energy sources at the site, it is sometimes impossible to predict the long-term viability of its utilization on a site-by-site basis. Currently, most zoning regulations do not directly preserve solar access rights which would contribute to the implementation of renewables. Also, current efficiency rates of solar panel technology do not enable taller buildings with limited real estate foot prints enough space to utilize and implement on-site solar applications at ratio which has dramatic increases in energy performance.

2. Solar power
   Most buildings and their infrastructure do not run on DC power, which is the predominate output of renewables. Control systems, micro inverters, and meters need to better adapt to swing between DC and AC power voltages in a more efficient, real-time and cost effective way. Better efficiency of conversion and storage of solar energy, including DC to AC power inverters, could contribute toward better efficacy and integration with other building power needs and times of occupancy.

3. Daylighting, views and the curtain wall
   With the increased importance placed on day-light and views in built environments, often times this increases the demands for curtain wall systems (glass façade), the exterior glass system which are traditionally the worst performing elements in building envelop systems. More research needs to address higher performing curtain wall systems, even including phase change or self-regulating systems which have the ability to store solar heat when needed, reflect solar gain when not, and are more thermally resistant to harsh exterior environments which ultimately reduce energy and interior lighting consumption.

4. Supply side technologies
   Finally, we cannot look at renewable energy technologies exclusively from the demand side. On the supply side, water, is often overlooked as a renewable energy as well as a resource. Additional research and technological innovation which can safely and effectively reuse grey water into a buildings overall water demand needs could benefit from reduced off site municipal management demands by enabling on-site purification for non-potable or even ideally potable use.

While technology has been and will continue to be a critical component of the success of renewable energy integration, technical solutions alone are not sufficient to reach the goals of optimization which lie ahead of us. It is important to understand the complex relationship between technological sustainable development, the behavioral impacts of occupants and building owners, and the policy and financial costs of implementation; but more importantly, that future solutions must encompass the multitude of these challenges if we are to achieve optimal results.

Thank you again for the opportunity to testify today. I would be happy to answer any questions you may have.