Charting a Path to Net-Zero Energy:
Public-Private Sector Perspectives of the Commercial Buildings Consortium

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ABSTRACT

Transforming the commercial buildings market to become "net-zero-energy-capable" will require dramatically lower levels of energy use sectorwide. A comprehensive and concerted industry effort, partnering with utilities and government, must be sufficient in scale to influence the more than $600 billion per year spent on commercial new construction, renovation, and energy bills by fundamentally reinventing today's standard "design-build-operate" building delivery process as an integrated system throughout a building's life cycle.

In response to this need, in 2007 Congress called for creation of a Commercial Buildings Consortium (CBC) as a joint effort by the US Department of Energy (DOE), building owners and developers, states, utilities, and other stakeholders to develop and implement a multi-year agenda to transform the market through coordinated technology development, demonstration, and deployment. Since 2009, the CBC has attracted over 500 members, many of whom contributed actively, through 12 working groups, in developing two major reports released in early 2011: *Next Generation Technologies Barriers and Industry Recommendations* and an *Analysis of Cost and Non-cost Barriers and Policy Solutions.*

The technologies report addresses barriers and recommendations on the building envelope, mechanical systems and controls, lighting and daylighting, miscellaneous IT and process equipment, CHP and multi-building systems, grid integration, and energy modeling. The report on market barriers and policy solutions examines energy codes and standards, integrated design and building delivery, benchmarking and performance assurance, voluntary programs, finance and valuation, owners and tenants issues, and workforce development. Both reports emphasize that achieving low- and net-zero energy performance depends less on individual technologies than on well-executed integrated design.

This paper reviews the concept of net-zero energy (NZE) buildings and where we stand today. We discuss some of the near-term actions and longer-term strategies needed to accelerate technology innovation; make today's best practices tomorrow's business-as-usual; and deliver dramatically lower levels of energy use along with high-quality, healthy, and pleasant indoor environments that are resilient, adaptable, durable, and grid-responsive – while achieving market-accepted economics.

INTRODUCTION

The Zero Energy Commercial Buildings Consortium (CBC) was created in 2009 to address the need for a coordinated, broad-based industry/ government effort to move the entire commercial sector over time, both new buildings and existing stock, to "net-zero" levels of energy performance. The effort must be sufficient in scale to influence the more than $600 billion that commercial building owners spend each year on new construction, renovation, and energy (DOE EERE 2009).

Buildings in the U.S. account for about 40 percent of both energy consumption and greenhouse gas emissions (DOE EIA 2010). With commercial building accounting for half of that energy, a public-private partnership was needed to "reshape the overall 'invest – design – build – operate' playing field for commercial buildings so that zero energy buildings become the expected norm in less than 25 years" (Selkowitz *et al*. 2008; DOE EERE 2009a).

Recognizing that transforming the energy performance of commercial buildings is one of the quickest and most cost-effective ways to slow greenhouse gas (GHG) emissions, while also reducing the impact of rising and increasingly volatile energy prices, several leading organizations[1]

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[1] Alliance to Save Energy (ASE), American Institute of Architects (AIA); American Society of Heating,

prepared the first draft of the Commercial Buildings Initiative Action Plan and convened a series of meetings, starting in October 2006 and culminating in a one-day public workshop in December 2007 with support from the U.S. Department of Energy (DOE).

In late 2007, Congress created the Zero Net Energy Commercial Buildings Initiative (CBI) as part of the Energy Independence and Security Act (EISA) (P.L. 110-140, §421, 422 *et seq*.). The CBI's goals are to develop and disseminate technologies, practices, and policies for establishment of zero net energy commercial buildings. Congress also set major milestones toward achieving zero net energy performance: 1) for new commercial buildings by 2030; 2) for 50% percent of all commercial buildings in the stock by 2040; and 3) for all U.S. commercial buildings by 2050.

Authorized by the EISA legislation, DOE officially launched the Commercial Buildings Initiative (CBI) in August 2008, and in 2009 took steps to recognize the Zero Energy Commercial Buildings Consortium (CBC) as the supporting consortium for the goals of the CBI. As a result of a competitive solicitation, the CBC was funded to coordinate private and public sector involvement in technology and market assessments along with other activities to help accomplish the CBI goals. Since Congress authorized this initiative in 2007 the DOE budget for commercial buildings has grown to $33 million in FY09 and $39 million in FY10, thanks to strong support from several industry advocates and non-government organizations. Additional resources from the American Recovery and Reinvestment Act have contributed to the CBI goals.

Since its launch in 2009, the CBC has grown to 500+ member organizations committed to a market transformation to achieve eventual net-zero energy performance for commercial buildings. CBC members participated in 12 working groups to help develop two major reports released in early 2011: *Next Generation Technologies Barriers and Industry Recommendations* report and an *Analysis of Cost and Non-cost Barriers and Policy Solutions*.[2]

Since these reports were issued, the CBC continues to expand and engage its membership. The Consortium is particularly interest in increasing membership by and collaboration with local and state government agencies, both to assure representation of the non-federal public sector and to serve as an outreach channel to this audience for policy ideas, informational resources, and decision tools as part of the State Energy Efficiency Action Network (SEE-Action).[3] Also, as major building owners and managers of public building portfolios in their own right, state and local governments can lead by example by becoming early adopters of advanced technologies and energy management and continuous energy improvement practices.

GETTING TO NET-ZERO ENERGY: THE ROAD AHEAD

Undertaking a full scale transformation to net-zero energy commercial buildings is a major task, particularly for existing buildings. **Figure 1** provides a snapshot of the path to this goal. According to the 2003 Commercial Building Energy Consumption Survey (CBECS) the average site energy use intensity (EUI) for commercial buildings is about 90,000 Btu per square foot per year (DOE EIA). If all commercial buildings were built to the ASHRAE 90.1-2004 standard, the sector could achieve about a 20% reduction in energy use – and compliance with the latest ASHRAE 90.1-2010 standard (not shown) will achieve about a 45% reduction. Just a few buildings have been able to reach between 55%-70% energy reductions by implementing today's technologies and best practices and currently eight are documented in DOE's Zero Energy Buildings Database.[4] Designed to reach net-zero energy, these buildings focus on maximizing energy efficiency and incorporating on-site renewable energy. Though most of these buildings are relatively small, averaging about 6,000 sq.ft., a recent exception is the 222,000 sq.ft. Research Support Facility at the DOE National Renewable Energy Laboratory (NREL) in Golden, Colorado. Construction was completed in 2011 on this "living laboratory," designed to be the largest net-zero energy building in the nation; performance data are currently being collected.[5]

Refrigeration, and Air-Conditioning Engineers (ASHRAE); US Green Building Council (USGBC); Lawrence Berkeley National Laboratory (LBNL).

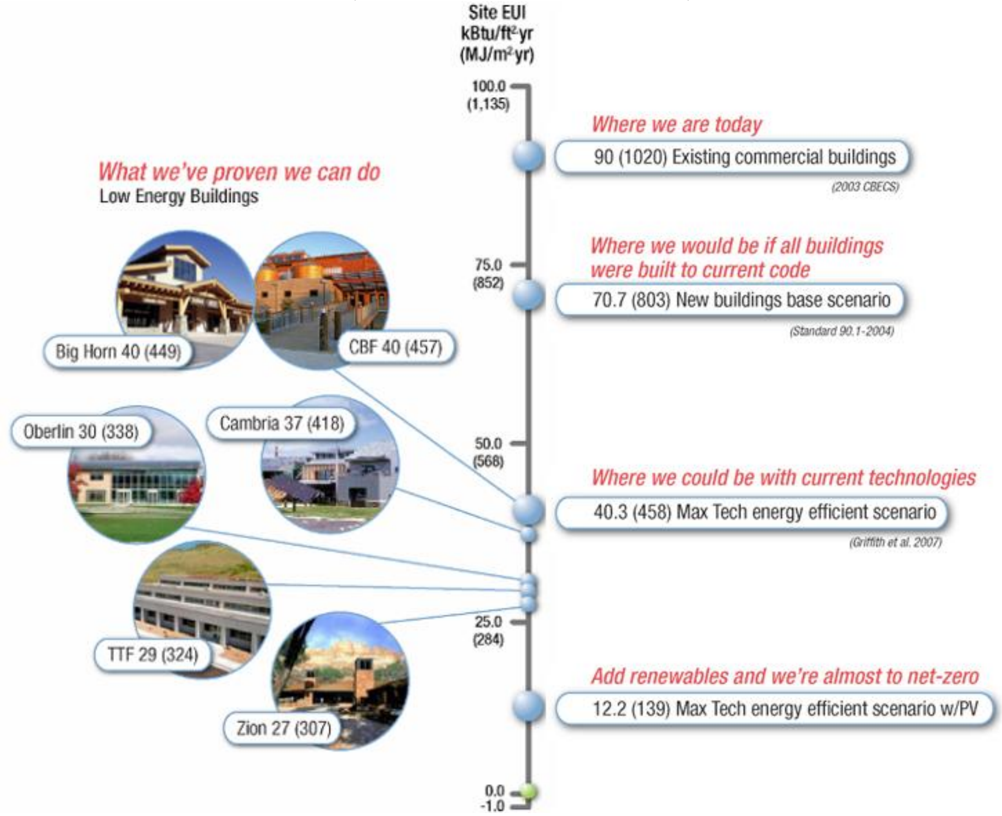
2 http://zeroenergycbc.org/pdf/CBC%20Technologies%20Report%202011.pdf and http://zeroenergycbc.org/pdf/CBC%20Market-Policy%20Report%202011.pdf

3 http://www1.eere.energy.gov/seeaction/

4 http://zeb.buildinggreen.com/

5 http://www.nrel.gov/sustainable_nrel/rsf.html

Figure 1. Average Commercial Sector EUI Scenarios
(Source: Griffith *et al*. 2007, xii)



The scarcity of high-performance and zero energy commercial buildings is a reflection of the magnitude of the challenge ahead. In general, to deliver and operate very low-energy or zero-energy buildings takes a dedicated and well-financed owner or developer, supported by experienced and innovative design, construction, and building operations personnel, as well as a sustained effort to educate and motivate building occupants. Today there are just a few of these pioneering zero-energy commercial buildings. In general they are located in moderate climates rather than areas with very high winter heating loads or summer cooling and dehumidification requirements. Most are low-rise buildings, which increases the ratio of roof area available for photovoltaics (PV) or/and solar thermal collectors to total floor area. However, low-rise buildings that limit development density can also limit the developer's profit margins, while failing to address energy savings beyond the building perimeter, at neighborhood and urban scales, for both buildings, utility infrastructure, and transportation (Carlisle *et al*. 2009).

The challenges ahead are to improve technology, bring down costs, and most importantly make it easier for everyone involved in the building delivery process to be invested early on – personally and institutionally as well as financially.

NET ZERO ENERGY BUILDINGS: UNDERSTANDING THE GOAL

"Net-zero energy" can be defined in a number of different ways and it is not easy to reach a consensus on any single definition (Torcellini *et al*. 2006). What DOE means by net-zero, what Congress had in mind when authorizing the initiative in EISA Section 422, and what individual developers, owners, architects, lenders, appraisers, or researchers have in mind may all be different.

However, there is so far to go to reach the ultimate goal of sectorwide net-zero that the absence of a single "correct" answer need not deterred us, for the time being, from pursuing the EISA statutory goals for commercial buildings. Despite the ongoing debate about what exactly defines a net-zero energy commercial building, there are certain attributes that any such building is very likely to have – starting with a dramatically reduced level of energy consumption and at least the potential to capture solar (or perhaps wind or other renewable) energy on-site (Madsen 2007).

The EISA legislation defines "zero-net-energy commercial building'' to mean a high-performance commercial building that is designed, constructed, and operated—

- to require a greatly reduced quantity of energy to operate;
- to meet the balance of energy needs from sources of energy that do not produce greenhouse gases;
- in a manner that will result in no net emissions of greenhouse gases; and
- to be economically viable.

Digging deeper, four commonly used definitions can be summarized as:

- *Net Zero Site Energy:* A building that produces at least as much energy as it uses in a year, when accounted for in site energy (not including electricity system losses).
- *Net Zero Source Energy:* A building that produces at least as much energy as it uses in a year, when accounted for in source (primary) energy, including electricity system losses.
- *Net Zero Energy Costs:* A building that receives at least as much annual revenue from the utility for on-site energy exported to the grid as the amount paid to the utility (or utilities) for energy used over the year.
- *Net Zero Energy Emissions:* [6] A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources. (Torcellini *et al*. 2006).

Recently, a report by the California Energy Commission expanded on the cost-based definition in an interesting way, one that may encompass the last three of four definitions above (emphasis added):

> "A ZNE building is a building in which the **societal value** of energy consumed over the course of a typical year is less than or equal to the societal value of the onsite renewable energy generated. The **societal value** of energy is the long-term projected cost of energy, including the peak demand cost (time-dependent valuation of energy), the value of associated carbon emissions, and other externalized costs." (CEC 2011)

A net-zero energy building that takes maximum advantage of energy efficiency features and then uses on-site power to meet the remaining energy needs will also need to draw on an integrated design approach, one that also extends past commissioning and the certificate-of-occupancy to tie in efficient operation and performance feedback to operators, occupants, and owners. This expanded view of integrated design, delivery, and operation was a recurring theme throughout the CBC working groups' recommendations in the reports.

Other considerations that may enter into the definition of net-zero energy (as well as project criteria for NZE buildings) include:

- *Economics* – Economic feasibility is essential if NZE buildings are to have a chance to be widely adopted. The total cost of ownership (including payments to amortize first-costs and the annual energy bill plus and other operating costs) must be in the same range as for a conventional, non-NZE building.[7]
- *Site vs source energy* – While this topic remains a source of controversy, energy performance metrics for commercial buildings such as ENERGY STAR benchmarking and "Portfolio Manager" lean toward source (primary) energy accounting in order to account for off-site energy losses in production and distribution, especially for electricity. Source energy also tracks more closely with energy costs and with GHG emissions, compared with site (delivered) energy, and avoids inadvertently signaling a net efficiency gain when a building or end-use is switched from on-site fuel consumption to electricity (off-site fuel consumption).
- *Grid connectivity vs grid-independence* –The concept of a *net* zero building implies either substantial on-site energy storage or grid connectivity, although such buildings are more likely to be resilient and remain functional in the event of a grid failure or brownout.
- *Peak electrical demand and load-shape* – Effective grid-integration of an NZE building is important to avoid imposing added electricity load during peak demand periods, as well as to make use of excess power from on-site generation as a source of revenue to the owner. The value of controlling and dispatching loads and on-site power needs to be recognized in utility tariffs or contractual arrangements.

[6] This last definition can apply to either greenhouse gas (GHG) emissions or/and other air and water pollutant emissions.

[7] A broad view of economic feasibility would also take into account societal and environmental costs currently treated as externalities, such as the cost of CO2 and other GHG emissions, use of exhaustible fossil fuels and other natural resources, air and water pollutants, traffic congestion, etc.

- *Renewable energy credits (and urban density)* – In some cases, the NZE equation may recognize use of off-site, purchased renewable electricity or "renewable energy credits." This is especially applicable to taller buildings in urban areas where density and mixed-use development offer benefits in off-site energy use for transportation and infrastructure services. In these cases, it may be more physically or economically feasible to produce renewable energy not on the building's rooftop but at another location – close by in a campus setting, in the same community, or elsewhere in the region.
- *Net-zero building or "community"* – A corollary to this argument is that if each NZE building is required to produce the needed renewable energy within its own footprint the result will be low-rise and thus low-density, sprawling development (Carlisle *et al* 2009, Malin 2010). Thus, a modified NZE criterion would require that a building's energy use be reduced to the level that *could* be met with rooftop PV (etc.) if the building were only 2-3 stories tall. Then higher-rise buildings or those with limited solar exposure could aim for the same energy consumption target with their renewable energy purchased off-site. As the NZE concept gathers momentum, it should not be allowed to dilute urban density in favor of low-rise sprawl; while this might technically satisfy NZE for an individual building it would lead to a sub-optimal solution for buildings as a whole.
- *Embodied energy* – Embodied energy (in building materials, equipment fabrication, and the construction process itself) is currently around 15% of a building's total life-cycle energy use, but this percentage will grow as the building-use energy is reduced in the move toward net-zero. For an NZE building using about 20% of today's average, embodied energy begins to approach the level of in-use energy, making it an important factor to address through careful choice of materials, tight management of construction processes, and designing components and systems to be modular, flexible, and re-usable.
- *Indirect and induced energy use* – Similarly, the energy used to transport building occupants and other users (as well as operating supplies and waste materials) to and from the building should be addressed through locational decisions; access to transit, bicycle, or pedestrian paths; and mixed-use development.
- *Beyond energy to overall building performance* – To be commercially viable and a preferred choice for building developers, owners and occupants, a low-energy or NZE building must also provide the expected level – and preferably superior levels – of building services and amenities, including thermal comfort, lighting quality and visual comfort, and indoor air quality.
- *Lifetime performance* – With most new commercial buildings likely to remain in service for many decades, an NZE building must deliver not only initial energy performance but sustained performance and high-quality building services.
- *Planning ahead ("NZE-ready")* – A new or renovated building should be configured not only to maintain it initial energy performance but to improve it in the future – in other words to be NZE-ready or "future-proofed." For example, while some costly features (such as rooftop PV, solar hot water collectors, space for a thermal energy storage tank, or a ground-loop for heating and cooling) may not be installed initially, features such as roof orientation, extra mechanical room space, and wiring or plumbing chases can be designed into a new building to help make these future upgrades feasible at much lower cost.
- *Water Consumption* – Managing water use is an increasingly concern in many regions, and water use efficiency is an energy issue because of the significant amount of energy embodied in water supply and post-use treatment – as well as the added required to heat water for uses such as kitchen sanitation, laundries, showers, etc.

While the CBC has not adopted a formal definition of an NZE building, we see the need to address all the elements mentioned above. High-performance NZE commercial buildings must maximize energy efficiency to achieve very low annual energy use, at a level that can be met with on-site renewable energy produced within the footprint of a 2-3 story structure. NZE buildings should also take into account GHG emissions; economic feasibility; load-shape impacts on the utility grid and other customers; indoor environmental quality and occupant comfort and amenity; energy embodied in construction; transportation energy indirectly required by occupants and visitors; and efficient use of water and other non-energy resources. At present, the CBC is focusing on major reductions in energy use, keeping those other factors in mind while recognizing that a more precise definition of the goal can wait until we get closer to net-zero.

INDUSTRY RECOMMENDATIONS ON TECHNOLOGIES AND POLICIES TO ADVANCE NET-ZERO ENERGY COMMERCIAL BUILDINGS

As noted, with significant input from working group members the CBC issued two reports in early 2011 identifying opportunities, issues, and recommended actions. These two reports[8] focus on innovative technologies and practices as well as market-based strategies and policies to advance net-zero energy commercial buildings. This section summarizes some key themes in these reports.

While the CBC's vision is to ultimately transform the entire commercial sector to net-zero energy, all stakeholders recognize today's market realities of a slowly recovering commercial real estate market as well as the importance of practical, near-term actions to address the existing building stock as well as new construction. The CBC's approach emphasizes that substantial improvements in energy efficiency are the most important first step toward net-zero, both for new buildings and for deep energy savings and sustained energy management practice in existing buildings.

To advance building technology at the component, system, whole-building, and multi-building (community) scale, we need an increased commitment to both basic and applied R&D, along with "test beds" for new technologies; post-occupancy measurement and evaluations to provide feedback from real, occupied buildings; and more attention to behavioral research on how individuals and organizations make energy-related decisions.

Another consistent theme in the working group discussions and CBC reports was the need for wide adoption of an integrated design and delivery process. In order to design and operate buildings as effective systems, the industry needs to move beyond a fragmented, sequential design and construction process that results in narrowly-based decision-making, and towards a collaborative, integrated process that engages developers, designers, owners, operators, and even occupants to jointly engage in systems-level thinking and optimization that addresses total building performance over an extended period of time.

[8] *Next Generation Technologies Barriers and Industry Recommendations* and an *Analysis of Cost and Non-cost Barriers and Policy Solutions*.

In the process of identifying specific technology opportunities and barriers, the CBC recognized that many currently available technologies remain underutilized despite their energy savings potential and life-cycle cost-effectiveness – underscoring the persistence of market barriers. If these existing technologies were to become standard practice huge energy savings would be achieved – and yet additional efforts would still be needed to spur innovation for the next generation of energy-saving technologies.

As discussed in the next section, throughout the multi-decade life of a commercial building, effective and sustained energy management is essential to ensure that the building continues to operate as intended. Energy-efficient operation must encompass not only installed mechanical systems and lighting, but attention to managing plug loads and process energy such as computers and IT, commercial kitchens, and medical or research equipment. The percentage share of these plug and process loads, unregulated by most building energy codes, can already represent 25-30+% of total energy use in some commercial buildings, and will only increase over time.

Last, more innovative and financing, including appraisal practices that recognize the asset-value of future energy savings, are essential to achieving NZE goals in both new and existing commercial buildings. Recent initiatives related to "Property Assessed Clean Energy" (PACE) financing for commercial building retrofits (Pike Research 2010; LBNL 2011) and DOE collaboration with the commercial property appraisal community are important steps in this direction.[9]

FIRST STEPS ON THE ROAD TO NET-ZERO – CONTINUOUS ENERGY EFFICIENCY IMPROVEMENT IN EXISTING BUILDINGS

A productive path toward net-zero building energy use for the entire commercial sector must encompass both newly constructed buildings and the millions of existing buildings in the current stock. For both new and existing buildings, energy use needs to be managed as part of a long-term process of continuous improvement, achieved through periodic or continuous commissioning of systems, effective operations and maintenance, and using every modification of building systems – from routine equipment replacement and tenant improvements to

[9] For DOE's initiative with the Appraisal Institute see http://www.energy.gov/news/10363.htm.

occasional gut-level renovation – as an opportunity for energy efficiency upgrades, as well. This approach to continuous efficiency improvement views energy management as an ongoing *process* integrated with asset management, rather than a one-time (retrofit or equipment replacement) *event* driven solely by energy cost savings. As an organizational framework and asset management philosophy, continuous efficiency improvement must be supported by an organizational structure that: a) clearly assigns responsibility and accountability for decisions that impact energy performance, and b) reliably tracks performance trends against efficiency goals and industry best practices.

As the continuous efficiency improvement concept gains traction in the market, the energy efficiency community is beginning to respond with resources, programs and standards to firmly ground energy management principles within the standard operation of commercial buildings. In July, 2011, the International Standards Organization (ISO) released ISO 50001:2011, a voluntary energy management standard that establishes a systematic approach to continuous improvement in energy performance for both commercial and government/institutional buildings and industrial facilities.[10] This internationally-recognized standard, targeted to a wide range of energy-using facilities, is both an operational guide and a means of verifying that sound energy management practices are in place. For commercial buildings, ISO 50001:2011 will help communicate to the market a property owner's commitment to energy management and energy-efficient operation.

ISO 50001 is also a foundational element of the Superior Energy Performance (SEP) and Global Superior Energy Performance (GSEP) initiatives under development by the U.S. DOE in collaboration with U.S. industry, large owners of commercial properties, and other stakeholders. These programs, currently in a pilot phase, are designed to support and certify compliance by both commercial buildings and industrial facilities with ISO 50001 and to recognize achievement of specified goals for continuous energy performance improvement. [11]

In order to stimulate private investment in the energy efficiency of commercial buildings, a number of other programs and initiatives are emerging at both local and national levels. The Better Buildings Challenge, a flagship campaign of the U.S. DOE Building Technologies Program, aims to increase the energy efficiency of existing buildings 20 percent by 2020.[12] To support this objective, the White House has proposed a series of initiatives in the President's 2012 budget, including: new tax incentives; additional financing mechanisms to support commercial retrofits; improved energy information to inform more accurate property appraisals; workforce training; and enhanced building codes at the state and local levels. This program has garnered initial commitments from several private companies, universities and municipalities to improve the energy efficiency of their own building portfolios 20 percent by 2020.

Finally, a number of utility companies throughout the U.S. are beginning to shift their energy efficiency program models from one-time energy audit, retrofit rebates, or design assistance for construction and renovation to an ongoing partner relationship with their major commercial customers, aimed at continuous energy efficiency improvement through practices such as retrocommissioning; better instrumentation, software, and operator training to improve energy management; and staged efficiency upgrades (CEE 2011).

CONCLUSION

In addition to federal policies and funding to support for R&D and technology deployment, a supporting policy and program framework at the state and local levels is important to accelerate market transformation towards net-zero. Policies such as building energy codes and expanded coverage of equipment efficiency standards help set a floor for minimum energy performance. Utility demand-side management programs for commercial customers are spurred by incentive-based ratemaking, renewable or energy efficiency portfolio standards, statewide energy efficiency or greenhouse gas reduction targets, and regional GHG trading schemes such as the Regional Greenhouse Gas Initiative in the Northeast (RGGI). All levels of government can help push the envelope through voluntary initiatives, performance rating, and recognition programs such as

[10] For an overview of ISO-50001 see http://www.iso.org/iso/iso_50001_energy.pdf.

[11] More specifics on SEP and GSEP are at http://www.superiorenergyperformance.net/, http://www.cleanenergyministerial.org/gsep/.

[12] BetterBuildings is described at http://www1.eere.energy.gov/buildings/betterbuildings/.

building energy "reach" codes, building energy rating and disclosure requirements, certification of high-performance buildings through ENERGY STAR or DOE's proposed Superior Energy Performance initiative for ISO-50001 compliant buildings, innovative financing, and property appraisal that recognizes energy cost savings in asset value. These voluntary policies serve to establish both industry and customer expectations for continuous energy efficiency improvements in the future – charting a path towards net-zero energy goals and enabling the private sector to invest in this area by recognizing the market value of efficiency and reducing the risk for innovation.

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