Commercial Buildings Integration Multi-Year Program Plan
FY 2009 - 2014

Introduction

Consistent with the Energy Independence and Security Act of 2007 (EISA), Section 422, Net-Zero Energy Commercial Buildings Initiative (CBI), the goal of DOE's Commercial Buildings Program is ultimately to achieve the development of net-zero energy commercial buildings (NZEBs) in the United States. The Program's goals for commercial buildings are as follows:

- Improve the whole-building energy performance in *new* construction by 50% by 2015; and by 70% by 2025, relative to ASHRAE/IESNA/ANSI Standard 90.1-2004. A 70% reduction in whole building energy use, combined with renewables, provides net-zero energy buildings (NZEB).
- Improve existing building stock energy performance by 50% by 2030 over the Commercial Buildings Energy Consumption Survey (CBECS) 2003 baseline.

EISA Section 422 specifically calls for "the development and establishment of net-zero energy commercial buildings for: (1) any commercial building newly constructed in the United States by 2030; (2) 50 % of the commercial building stock of the United States by 2040; and (3) all commercial buildings in the United States by 2050." With regard to the 2030 net-zero energy goal for new buildings, DOE's NZEB goals (*in place since 2005*) directly support EISA's call for NZEB performance in *any* new building by 2030. [1] In regard to the NZEB goals for 50% of the stock by 2040 and all buildings by 2050, DOE's focus on marketable new NZEBs is a necessary condition for wider adoption of net-zero performance in existing, and thus all, buildings in later years. Improving the existing stock's performance by 30% by 2025 is also an important milestone on the way to NZEBs by 2040. Elements in other parts of DOE's buildings portfolio also support the Section 422 NZEB goals, including 30% more stringent model codes for commercial buildings, more stringent equipment and lighting standards as promulgated in EISA, and aggressive component research in lighting, HVAC systems and other areas.

The importance of commercial buildings work was emphasized on August 5, 2008, with the formal launching of DOE's Net-Zero Energy Commercial Building Initiative (CBI) and the establishment of the National Laboratory Collaborative on Building Technologies (NLCBT).[2] These two efforts both focus on DOE's ongoing work to develop market-ready commercial NZEBs by 2025. As noted above, EISA 2007 authorizes DOE to collaborate with its national laboratories, the private sector, other federal agencies, and non-governmental organizations to advance high-performance commercial green buildings. The role of the NLCBT will be to provide intellectual and scientific resources to support of the CBI; the NLCBT laboratories include Argonne National Laboratory, Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory.

---

[1] Research, Development, Regulatory and Market Introduction Plan: Planned program activities for 2006-2011, August 2005, Building Technologies Program, DOE, page 1-14.
[2] DOE Press Release, August 5, 2008, *DOE to Pursue Zero-Net Energy Commercial Buildings.*

DOE's Commercial Buildings Program includes research, development, and demonstration of high-performance and green building technologies, and active engagement with significant market actors, design methods, and operational practices. Technology development efforts focus on the breakthrough technologies needed to realize exemplary energy performance levels, including advanced evaporative cooling/ice storage rooftop unit, liquid desiccant dehumidification, radiant floor heating and cooling, efficient low-lift cooling, advanced controls, advanced ventilation systems and advanced lighting systems. These efforts support the EISA Section 422 NZEB goal, not only by reducing building energy needs and carbon emissions, but also by developing design methods and operating strategies which seamlessly incorporate solar and other renewable technologies into commercial buildings. EISA's call for the CBI directs strong engagement with market actors, including "deployment, dissemination, and technical assistance activities to *encourage widespread adoption of technologies*, practices" and "conducting pilot programs and demonstration projects to *evaluate replicable approaches* to achieving energy-efficient commercial buildings for a variety of building types in a variety of climate zones." [Emphasis added.] Pursuant to this resolute market emphasis, DOE's Commercial Building Energy Alliances, along with close technical support of National Accounts, will be *the* vehicles for evaluating, testing, and ultimately implementing these approaches across the nation's climate zones.

Due to the passage of the EISA 2007, signed into law by the President in December 2007, this Multi-Year Program Plan (MYPP) represents a further refinement of the approach described in the FY2008-13 BTP MYYP.

The Commercial Team wishes to communicate the plan for the next five years clearly at the outset of this MYPP, and following the example from last year, has restructured the MYPP Template accordingly. While the plan will cover the information required in the MYPP Template, much of that information – including unaddressed opportunities, technical pathways to zero energy performance, and intra-BTP integration of efforts – has been included in the appendices. The major focus here will be on the plan of action for the next five years, as summarized in the Gantt chart (attached) as an Acrobat file.

The important themes of this MYPP may be summarized as follows:

1. DOE's goals in new construction are aggressive, as they must be, in hewing to the NZEB intent of the EISA 2007. They are to realize whole-building improvements of 50% by 2015 and 70% by 2025, relative to ANSI/ASHRAE/IESNA Standard 90.1-2004. As an example of its commitment to the 50% goal, in FY09 DOE will complete five Technical Support Documents (TSDs) that show how to achieve 50% energy savings in big-box retail, grocery stores, small- and medium-sized office buildings, warehouses, and hospitals. In addition, DOE is funding its national laboratories to work as part of National Accounts Teams to demonstrate 50% savings in new construction.
2. Also consistent with the NZEB provisions of EISA, DOE will increase efforts to improve the energy performance of buildings in the existing stock. DOE's goals in the large stock of existing buildings are to provide the technical capability to

improve energy performance 30% by 2025 over CBECS 2003 baselines for existing buildings. DOE's Retailer Energy Alliance, for example, offers an ideal opportunity to work with its 24 current members (including Walmart, REI, Food Lion, Home Depot, and McDonald's) to improve the energy performance of their *50,000 plus* existing stores.

3. Active private sector involvement is absolutely critical to success. Independent associations of commercial building owners, operators and tenants by sector, the Commercial Building Energy Alliances (CBEAs) are playing, and will play, many roles: as an information network for sharing best practices, as a tapper of DOE national lab expertise and shaper of DOE R&D priorities, as an avenue for advanced technology deployment, and as an evaluator of "in-field" performance and marketability. National Accounts - businesses with significant building portfolios, regular new construction and retrofit of existing buildings – are also key, as they will pilot, test, evaluate, and demonstrate technologies and approaches in their quest to realize 50% savings in new buildings and 30% in existing buildings within the next several years.
4. In working with private sector partners, guiding watchwords include "flexibility," "collaborative," "creative," "responsive" and "can-do."
5. The formal launching of the National Laboratory Collaborative on Building Technologies (NLCBT) enables DOE to coordinate application of its national laboratories' strengths, including R&D, field validation of performance, and analysis, all to serve the goals and priorities of DOE and its partners.
6. Stage-Gate thinking and principles infuse this plan. In generic terms, the general approach is "plan – develop - demonstrate – test – evaluate results – decide to go, recycle, or terminate."
7. *All* of DOE's commercial portfolio, from research to analysis, will be refocused to support DOE's goals and its market engagement strategy *directly*. Research elements that DOE has traditionally supported in level-of-effort manner, such as Indoor Environmental Quality, are being redirected – through the AOP process – to deliver priority technology solutions that can be implemented in buildings. Analysis work will be targeted directly to answer questions in direct support of portfolio decision-making.
8. DOE's commercial buildings portfolio currently includes only some of the many opportunities for realizing exemplary and net-zero energy performance. The Commercial Team has identified many opportunities that DOE could potentially address at different budgetary levels, including input from the NLCBT, Esource, Team members, and from buildings efficiency literature. Some higher priority gaps are identified in Appendix A.
9. The Team understands that one of its central functions within BTP is to provide clear guidance on the Technical Pathways needed to achieve exemplary energy performance levels, including specification of component performance levels. This specification will in turn inform the research activities of the component programs – HVAC systems, envelope, and windows – and codes in the Annual Operating Plan's "statement of needs." This plan (see Appendix B) includes preliminary EnergyPlus-based analysis by NREL that provides such guidance for offices and big-box retail. The Technical Pathways will be refined in a

subsequent iteration of this MYPP, following the November 2008 MYPP Integration Workshop.

Program Structure

The Commercial Buildings Program has three interrelated elements:

- Market Outreach and Engagement – Commercial Building Energy Alliances and National Accounts are strategic alliances between DOE, private businesses and organizations created to achieve strong market demand for buildings with exemplary energy performance in large numbers of new and existing buildings;
- Building Package Research and Development – DOE-sponsored development of advanced design guide products, building decision tools, and technology solutions to support realization of 50% and better buildings.
- Management – transparent management of the portfolio, including clear delineation of Stage-Gate decision points, and development of supporting analysis and materials; development of contractor solicitations to support program activities; provision of performance requirements to the component programs in BTP's Emerging Technologies Division; and active planning throughout the fiscal year to adjust to changing circumstances and opportunities.

This plan provides a detailed narrative description of each of these three elements. The reader should refer to the attached Gantt chart as a guide to the narrative below. **Please note that the Section numbering in this plan mirrors the Work Breakdown Structure (WBS) in the Gantt chart.**

1. Market Engagement

DOE's strategy of systematic market engagement – to realize deep energy savings, at scale, in new construction and existing buildings – relies on two foundational elements: the creation of the Commercial Building Energy Alliances, and the involvement and commitment of National Accounts.

1.1 Commercial Building Energy Alliances

Commercial Building Energy Alliances (CBEAs) are informal associations of commercial building owners and operators by sector (retail, commercial real estate, institutions) who want to significantly reduce energy consumption and carbon emissions. These Alliances will function in a number of capacities, including the following:

- Sharing best practices, energy-use measurement, and benchmarking – in essence, serving as an organic, real-time information network;
- Tapping the technical expertise of DOE and its national laboratories to shape federal building R&D to advance the business case for energy efficiency;
- Deploying advanced technology through technology procurements and information-sharing within commercial sub-sectors;
- Conducting deployment, dissemination, and technical assistance activities to encourage and assist adoption of technologies, practices, and policies;

- Developing training materials and courses for building professionals and trades—which in turn will be deployed by Alliance partners;
- Developing and disseminating public education materials on benefits and cost-effectiveness of high-performance, energy-efficient buildings.

Each of the Commercial Building Energy Alliances is established with a public launching. DOE launched the first CBEA, the Retailer Energy Alliance (REA), in February 2008. It is focused on the following retail building types: big-box retail, grocery, mixed retail and grocery, restaurant, and warehousing/distribution. In the next two years, DOE plans to stand-up and launch additional CBEAs (also see the attached Gantt chart):

- The Commercial Real Estate Energy Alliance will be launched by Q3 2009 and will include offices, shopping centers, hospitality, medical offices, and federal government offices operated or leased by the U.S. General Services Administration (GSA);
- The Commercial Building Industry Energy Alliance will be launched by Q4 2009 and will include the design community, utilities, finance, manufacturers, suppliers and energy service companies;
- Institutional Energy Alliances will feature the following individual Alliances with the following launch dates:
    - Hospitals – by Q2 2009
    - Government – Federal, State and Local – by Q2 2010
    - Colleges and Universities by Q1 2010

CBEA members will participate in meetings, hosted by DOE, on the status of the Alliances and subcommittees, share lessons learned, as well as learn about emerging technologies of relevance, including those under development by DOE and its national labs. CBEA subcommittees, focusing on particular technology areas or industry sub-sectors (such as the REA's Restaurant and Food Preparation Subcommittee), will also hold monthly conference calls to prioritize their work and to move forward with current projects, such as technology procurements – or in the case of the Restaurant Subcommittee – benchmarking. Each Alliance will develop Best Practices information, guides, and materials as they prioritize their needs on an annual basis. As much of this data is business-sensitive, DOE will work with members to "mask" such data, or to release only that information which the members wish to share openly among their peers. This Best Practices analysis will annually determine if Alliance members have improved energy use in existing buildings and if DOE, through these Alliances, has been able to increase the uptake of exemplary building designs.

1.2 Crosscutting Alliance Activities

In addition to the CBEAs themselves, DOE will support crosscutting activities that directly support the goals of the Alliances.[3] Funded and scoped by DOE, this work will effectively be managed within the auspices of the CBEAs, as that is the most effective way to tailor products – in real time – to the interests of a dynamic marketplace.

[3] The term crosscutting specifically means that the work will generally apply to more than one CBEA.

The content of this crosscutting work will change over time, determined by Departmental resources and the interests of the CBEAs. At the current time, there are three major crosscutting thrusts: procurements of advanced technologies; solutions using currently available technologies to address lighting, the largest single energy use in commercial buildings; and ongoing technology evaluation and screening to bring promising technologies to the attention of the CBEAs.

1.2.1 Technology Procurements

The purpose of a technology procurement, by its design, is to bring superior equipment to the market, where "superior" is defined to be innovative energy-saving technology that is either 1) not previously available, or 2) significantly underutilized (currently has very low market penetration). DOE has used this approach successfully in the past, such as with the introduction of (efficient) compact fluorescent lamps with attributes – from geometry to brightness – allowing for easy substitution of incandescent lamps.[4] When the energy savings goal is aggressive, as per the goals of the CBEAs, then improvements across a range of energy-using technologies are required. Via this technique, CBEA members will use their combined purchasing power to bring advanced energy-efficient, competitively-priced technologies into the marketplace.

One of the first steps in the technology procurement process is identifying potential technology candidates both in terms of energy savings potential and the active interest of CBEA members. For the first technology procurement project, the Retailer Energy Alliance's members selected LED parking lot lighting as the target technology of most promise, and in April 2008, the REA established a working group to pursue a Technology Procurement for it.As shown in the Gantt chart, a draft specification for LED parking lot lighting is expected Q1 of FY09, followed by the issuance of a final specification soon after, selection of winning products, and monitoring and validation of actual field performance. The timeline shown is largely based on the past experience of PNNL, which indicates that technology procurement projects typically require about 2 years to complete.

A second Technology Procurement project to be identified by the CBEAs is expected to be launched in Q3 of FY09 Additional rounds of technology procurements will follow, depending on the interests of CBEA members. (These are not called out on the Gantt chart, so as to avoid excessive clutter). This is an activity that will likely be repeated

---

[4] Hollomon B, MR Ledbetter, LJ Sandahl, and TL Shoemaker. 2002. "Seven Years Since SERP: Successes and Setbacks in Technology Procurement ." In *2002 American Council for an Energy-Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Buildings. Part 6--Market transformation energy efficiency in buildings; teaming for efficiency* , vol. 6, pp. 6.125 - 6.138. ACEEE, Washington, DC. http://www.pnl.gov/publications/abstracts.asp?report=152629 Ledbetter, Marc, et. al. 1999. U.S. Energy-Efficient Technology Procurement Projects: Evaluation and Lessons Learned, prepared for the U.S. Dept. of Energy, PNNL-12118, Pacific Northwest National Laboratory.

through time, assuming that formal Stage-Gate evaluations determine that further work is merited. DOE intends to evaluate the LED parking lot lighting project in a formal Stage-Gate evaluation in Q4 of FY09 to determine its success, and intends to evaluate the efficacy of this mechanism overall by Q4 of 2010. A "no-go" decision would result in program redesign and different approaches with the CBEAs.

A detailed strategy for technology procurement will be developed for the Commercial Real Estate Energy Alliance by its mid-FY09 launch date (1.2.1.1); similar plans will also be developed for the other CBEAs (Gantt 1.2.1.2) assuming a "go" for the aforementioned Stage-Gate in Q4 2010.

1.2.2 Commercial Lighting Solutions (CLS)

Any endeavor to realize deep energy savings must include lighting as part of its "solution set" because fully one-quarter of commercial buildings energy use (on average) is lighting; sector wide, commercial buildings, require 4.45 source quads per year to provide illumination services.[5] In addition to direct energy consumption, the heat generated by lighting during normal operation increases buildings cooling requirements, and accounts for up to 42% of cooling load in a "typical" commercial building.[6] This implies that well designed lighting efficiency, which also lowers internal gains, is an effective strategy for cooling.

DOE's CLS activity uses numerous strategies in keeping with the engineering standard of care to save lighting energy, including integration of high-performance products, expert electric and daylighting design, controls, and installation and commissioning guidance. These strategies are far superior to standard practice in lighting, which uses commodity products and outdated approaches, without daylighting or controls. CLS will be analyzed to verify energy savings, costs and system reliability and then will be deployed into utility and energy efficiency programs. Rebates and incentives by utilities for systems rather than components will address the first cost barrier, representing a significant shift in approach and an opportunity to get traction in the market for advanced systems.

The delivery mechanism for CLS is a Web tool which is critical to widespread usage and includes a strong interactive element that both educates and guides the end-user through the application of the solutions. The Web tool is also critical for capturing impact and usage of the solutions.

Some key activities under CLS are shown in FY09 (see Gantt) and include the following:

- Launch of Version 1.0 of the Retail Web tool in Q3 of FY09 (currently in BETA)
- Release of a BETA version of the Web tool with Office Solutions by Q3 of FY09, for unveiling at the *LightFair* conference

[5] 2008 Buildings Energy Data Book, Table 3.1.4, http://buildingsdatabook.eere.energy.gov/docs/xls_pdf/3.1.4.pdf
[6] IBID, Table 3.1.12, http://buildingsdatabook.eere.energy.gov/docs/xls_pdf/3.1.12.pdf

- Development of draft plans for lighting solutions for the other CBEAs by Q2 of FY09. As part of this process, DOE will develop deliverables and milestones into FY10 and beyond.

1.2.3 Technology Evaluation & Screening

DOE's goals are aggressive: 50% energy savings by 2015, and net-zero energy buildings by 2025. Which technologies are most promising in terms of reaching these goals? What is available today, but underutilized? Which technologies are critical to success, irrespective of climate zone or building type? Which technologies over-promise but, in actual field testing, under-deliver? The purpose of this activity is to help answer questions such as these. DOE, through its national laboratories and contractors, can help provide answers to these questions by objectively evaluating the literature on emerging technologies, and by carefully screening them for applicability to the commercial market sectors, including new construction and retrofit of existing buildings. DOE envisions that this activity will be conducted on an ongoing basis, with quarterly status updates, in part because there is a large volume of technology information to process and make objective sense of, and in part because the interests of the CBEAs are likely to be dynamic.

Finally, it is worth noting that the results of two other efforts managed by DOE will be highly germane to the attention of the Alliances. These are Decision Tools for Evaluating "Package" Selections and Design Package R&D. Both efforts are described in more detail in Section 2. The Decision Tools should inform development of advanced new construction building prototype designs, and will also help select solution sets appropriate to the building type and the owner/designer performance target. The tools will present a continuum of efficiency levels from 50% and beyond.

Design Package R&D is essentially the core R&D activity in the Commercial Program and may include HVAC/R, Indoor Environmental Quality, Controls and Miscellaneous Uses. DOE will work with the CBEA members to help determine its R&D priorities, to explore cost-sharing possibilities, and to provide updates on R&D.

1.3 National Accounts

The use of National Accounts is the other key aspect of DOE's market engagement strategy. A National Account is a company or organization that designs, builds, owns, manages, or operates its own stock of buildings (for instance, chains such as Whole Foods Market, Toyota, Macy's and Best Buy, as well as major commercial real estate companies, such as owner-operators CB Richard Ellis, InterContinental Hotels Group, and Forest City Enterprises). The National Account teams will work with a Commercial Building Design Team (CBDT), comprised of a national lab as the CBDT lead investigator, and expert design consultants (e.g., A/E firms, HVAC consultants), to design, build, commission, and operate both retrofit and new prototype buildings projects that promise unprecedented insight into private sector decision processes, business models, and financial drivers. In identifying approaches that can be replicated across the

nation, the teams' efforts will impact the work of researchers, building professionals, the construction industry, and component and equipment suppliers.

From DOE's perspective, the ultimate goal is to develop prototype designs for each building type in each of the nation's climate zones that achieve cost-effective enhancement of new commercial building designs and retrofit of existing buildings to achieve at least 50% and 30% energy savings, respectively, above ASHRAE Standard 90.1-2004. (The energy savings targets for the EnergySmart Hospitals sub-sector are 20% for retrofits and 30% for new buildings.) DOE recognizes, however, that the National Account will select the design, and associated efficiency level, that meets its cost constraints and operating needs. However, the full spectrum of choices, as embodied in the Building Package Solution, from 30 to 50% energy savings, or greater, will be analyzed and documented so that other alliance members have the ability to make alternative choices.

The NA Team and DOE agree to:
1. Set energy performance and demand, environmental, and cost targets for each building redesign and retrofit project in advance.
2. Share the results of the redesign with the respective CBEA and, as mutually agreed upon, more broadly.

CBDT Responsibilities
The CBDT Lead provides independent expertise to review design concepts, construction document submissions and equipment specifications, aids in contract modifications to further energy efficiencies, participates in commissioning activities, assists in design and debug of controls and operational sequences, and assists in developing the monitoring and energy management systems. The CBDT will also prepare business cases and individual case studies following testing/monitoring of new and retrofit buildings to verify energy performance and demand, environmental, and cost targets. The detailed findings will be documented in reports for distribution to the respective CBEA.

NAC Responsibilities
Each NAC will take a lead role in designing, constructing, analyzing, retrofitting, and replicating at least one or more energy efficient buildings as the business case warrants to meet the energy performance and demand, environmental, and cost targets agreed upon with DOE after award.

The NAC will monitor and verify energy performance and demand in the newly constructed prototype. This monitoring process is expected to continue for at least one year after occupancy.

Task Structure
The format, key requirements, and task titles to be used in each specific NAC-focused design, construction, commissioning, and retrofit subproject follows:

Task 1) Project Management Plan – The Project Management Plan will be revised after award and upon completion of each stage of project progression.

Task 2) Benchmarking – The CBDT shall evaluate building types for each NAC and determine which buildings are to be further evaluated based upon potential cost-effective energy savings. Following this evaluation, the CBDT will propose a group(s) of buildings to be the focus of the remainder of the project.

Go/recycle/no-go – DOE will determine whether or not to proceed. Should DOE determine that the proposed buildings do not fulfill programmatic expectations, another NAC shall be selected and Task 1 shall be repeated.

Task 3) Design/Redesign – The CBDT will work with the NACs to design a new building or redesign an existing building and/or specify equipment upgrades to be further considered. Detailed energy and cost analyses will be conducted in conjunction with this effort to ensure that proposed changes meet performance expectations and are within the NAC business targets.

Go/recycle/no-go – DOE will determine whether or not to proceed.

Task 4) Performance Verification – A DOE-approved monitoring and performance verification plan must be developed by the CBDT prior to energy performance and demand determinations. Following retrofit or construction of a new building according to the Task 3 design/redesign, energy performance and demand, environmental, and cost targets shall be verified by the CBDT through monitoring, calculation, and/or modeling.

Go/recycle/no-go – DOE will determine whether or not to proceed.

Task 5) Case Study - The CBDT will develop a case study final report documenting all findings to include energy savings, redesign costs, and payback period for each building constructed or retrofitted. This case study shall be distributed to DOE and respective CBEA members. These must be laboratory technical quality, peer-reviewed reports for public distribution.

Task 6) Research Report – The CBDT will prepare an annual summary research report for DOE internal use on lessons learned, design practices and useful tools, construction and installation guidelines, commissioning, and controls experience gained for all buildings constructed or retrofitted. The final research report will be a comprehensive summary of the entire project and must be prepared as a laboratory technical quality, peer-reviewed report for public distribution.

Task 7) Business Case - Each NAC, working with the CBDT, will create at least one business case for each new and retrofit building designed/redesigned in this project.

DOE envisions that the National Account prototype design and construction process described above will be repeated for other building types and for priority building

subsector targets (see Gantt chart). Identification and selection of National Accounts within future Alliances will follow.

At the end of FY08, DOE announced the creation of the first phase of National Accounts awards, valued at $15 million. Twenty-one companies, which will include retailers, financial institutions and commercial real estate firms, will team with two of DOE's National Laboratories to speed market adoption of current energy-saving technologies and produce real-building design solutions yielding significant, measurable energy savings in their commercial buildings.

The awards, which are in the form of technical assistance provided by DOE's Pacific Northwest National Laboratory (PNNL) and National Renewable Energy Laboratory (NREL), have attracted some of the biggest names in retail, commercial real estate and financial institutions, including:

- Retailers: Best Buy, JCPenney, John Deere, Macy's, SuperValu, Target, Toyota, and Whole Foods Market.
- Commercial real estate firms: CB Richard Ellis, Forest City Enterprises, Hines, InterContinental Hotels Group, The Opus Group, ProLogis, Regency Centers, Ryan Companies US, Simon Property Group, Tishman Speyer, and The Westfield Group.
- Financial Institutions: Bank of America and the PNC Financial Services Group.

2.0 Building Design Package Research and Development

Building Package R&D develops the design guides, decision tools and underlying technology innovations necessary to realize 50% and 70% whole-building energy savings levels across a variety of climate zones, building types, energy intensities and sizes. Building Package R&D features three core elements (Element 2.0 in the Gantt chart):

- **50% Above-Code AEDGs and Technical Support Documents** are information products that indicate how to achieve exemplary whole-building energy performance levels, in new construction, for specific building types;
- **Decision Tools for Evaluating "Package" Selections** are tools which enable building designers and owners to look across sets of energy efficient technology solutions, and then to select appropriate ones for inclusion in building designs in order to achieve exemplary performance levels. These Decision Tools do not present a single solution (unlike the Guides) but instead allow for a variety of solutions, based on user inputs, costs and constraints.
- **Design Package R&D** is defined as integrated packages of energy-efficient solutions for a building type in a particular climate zone. Design Package R&D may include equipment and hardware, strategies, software, and systems. Specific examples include approaches to delivering illumination services (and consideration of their impacts on space conditioning), approaches to ventilation and the impacts on indoor air quality, and methods for providing space conditioning services.

2.1 50% Above-Code Advanced Energy Design Guides (AEDGs) & Technical Support Documents

There are two principal products under this element. An *Advanced Energy Design Guide* (AEDG) is a publication targeted at architects, engineers and other design practitioners that provides specific guidance on how to achieve certain levels of high-energy performance. AEDGs have historically been published by ASHRAE, with very active DOE financial and technical support, and in collaboration with these partnering organizations: The American Institute of Architects (AIA), the Illuminating Engineering Society of North America (IESNA), and the U.S. Green Building Council (USGBC). A Technical Support Document (TSD) is a "background" document commissioned by DOE to describe the assumptions, methodologies, and analyses used to achieve levels of energy performance. AEDGs supported by DOE invariably have concomitant TSDs (to document the rationale behind the design decisions), but not all TSDs are necessarily associated with AEDGs.

2.1.1 50% Above-Code AEDGs

One way to achieve above-code exemplary energy performance in new construction is to provide a prescriptive guide that indicates, measure by measure, how to do it. To this end, DOE has actively supported development of a series of *Advanced Energy Design Guides* (AEDGs), publications designed to provide recommendations for achieving 30% energy savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999. Four 30% Above-Code AEDGs have been published for small offices, small retail buildings, K-12 schools, and small warehouses, with two more 30% guides forthcoming on highway lodging and small healthcare facilities. To date, 120,000 copies of the four published guides have been disseminated, including free downloads from the ASHRAE Web site. Having demonstrated the technical feasibility of 30% savings across six building types, DOE's focus is moving to the next major challenge on the road to net-zero performance: 50% above-code energy savings.

DOE is supporting the development of five 50% AEDGs in FY09: General Merchandise or Big-Box Retail, Grocery, Combination Big-Box Retail/Grocery Stores, Warehouses, and K-12 Schools. As the Gantt chart reveals, all five are expected to be published and available to the public in FY10. These elegant "how to" guides, published with the imprimatur of AIA, ASHRAE, DOE, IESNA and USGBC, will be especially timely in demonstrating to National Accounts that a pathway to 50% energy savings exists today with available technology.

2.1.2 50% Above-Code Technical Support Documents

In addition to the formal guides noted above, DOE also develops Technical Support Documents (TSDs) that detail how to realize exemplary performance. These TSDs document the process and methodology used to develop the technology packages used in the formal AEDGs and by themselves, document how to achieve the savings targets. DOE always commissions TSDs for the AEDGs it supports, and these typically are the "Joule" metrics for the Commercial Buildings Program. But in FY09, DOE is also

developing TSDs that document how to achieve 50% savings. These will not be formal ASHRAE publications. Elements of TSDs commonly include:

- Development of prototype buildings to represent the market segment of interest
- Rationale for the measures selected
- Simulation approach used to meet the energy savings target
- Energy savings results by climate region.

DOE plans to complete seven 50% TSDs in FY09 and FY10, as follows, with performers listed:

- Combination Big-Box Retail/Grocery Stores (NREL)
- Grocery Stores (NREL)
- Big Box Retail (NREL)
- Warehouse/Self Storage (NREL)
- K-12 Schools (NREL)
- Highway Lodging (PNNL)
- Small and Medium Office (PNNL)

The first five of these will support the formal AEDGs noted under 2.1.1, but the last two – highway lodging and small and medium offices – do not have associated AEDGs. These documents will be especially timely in demonstrating to National Accounts that exemplary energy performance is feasible today with available technology.

2.2 Decision Tool for Evaluating Technology Package Selections

To aid National Accounts and CBEA members in deciding which packages of technology to choose to reach 50% and higher levels of performance in their new buildings, DOE is initiating the development of simplified decision tools that will enable design practitioners to evaluate – quickly and efficiently – the energy-saving contributions of various technology "solutions."

DOE has set program priorities to develop design guides for 30% and 50% energy savings by 2010. ASHRAE and DOE have been collaborating on a series of *Advanced Energy Design Guides* as described above in 2.1.1. However, at the current rate of two to four guides per year, it is unlikely that a series of guides can be completed in a timely manner that cover the entire commercial sector with different levels of savings (30%, 50%, NZEB). More significantly, these design guides lack flexibility – they indicate "one road to Rome" when in fact there may be many roads that National Accounts may wish to explore. Finally, the guides also suffer from being static over time and do not capture improvements in technology, improvements in underlying analysis methods, or changes to the ASHRAE 90.1 standard as the baseline.

Therefore, DOE is initiating research to develop a flexible Decision Tool to investigate the technical pathways of attaining specific energy and economic goals for specific projects. The output is expected to be design guidance that is tailored to the requirements of National Accounts with specific projects. Because this Decision Tool will, in essence, be evaluating packages of technologies, including the broad categories of daylighting,

ventilation strategies, and holistic space-conditioning approaches, this area of work is called a Decision Tool for Evaluating Technology Package Selections.

In support of this endeavor, NREL has developed a collection of computer scripts that automate energy analysis using EnergyPlus. One incarnation of these is the EnergyPlus Example File Generator (EEFG), which is a Web-based service that provides users with an EnergyPlus model and results for baseline buildings. The concept for an automated design guide would be similar to the EEFG. The key difference is that instead of a single EnergyPlus run, the design guide service would conduct a long series of EnergyPlus runs and create a summary of the results and describe Technology Package Selections for designers to consider. In other words, instead of providing one answer, the Tool would provide multiple answers. CBEA members will ideally be able to specify energy-performance and cost-performance targets and explore the design and technology options for attaining them. It is also anticipated the tool will reveal that certain technology packages are *necessary* for achieving increasingly higher levels of energy savings.

As shown on the Gantt Chart. DOE will conduct this work following a well-established pattern proven in other tools development work. That pattern, in brief, is to develop an Alpha version for evaluation by an informed subset of interested users, to develop a Beta version based on that technical feedback, to test for software bugs and usability, and then to release a public version of the software, followed in turn by a long public comment period based on actual use.

In line with its priorities, as reflected in the preliminary ranking of CBEA launches by building type, DOE will first develop an Alpha prototype tool for Retail, specifically General Merchandise and Food-Only Grocery, with an energy savings target of 50% by Q4 FY09. The tool will be evaluated by interested National Accounts in FY10, and that market input and test of actual usability will govern development of the Beta prototype by Q2 FY10, followed by release of Version 1.0 of the tool to the public by Q3, FY10.

2.3 Design Package R&D (Solicited and Directed)

To reach net-zero energy performance by 2025 across a range of heterogeneous building types and climate zones will require technological innovation and breakthroughs in many areas. This work will be done in "Design Package R&D," and has four distinct elements:

a. the prioritization of the R&D needed to attain high levels of buildings performance;
b. the formulation of an action plan to execute around these priorities;
c. the issuance of solicitations to engage the energies of the private sector in developing innovative R&D solutions;
d. and, DOE directed R&D to its national laboratories and other contracted researchers as part of the Annual Operating Plan call for proposals.

2.3.1 DOE Prioritized List of R&D Needs

The purpose of this annual activity is to produce a rank-ordered list of R&D needs to attain DOE's aggressive goals, by the 2nd quarter of each Fiscal Year. DOE envisions

several steps in developing such a list. First, DOE will seek to identify – in concert with the CBEA members - the possible universe of needs applicable to its priority building markets, namely Retail[7], Commercial Real Estate, and Institutional[8]; the purpose will be to identify as many candidates as is practicable.

Second, DOE will work to establish actionable criteria for prioritization, working with CBEA members, DOE TDMs, and DOE Technical Experts. Based on past experience, DOE expects that such criteria may include the following: degree of importance in achieving new construction and existing building savings targets; likelihood of future adoption by Alliance partners in their buildings; degree to which other organizations are researching the area; degree of clarity about the appropriateness of the DOE research role.

Third, DOE will prioritize this list, based on the criteria developed. DOE will actively seek input on these initial findings from the CBEAs, National Accounts, and others at one of the quarterly management meetings discussed in Section 3.1 of this plan. Based on any input provided, DOE will then produce a final list of R&D priorities.

2.3.2 Formulate R&D Action Plan

Developing a list of R&D priorities is a necessary step in the development of a plan, but by itself it is insufficient. Other elements are also required, and include timing, budgets, cost-sharing, performers (via competitive solicitation or directed) and explicit inclusion of Stage-Gate thinking and decision points. Under 2.3.2, such an action plan will be developed by Q3 of each fiscal year. The plan will provide a multi-year look at R&D, but will be mostly focused on the upcoming two fiscal years. An executive summary of this plan will be presented at the Q3 Quarterly Team Meeting (see 3.1.1) for review.

2.3.3 Issue Solicitation for R&D

The action plan in 2.3.2 will identify a significant portion of DOE's R&D that will be conducted by the competitive solicitation process, following the model established by the Solid State Lighting program. DOE plans to issue an R&D solicitation by Q4 of the Fiscal Year, and will place awards by Q1 of the following FY. (The action plan will also be reflected in updates to this MYPP.)

2.3.4 Directed DOE R&D

Following past practice, DOE will also continue to conduct R&D directly with its national laboratories and other contracted researchers. This R&D is termed "directed" because DOE determines priority areas and then selects the performers based on core expertise (and reputation for delivery: on time and within budget) without going through

[7] Recall that DOE recognizes five types of "retail" buildings: Food Sales/General Merchandise – e.g., Walmart, Target; Food Only – e.g., Whole Foods Market, Food Lion; General Merchandise Only – e.g., Home Depot, Best Buy; Food Service – e.g., McDonald, Applebees; and Warehousing and Distribution – e.g., United Parcel Service, Federal Express.

[8] Defined as Colleges/Universities, Hospitals, and Federal, State and Local government.

a formal solicitations process. LBNL, for example, has nationally-recognized expertise in Indoor Environmental Quality; DOE has supported research in this area at LBNL for nearly 30 years. In FY09, DOE is continuing to support work at LBNL in this area; thus the work is "directed."

In recent years, DOE has supported work at its national laboratories in the following areas:

- indoor environmental quality (and ventilation),
- controls and diagnostics
- space conditioning
- commissioning.

2.3.4.1 Indoor Environmental Quality (IEQ)

IEQ, broadly speaking, seeks to improve the health, comfort and energy efficiency of the indoor environment. Research typically focuses on reducing the energy used for thermally conditioning and distributing ventilation air in buildings, improving indoor air quality (IAQ), thermal comfort and the health and productivity of building occupants, and understanding human exposures to environmental pollutants found in indoor and outdoor air.

In FY09, DOE is conducting work in energy efficiency commercial ventilation.

2.3.4.1.1 Technologies for Energy Efficient Commercial Building Ventilation

An estimated one quad of energy is used annually for thermal conditioning of the ventilation air provided to U.S. commercial buildings. Given global climate change risks, ventilation-related energy consumption needs to be reduced substantially below the current level. Consequently, there is a critical need for this research.

DOE's current R&D at LBNL focuses on two technologies for commercial building ventilation. The first technology is the use of the count of cash register transactions as an indicator of occupancy in retail buildings and as the basis for a HVAC control signal that modulates building ventilation rates. This approach has the potential to be very cost effective because it obviates the need to purchase, install, and maintain carbon dioxide sensors for determining ventilation requirements over time, which are often inaccurate based on recent research.

Key deliverables include:

- Documents and presentations for Stage-Gate review Q2 FY09 (The purpose of the review will be to determine the merits of this form of DCV, to assess progress to date, and to enable DOE to decide whether to continue the project in FY10).
- Technical report Q4, FY09

The goal of the second technology is to identify effective ozone removal systems with a reasonable cost and a low airflow resistance in order to minimize fan energy

consumption. The EPA has recently lowered the national ambient air quality standard for ozone – making areas of the United States with approximately 100 million residents out of compliance with the standard.

Key deliverables include:

- Documents and presentations for Stage-Gate review Q3 FY09 (The purpose of the review will be to determine the merits of this form of ozone removal, to assess progress to date, and to enable DOE to decide whether to continue the project in FY10)
- Technical report Q4 FY09

2.3.4.2 Building Controls and Diagnostics

Major reductions in building energy use will depend not only on the availability and use of more efficient components and systems but on the effective coordination of all interacting components in the building, either through formal optimal control methods or through simpler control methods that approach optimal performance. Significant challenges include development of methods for different combinations of interacting building systems and implementation using commercially available platforms. As the specific control needs of the Building Design Packages become apparent, control methods and implementation solutions will need to be developed in the project. Of great importance is to mitigate the risk that inadequate control system capabilities will significantly compromise the ability to achieve the long-term goal of net-zero energy commercial buildings.

2.3.4.2.1 Building Controls Virtual Test Bed

The overall goal of the work conducted at LBNL is to support the production of net-zero energy buildings by developing, testing and demonstrating control systems that minimize energy consumption while maintaining required indoor environmental conditions.

The FY09 goals are to complete the construction of a development environment for building control systems, a Building Controls Virtual Test Bed (BCVTB, which addresses all levels of control, demonstrate its value by developing and testing energy-oriented controls for two applications, and define R&D needs in the area of system integration. Major objectives in FY09, building on previous DOE investments, are:

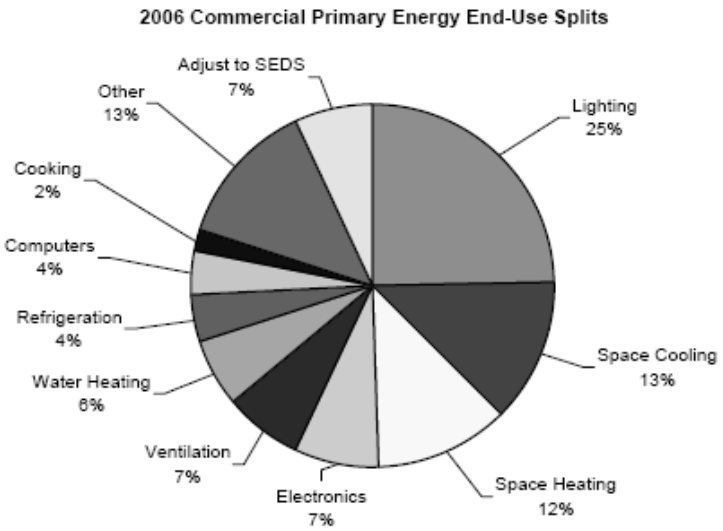
- Completion of the BCVTB for local loop control.
- Implementation of a fully featured Modelica-based system simulation capability linked to EnergyPlus through the BCVTB.
- Development and testing of energy-efficient standard sequences of operation for HVAC secondary systems using the BCVTB.
- Use of the BCVTB to develop and test integrated control strategies for active facades, lighting and HVAC and verify applicability to legacy control systems coupled with commercial integration platforms.

Major deliverables include:

- Report on integrated control strategy development, by Q2 FY09
- Stage-Gate Decision, to determine if work should be continued in FY10, by Q4 FY09
- Final report on controls performance, Q4 FY09

2.3.4.3 Space Conditioning

The importance of space heating and cooling is captured in this graphic from the *2008 Buildings Energy Data Book*, Table 3.1.4, below. Space conditioning accounts for fully one quarter of total sector energy use – any path to NZEB must significantly improve the efficiency of space conditioning.



2.3.4.3.1 Cost-Effective Integration of Efficient Low-Lift Base Load Cooling Equipment

In FY07, DOE initiated work in this area (at PNNL) and after a Stage-Gate evaluation, including a scoping study to determine potential energy savings, continued to support this research in FY08 and FY09. Low-Lift Cooling is an integration of five elements:
1. Peak-load shifting by means of active or passive thermal energy storage (TES).
2. Dedicated outdoor air supply with enthalpy heat recovery from exhaust air.
3. Radiant heating and cooling panels or floor system.
4. Low-lift vapor compression cooling equipment.
5. Advanced controls at the HVAC equipment and HVAC system (supervisory) levels.

Although these technologies can and have been used independently to provide incremental savings, when used together, they achieve significant energy savings by integrating HVAC equipment, distribution and control in a highly synergistic manner. Peak shifting and active and passive thermal energy storage are proven technologies that improve chiller load factor and can increase chiller efficiency. DOAS with enthalpy recovery provide more efficient latent cooling so that radiant cooling can be used to

satisfy sensible cooling loads. Radiant cooling further increases chiller efficiency by allowing the temperature of the radiant panel/ceiling, and hence of the chilled water supplied, to be only a few degrees below room temperature. Compared to all-air systems, the fan energy use of a radiant cooling panel (RCP)/dedicated outdoor air system is dramatically reduced. If water is used as a transport medium for heating and cooling, it can actually be used as short-term thermal storage to alleviate temporary peak demands. When advanced controls are integrated with the above technologies, additional energy and peak demand savings can be achieved by coordinating variable-speed compressors, fans and pumps for maximum efficiency, by anticipating and shifting daytime cooling loads, and by eliminating simultaneous heating and cooling.

Key deliverables include:

- Stage 2 Final Report, Q2 FY09
- Letter Report – Identification and Evaluation of Potential Alternate Low-Lift Options by Q2 FY 2010
- Business Case Presentation to DOE (and executive summary letter report) – on National Account/CBEA Member Engagement, Q1 FY10
- Final Report, including Stage 3 Research Plan, Q2 FY10

3.0 Management

This program has four core management elements. They are the conduct of quarterly team meetings; multi-year program planning and annual update of the Commercial Program MYPP, a précis of which is included in BTP's corporate MYPP; the issuance of support service and research solicitations; and analysis to help guide portfolio decision making.

3.1 Quarterly Team Meetings

The quarterly team meeting approach employed by Residential Buildings Integration has proven to be a useful mechanism for managing the Residential portfolio, with its large number of market and contractor players. Quarterly team meetings help monitor technical process, share lessons learned, and identify challenges and problems; they are also convenient venues for planning, including preparation for Stage-Gate decisions.

DOE's Commercial Buildings Team intends to initiate a process similar to Building America beginning in FY09, and to assemble its critical partners once per quarter in Washington, DC. DOE will use these meetings very actively to help manage and integrate the program. Examples of quarterly meeting topics include:

- Soliciting input for the conduct of Go/recycle/no-go Stage-Gate decisions on a range of topics, including several identified in Section 1.3, National Accounts (see "Task Structure" section). Such National Account-based decisions include determining:
    - whether or not to proceed on target group of buildings, based on benchmarking analysis;
    - whether or not to proceed with a set of building designs;

    - whether or not to proceed with designs, following actual construction to that design and actual field verification of performance;
- Identifying and rank ordering technologies for potential inclusion in technology procurements by the CBEAs;
- Identifying gaps in DOE's R&D portfolio deemed necessary to achieve 50% and higher levels of building performance, for potential inclusion in DOE's annual "statement of needs" process;
- Discussing the results of analyses across a range of relevant topics, including those conducted by DOE (see Section 3.1.4 below) – such as on miscellaneous electric loads and benchmarks;
- Identifying potential process improvements to the CBEAs or the working arrangements with the National Accounts to ensure project success.

3.2 Multi-Year Program Planning

DOE/BTP annually develops a five-year plan for the entire program, which is posted on the BTP Web site in Q2 of the fiscal year. This integrated plan establishes the goals, strategy and tactics of the overall program, and in turn, guides the Annual Operating Plan call for directed research proposals for next fiscal year in the cycle.

A critical input to this process is the more detailed plan developed by each program, of which this document is an example. A précis of the detailed plan becomes the chapter in the overall BTP MYPP. The Gantt chart identifies the key steps in the process to developing this detailed MYPP. These steps, which are repeated annually, are:

- Identifying the gaps and unaddressed opportunities in the DOE portfolio to guide the development of future RD&D portfolios and to answer questions about what the program would do with greater resource allocations. [See Appendix A].
- Updating a Draft of the Commercial MYPP by the end of the Fiscal Year, which summarizes high-priority portfolio gaps, identifies the technical pathways to net-zero energy performance, and delineates coordination and integration with other elements in BTP.
- Participating in BTP's annual Q1 Technology Integration Workshop, at which critical questions about crosscutting priorities, TDM roles, and coordination of efforts are resolved.
- Finalizing of the Commercial Buildings MYPP, post-Workshop, and approval by BTP management.
- Development of a précis of the MYPP for inclusion in the corporate MYPP (performed by Navigant Consulting, LLC).
- Derivation of a Statement of Needs for the Annual Operating Plan call for proposals, so that the MYPP's priorities "flow down" directly to the annual funding decisions. This step is critical in order to translate stated priorities into funded actions.

This process is repeated on an annual basis. Especially for such a dynamic program as this, annual planning is critical, as plans must be revised to fit the actualities of

experience with many different market partners. (To avoid excessive clutter, the MYPP process is only shown for FY09 in the Gantt chart).

3.3 Solicitations

To conduct research, the Department has at least two pathways it may take. It may conduct directed research, wherein a DOE national laboratory or contractor is directly funded to conduct a particular line of research, based on a statement of work that DOE has approved. The Department may also develop a more general request, and then through a competitive solicitations process, select the best performer to carry out the work.

DOE plans to issue the following solicitations:

3.3.1 High-Performance Green Building Partnership Consortia

Per EISA 421(f): "Not later than 90 days after the date of the enactment of this Act, the Commercial Director shall formally recognize one or more groups…to provide high-performance green building information and disseminate research results." In response to this provision, DOE will issue a Federal Register Notice for HPGBP Consortia in Q1 FY09, and announce them in Q2 FY09. Section 421(f)(2) requires that a group seeking recognition as a Partnership Consortia must include representation from each of the following areas:

- Design professions and national associations of architects and engineers.
- The development, construction, financial, and real estate industries.
- Building owners and operators from the public and private sectors.
- Academic and research organizations.[9]
- Building code agencies and organizations, including a model energy code setting organization.
- Independent high-performance green building associations or councils.
- Experts in indoor air quality and environmental factors, intelligent buildings and integrated building information systems, and the public transportation industry.
- Utility energy efficiency programs.
- Manufacturers and providers of equipment and techniques used in high-performance green buildings.
- Non-governmental energy efficiency organizations.

3.3.2 High-Performance Green Building Consortium

Per EISA 422(b)(2): "Not later than 180 days after the date of enactment of this Act, the Commercial Director shall competitively select, and enter into an agreement with, a

[9] Section 421(f)(2)(D) states that representation of academic and research organizations must include at least "one national laboratory with extensive commercial building expertise". (42 U.S.C. 17081(f)(2)(D)) DOE is not specifying a consortia's representation include at least one national laboratory as the national laboratories will be involved through DOE.

consortium to develop and carry out the initiative." In response to this provision, DOE will issue a Request for Proposal in Q2 FY09; and contract award will be in Q4 FY09. Per EISA, "The goal of the initiative shall be to develop and disseminate technologies, practices, and policies for the development and establishment of zero-net energy commercial buildings for:

(1) any commercial building newly constructed in the United States by 2030;
(2) 50 percent of the commercial building stock of the United States by 2040; and
(3) all commercial buildings in the United States by 2050."

In order to achieve the goal of the initiative, the Consortium will support DOE in providing a focus to accelerate the commercialization of high-performance building technologies through DOE access to the technical expertise of the Consortium's members, communication and dissemination of new technologies within the commercial building community, and cooperative efforts to promote demonstrations of high-performance building technologies.

DOE will use the following factors as part of the competitive selection for the High-Performance Green Building Consortium:

- Breadth of representation of the commercial building industry
- Plan for managing the membership of the consortium
- Demonstrated experience of the organization in organizing and managing technical meetings and program reviews, and
- Ability of organization to provide technical expertise for project and technical reviews.

3.3.3 National Accounts Solicitation

DOE will conduct a solicitation, under section 422(d) of EISA, for cost-shared National Account partnerships which may include:

- An agreement to build at least one new commercial building prototype at 50% energy savings and retrofit at least one existing commercial building to achieve 30% savings. (New commercial building targets will increase to 70% for 2015 and net-zero for 2018.)
- Cost-shared testing, evaluation, and demonstration of technologies and approaches.
- Carrying out pilot programs and demonstration projects to evaluate replicable approaches.

DOE plans to issue the competitive National Account RFP and associated call for national laboratory technical support in Q3 FY09, with award by Q1 FY10. DOE intends to repeat this process as necessary, and as funding permits.

3.4 Analysis in Support of Decision-making

DOE conducts analysis to support planning, prioritization and portfolio decision-making. It also conducts objective analysis where information is missing or of low quality and where such gaps may hinder good decision-making. Analysis activities generally fall

into two categories: foundational/continuous analysis, conducted on a regular intervals over a period of time, often to revise and update content as needed; and one-time topical analysis, designed to answer a specific question or questions.

3.4.1 Foundational and Continuous Analysis

Certain kinds of inquiry are integral to program planning, if not annually then biennially, and are never truly complete. A classic example might be analysis in support of the annual MYPP, since decisions about direction and portfolio must rest, in part, on analysis of changing technological, market and even political conditions.

In this MYPP, there are two such examples worthy of specific mention. The first concerns the DOE-developed commercial benchmark models for 17 building types. These cover new construction, post-1980 construction, and pre-1980 construction. The benchmarks form foundational reference points for commercial building energy research and for tracking progress towards net-zero energy performance. But they will require regular revisions; first because the simulation basis of the benchmarks is EnergyPlus, which is semi-annually updated, and second because users of the benchmarks, including DOE Lab PIs, ASHRAE, and others will identify areas of improvement. Subsequent versions of the benchmarks will be released (on the Web), as the Gantt chart shows under 3.4.1.1.

Another area of enduring interest will be DOE's objective and careful evaluation of the incremental costs of high-performance and net-zero energy buildings (3.4.1.2) Ultimately, market transformation at scale from today's average buildings to tomorrow's NZEBs will require significant declines in the first costs of advanced technologies and systems, the first step of which is to document what the costs of exemplary buildings built really are, both to help build the business case, and to guide the priorities of research itself.

3.4.2 One-Time Topical Analyses

How important are miscellaneous electric loads, relative to traditional building energy end-uses such as space conditioning? What level of whole building performance can be achieved, today, with a three- or five-year payback? What technologies could improve the operations and maintenance of existing buildings? Questions such as these can typically be answered with thoroughly documented and carefully reviewed reports. Although such reports may need occasional revising, depending on the rate of change of technology and market trends, they are most typically one-time efforts providing durable answers.

DOE has a long history of commissioning and supporting this kind of work, resulting in a large library, much of which is available at:
http://www.eere.energy.gov/buildings/highperformance/research_reports.html

In FY09, DOE is completing analysis (conducted by TIAX, LLC) to characterize commercial building miscellaneous electric loads, with a draft report due in Q2 and a final in Q4. An executive summary of the draft report findings will also be presented at the Q2 Quarterly Meeting, and review comments will be solicited at that time. A particular discussion topic will be to debate the implications, if any, for the CBEAs and DOE's RD&D portfolio.

APPENDIX A:
Unaddressed Opportunities in the Commercial Buildings Sector

Numerous advancements in the areas of technology development, policies, and practices are necessary to reach the 2025 goal of net-zero energy buildings. However, limited resources – both human and capital – restrict the Department of Energy's ability to fully address each of these key needs. Key needs requiring significant advancements but for which resources are not addressed in this Multi-Year Plan are referred to as opportunities and gaps.

In this context, opportunities might be present when other non-DOE activities or enterprises are working to address a key need necessary to support the 2025 goal of net-zero energy commercial buildings. For example, the nationwide trend of state and local governments enacting sustainable building requirements for all new commercial buildings within their jurisdictions may provide an opportunity for DOE to partner with the municipalities to ensure that energy efficiency opportunities are optimized through integrated design practices. Likewise, gaps are key needs that must be addressed to meet the long-term program goal, but for which there are insufficient on-going or planned actions necessary to address the need. Examples of gaps include building materials and equipment that have matured in terms of their energy efficiency potential, but still require additional improvements in order to help reach the 2025 goal. In this case, new technological approaches must be identified for evaluation and next generation products developed.

While many opportunities and gaps have been identified, this Multi-Year Plan addresses the opportunities and gaps that are considered to be highest priority.

A three-step process was used to develop this list of priority opportunities and gaps. First, input on potential ideas was obtained through several sources: DOE issued a call to the members of the National Laboratory Consortium on Building Technologies (Argonne National Laboratory, Lawrence Berkeley National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory) requesting their input; members of the DOE BTP Commercial Buildings team were also asked to submit their ideas for consideration; and a brief literature review was undertaken to identify issues of interest to prominent players in the commercial buildings energy-efficiency policy and evaluation community. Over 90 potential ideas were generated through this process. Next, all submitted ideas were consolidated and reviewed by the Commercial Buildings team to determine if they were indeed opportunities and gaps, and assign a priority rating – high, medium, and low – to each. Related ideas were combined as part of the team's review. In the final step, opportunities and gaps were filtered based on the team's overall assigned priority, the summary write-ups were developed, and the Commercial Buildings team completed its final review.

Heating, Ventilating, and Air Conditioning (HVAC)
HVAC, the largest commercial building energy consumer, accounts for over 31 percent of the total commercial building energy consumption with space heating, space cooling,

and ventilation accounting for 12.1, 12.6,, and 6.7 percent respectively.[10] It is also estimated that the parasitic energy use of HVAC systems – supply and return fans, exhaust fans, fan powered terminal boxes, condenser and cooling tower fans, and heating, condenser and chilled water pumps – account for about 10 percent of the commercial sector energy use.[11] Since HVAC is the major commercial building energy consumer, an aggressive effort aimed to develop low commercial building heating and cooling systems for different building climates and types is urgently needed.

Conventional heating, cooling, and humidity control systems for commercial buildings are based on mature technologies approaching their peak efficiencies; however, thermodynamic analysis reveals that significant opportunity to improve the energy efficiency of heating and cooling systems still exists. Examples of opportunities to consider include enhancing heat transfer using technologies such as micro-channels and nano-scale surface treatments, or the supplementing vapor-compression cycle with thermoelectric, thermoaccoustic, absorption, adsorption, and the Stirling cycle.

As building envelopes improve (better windows, less infiltration, and lower heat loss through the opaque envelope), ventilation and the conditioning of outside air may become the largest HVAC load in many buildings. Novel technologies for removing pollutants and CO_2 from indoor air may prove to be more cost effective than dilution through ventilation. In addition, there are questions regarding the amount of ventilation air needed for occupant health and pollution control. Examples of ventilation issues to address include offgassing of pollutants from new products in retail buildings and the 100 percent outside air requirement in hospitals. Credible improvements to indoor air quality standards require more building infiltration and occupant health data to support their development.

Performance Metrics for Sustainability

Without proper metrics to measure the performance of sustainable buildings, the true benefits that "green" attributes can contribute to a high-performance building are not well documented. The often competing and contradictory definitions of green building attributes can lead to both intentional and unintentional abuse in products and systems.[12] Clarity and consistency in the definitions and metrics used in measuring and verifying performance in sustainable buildings is critical to ensure widespread adoption of sustainable buildings, and ultimately net-zero energy buildings.

At the same time, governments at all levels across the U.S. are passing laws requiring the construction of buildings meeting a measured level of sustainability. The most frequently used sustainability measure in the U.S., LEED® (Leadership in Energy and

---

[10] 2008 Buildings Energy Data Book, Table 3.1.4, http://buildingsdatabook.eere.energy.gov/docs/xls_pdf/3.1.4.pdf

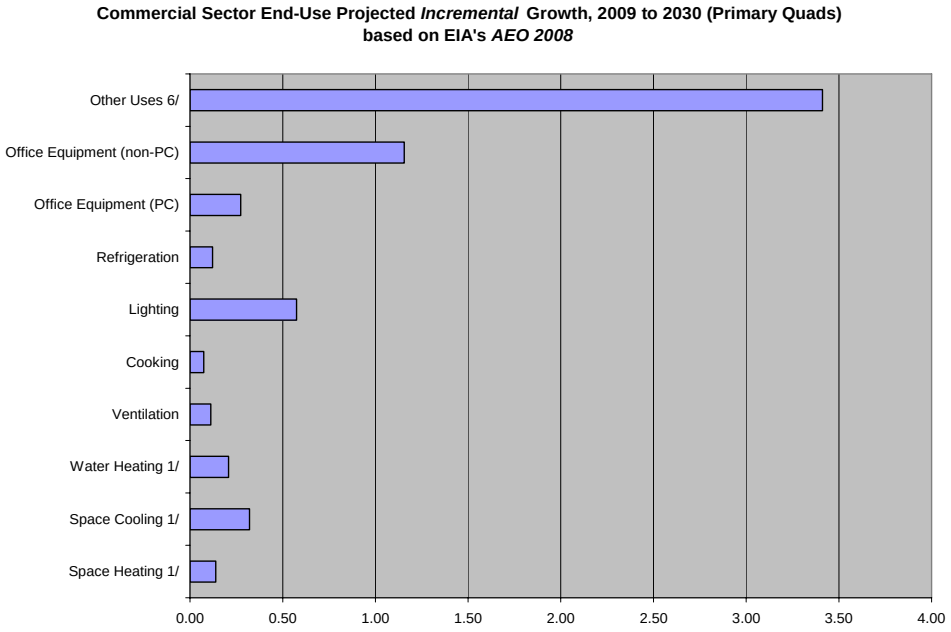
[11] Westphalen, D. and S. Koszlinski. 1999. Energy Consumption Characteristics of Commercial Building HVAC Systems. Volume II: Thermal Distribution, Auxiliary Equipment, and Ventilation. Authur D. Little, Inc. Reference No. 33745-00. Published for U.S. Department of Energy. Contract No. DE-AC01-96CE23798. Cambridge, MA. Authur D. Little, Inc.

[12] NIBS. 2008. Assessment to the US Congress and US Department of Energy on High Performance Buildings. National Institute of Building Sciences. Available URL: http://hpbccc.org/hpb_report.pdf

Environmental Design), applies a rating system that identifies criteria and credits in five categories: sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality. However, many feel that "energy efficiency" should be a cornerstone of a high-performance building. All energy consuming systems and products should be designed to achieve the highest level of energy efficiency consistent with the other design attributes."[13]

Miscellaneous Energy Loads

In the *Annual Energy Outlook 2008*, EIA estimates that the combination of non-PC office equipment and "other" uses will grow 57% between 2009 and 2030. The absolute magnitudes of incremental change are shown below between 2009 and 2030. The conclusion from this graphic would suggest that DOE should focus its RD&D energies on the top two end-uses, and spending little effort on space conditioning, at least in terms of new construction.



Note: See http://www.eia.doe.gov/oiaf/aeo/excel/aeotab_5.xls for more detail.

The truth is that we really do not know the current magnitude of the miscellaneous loads empirically; this is a very significant gap. EIA estimates it is *currently* about 43% of commercial sector primary energy consumption. Nor do we know what the appropriate growth rate is. One way to fill this gap would be to formally ask the EIA to brief DOE on what is "in" this large "drift net" end use. Another approach would be to influence EIA directly with data collection and reports.

DOE also needs look at the operations of the miscellaneous energy loads equipment to identify efficiency improvement opportunities. All types of electrical devices

[13] NIBS

contributing to miscellaneous electric loads need to be revisited to maximize transformer and other component efficiencies and minimize standby losses. Appliance and equipment minimum efficiency standards could be raised more rapidly if DOE were to initiate R&D activities aimed at selected plug and process loads with high potential for efficiency improvement.

Whole-Building Life-Cycle Approach

Current efforts to build low-energy, and ultimately net-zero energy buildings focus primarily on integrated building design practices. While decisions made during the building design process greatly impact the energy use over the remaining life of the building, decisions and actions throughout the building life-cycle – planning and financing, design, construction, and operation – all impact the overall energy use. Findings from field evaluations of high-performance buildings conducted by NREL demonstrate how decisions and actions throughout the development and construction process impacted, both positively and negatively, the final building performance:

- Owners provide the main motivation for low-energy buildings.
- Many decisions are not motivated by cost.
- Many examples of design features that were missing, installed incorrectly, or a lower quality product substituted.[14]

A clearer understanding of the participants and their roles in the building life-cycle process is needed if net-zero energy buildings are to be accepted by and promoted within the commercial market sector. This understanding requires a map identifying the key participants, their roles, and interactions across the range of participants. This map will help DOE can develop strategies – tools, outreach, training, etc. – to effectively integrate these participants in the building life-cycle process.

Financing

Many in the commercial building development and design communities feel that there is a significant cost premium associated with the design and construction of high-performance buildings. Further, these cost premiums are not recovered when the buildings are sold and or leased after the completion of construction. These perceptions provide a disincentive to developers to design and build high-performance buildings, as observed in a report completed for the California Institute for Energy Efficiency[15]:

> So what does all this mean for energy efficiency in new commercial office buildings? Given what we have learned about building markets and the nature of building industry interests, it is clear that increasing the energy efficiency of buildings is of little value to the building industry. In terms of the parameters important to the building industry, buildings *are* energy efficient. There is really

[14] Torcellini, P., S. Pless, M. Deru, B. Griffith, N. Long, and R. Judkoff. 2006. Lessons Learned from Case Studies of Six High-Performance Buildings. NREL/TP-550-37542. National Renewable Energy Laboratory. Golden, CO. Available URL: http://www.nrel.gov/docs/fy06osti/37542.pdf

[15] Lutzenhiser, L.N. Woolsey Biggart, R. Kunkle, T. Beamish, and T. Burr. 2001. Market Structure and Energy Efficiency: The Case of New Commercial Buildings. California Institute for Energy Efficiency.

no value to the building industry in making buildings more energy efficient – it is risky. The perceived market risks of doing energy efficiency are much greater than any potential benefits.

There are two gaps associated with financing. The first gap is the need for data from the field that allow for comparisons of cost differentials, if any, associated with the design and construction of high-performance buildings. The absence of this data will work to discourage widespread investments in high-performance buildings across the development community as these investments are not seen as financially rewarding. The second gap is the need to identify financing methods for new and retrofit commercial buildings that address the recovery of increased investment costs, and even provide incentives to design for high-performance. One approach might be the establishment of a bank fund having the authority to offer direct loans, loan guarantees, and insurance products to high-performance technology and building developers. A sample approach, the Clean Energy Investment Bank Fund, was been proposed in the Clean Energy Investment Bank Act of 2008 (Senate Bill 2730).[16]

Electric Grid and Energy Storage

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. Renewable generation is by its nature intermittent. Further, as building efficiency increases, the spread between base and peak electricity demands could widen substantially suggesting storage as a peak demand strategy for commercial buildings. As such, there is a need for consideration, planning, and active integration of renewable technologies and related storage in buildings. Alternatives at the building level include thermal or electrochemical storage (an oversized water storage tank or Plug-in Hybrid Electric Vehicle (PHEV) or dedicated batteries).

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. The goal then is to reduce the cost of making buildings as demand responsive as possible.

Controls/Intelligent Buildings

Identifying performance degradation in a timely manner is critical to maintaining operational efficiency. Maintaining the operational efficiency of building systems is critical to achieving expected performance in low-energy, and ultimately net-zero energy buildings. Application of sensors/metering systems can be used to alert building operators to developing inefficiencies before energy losses occur. This concept of equipment diagnostics is not new, but applications are limited. In fact, diagnostics and

[16] http://www.govtrack.us/congress/bill.xpd?bill=s110-2730&tab=summary

sophisticated controls have realized only a small portion of their energy savings potential due to general market and control diagnostic barriers.[17]

Previous studies have identified operational deficiencies in the field as well as identified several potential causes and outcomes. For example, systems/equipment in high-performance buildings typically do not operate as intended, in part because control systems often "lack control software or appropriate control logic to allow technologies to work together."[18] As building technologies advance, the ability to control the building systems in an integrated fashion will become increasingly more complex and critical to achieving desired design performance over the operating life-cycles. Examples include integration of on-site renewable technologies and daylighting. Also, because of their complexity, high-performance and net-zero energy buildings may be even more susceptible than average commercial buildings to efficiency degradation from inadequate operations and maintenance (O&M).

While there are several potential roles for DOE to play in advancing building controls and intelligent buildings, it has been determined that there is not an appropriate role for DOE to play in the development of measurement and control sensors.

Potential DOE Roles in Addressing Opportunities and Gaps

- Initiate a scoping study to identify the most promising new HVAC technologies.
- Develop a research approach to address the issues of ventilation and indoor air quality requirements.
- Lead in completing and/or supporting research necessary to establish performance metrics and verification protocols, and supporting protocol adoption by the public and private sectors.
- Engage the EIA to obtain an understanding of the growth rate of miscellaneous energy goals.
- Initiate R&D activities that identify and prioritize electrical devices efficiency improvement opportunities.
- Define methods of tests for miscellaneous energy load devices leading to Energy Star.
- Create a map identifying roles and interactions of partners and participants the high-performance building life-cycle from cradle to grave.
- Work with the commercial building development and design communities to determine if there is a first cost differential for high-performance buildings.
- Explore with building developers and owners the financial mechanisms that can provide an incentive to invest in high-performance buildings.
- Initiate a scoping study to identify the potential energy storage technologies and approaches, including technologies in the development stages, to determine

[17] Roth, K., D. Westphalen, M. Feng, P. Llana, and L. Quarararo. 2005. Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization, Energy Impact of Building Faults and Energy Savings Potential. TIAX Reference No. D0180. TIAX LLC, Cambridge, MA. http://www.eere.energy.gov/buildings/highperformance/pdfs/tiax_controls_diagnosics.pdf
[18] Torcellini et al

feasibility of renewable energy and thermal energy storage systems as a way to integrate net-zero energy buildings with the smart grid.

- Obtain an understanding of the ongoing efforts in diagnostic development and design in the R&D and commercial communities.
- Develop operational strategies and control sequences for high-performance buildings.
- Support whole building integration including the application of on-site renewables.

APPENDIX B: Technology Pathways to Achieve to Zero-Energy Commercial Buildings

The Commercial Team asked the National Renewable Energy Laboratory to develop initial technology pathways to achieve various levels of whole-building savings for offices and big box retail stores. These technology pathways represent the efficiency levels required in that area to achieve the energy performance level. These draft technology pathways meet are summarized in the table below. The values are essentially the range of "minimum to maximum" across the U.S. climate zones. The results for 50% and higher savings were derived from simulations analysis using EnergyPlus.[19] Further refinement and evaluation of these pathways is planned for early FY 09.

	Code	30% Savings	50% Savings	70% Savings	100% Savings
Design Process Pathways					
Design Guidance	90.1	30% AEDGs with prescriptive recommendations	50% AEDGs with performance recommendations; optimization tools for more complex buildings	Optimization tools for guidance	Optimization tools for guidance including optimization of renewable energy sources
Integrated Building Design	None	Suggested	Recommendations to direct integrated design	Use of Optimization tools for site specific EE design	RE fully integrated with EE through use of Optimization tools
Technology Pathways					
Form	None	Some Consideration to Form (more N and S windows, less E and W)	Single story or some Form optimization (Minimal E and W, maximize N and S windows)	Windows sized based on optimization—typically sized for daylighting and appropriate view glass.	Windows sized based on optimization—typically sized for daylighting and appropriate view glass.
Roofs	R-15 - R-25	R-15 – R-30	R-20 – R-35	R-25 – R-45	R-25 – R-45
Walls	R-2 -R-15	R-2 – R-15	R-10 – R-30	R-19 –R-35	R-19 –R-35
Windows	90.1	U-0.56 – U-0.33 SHGC: 0.45 – 0.25 Vt/SHCG: 1	U-0.40 – U-0.20 SHGC: 0.45 – 0.25 Vt/SHCG: 2	U-0.30 – U-0.13 SHGC: 0.5 – 0.25 Vt/SHCG: 2.5	U-0.30 – U-0.13 SHGC: 0.5 – 0.25 Vt/SHCG: 2.5
Daylighting	None specified	None Specified	25% Daylight Energy Reduction	50% Daylight Energy Reduction	70% Daylight Energy Reduction
Lighting	90.1	10% LPD reduction MLPW>70	20% LPD reduction MLPW>80	30% LPD reduction MLPW>100	50% LPD reduction MLPW>120
HVAC	90.1	0-30% efficiency increases	30% efficiency increases with some climate specific on secondary HVAC (cooling towers, 50%+ ERVs, GSHP)	50%increase in total HVAC efficiency increases climate specific primary HVAC: Examples could include evaporative cooling, liquid desiccant dehumidification.	50%increase in total HVAC efficiency increases climate specific primary HVAC: Examples could include evaporative cooling, liquid desiccant dehumidification.
Outdoor Air	Some economizers as specified by 90.1	Some ERVs, DCV, some economizers on smaller equipment	Reduction of energy associated by outside air by 50%. May include ERVs, DCV, mixed mode natural ventilation, and economizers	Reduction of energy associated by outside air by 75%. May include dedicated outside air systems, liquid desiccant dehumidification, Evaporative cooling, mixed mode natural ventilation, DCV, and	Same as 50%

[19] Griffith, B., N. Long, P. Torcellini, R. Judkoff, D. Crawley, J. Ryan. 2007. *Assessment of the Technical Potential for Achieving Net Zero-Energy Buildings in the Commercial Sector*, NREL/TP-550-41957, December 2007. Golden: National Renewable Energy Laboratory. www.**nrel.gov**/docs/fy08osti/41957.pdf

	Code	30% Savings	50% Savings	70% Savings	100% Savings
				economizers	
Plugs and Process	No change	EnergyStar appliances and equipment specified	10% peak, 30% nighttime reduction	15% peak savings, 40% nighttime reductions	25% peak savings, 60% nighttime reductions
SHW	80% Et	90% Et	90% Et	95% Et	95% Et
Energy Storage	None	None	None	Create a load factor of 50% or better.	Enough to result in load factor of 75% or better
Renewables					
PV	None	None	0% to 20% of building load	20%-75% of building load	75%+ of building load
Solar Hot Water	None	None	None	Solar fraction for SHW of 0.5	Solar Fraction for SHW of 0.75, solar regeneration of liquid desiccant, solar fraction for space heating with radiant heating of 0.5
Site Wind	None	None	10% + of building load in locations with wind speed class >4	20% + of building load in locations with wind speed class >4	30% + of building load in locations with wind speed class >3
Site Biomass	None	None	None	50%+ of SHW and space heating from biomass boilers if resource is local	80%+ of SHW and space heating from biomass boilers if resource is local
Off-site Purchases	None	None	None	None	Meet remaining loads after all other site renewables fully used

Table notes:

1. For each level of savings, not every technology must be applied or is needed for every building in every climate. The pathways represent a range of performance likely to be needed across the climate zones. Building and site specific optimization tools can be used to determine the most cost effective combination of pathways needed to reach the energy savings goals.
2. Daylight Lighting Reduction: Percent reduction in annual lighting energy measured from sunrise to sunset. Includes the concept of Daylighting Saturation Percent which is the percent of occupied hours times the percent of floor area that is fully daylit. Fully daylit is defined as daylighting that provides a minimum illuminance, but not more than a maximum illuminance (typically 400 footcandles). This metric includes the controls and related hardware necessary to achieve the savings from daylighting.
3. MLPW: Mean lumens per watt- lighting system (bulb, ballast system efficacy)
4. SHW: Service Hot Water
5. Vt/SHGC: Ratio of visible transmittance to solar heat gain coefficient. A high ratio has both good visible transmittance for daylighting and low thermal transmittance for controlling cooling loads
6. Wall and Roof Insulation Values given for a minimum and maximum depending on climate for insulation above deck roof construction and mass wall assemblies with continuous insulation.

7. Tables values estimated for low and medium energy density commercial building types (Performance values would be different for high density types such as labs and inpatient hospitals)
8. 30% savings data based on 30% AEDGs
9. 50% savings data based on 50% Grocery and Medium Box TSDs, experience with 50% designs from case studies and Greensburg examples
10. 70% savings data based on expected diminishing returns for each technology pathway based on 50% design optimizations
11. 100% savings data based on ongoing NZEB research and attempting various NZEB designs at NREL's new office building (RSF), Greensburg School analysis (NZEB goal), NZEB case study database portal.
12. HVAC system efficiencies include all primary and secondary systems needed to provide heat/cold to the occupants. Includes compressors, supply fans, condenser fan and pumps, primary pumps, controls, dampers, etc. Includes controls to make systems operate to full operating potential.
13. Wind speed class for the U.S. can be found here: http://www.eere.energy.gov/windandhydro/windpoweringamerica/pdfs/wind_maps/us_windmap.pdf
14. Plug loads include traditional plug loads, elevators, transformers, and all other equipment that is not directly tied to lighting or HVAC. Efficiency gains could include DC power distribution.

Metrics need to be refined to account for systems efficiencies, rather than individual components. Examples include using lighting power densities for specific room types. This accounts for increases in mean lumens per watt for the light source, increased fixture efficiencies, increased ballast efficiencies, and better lighting design. For HVAC, increased total systems efficiencies represent the energy delivered divided by the energy content as it enters the building including transformer losses, pumping energy, burner efficiencies, etc.

APPENDIX C: Integration

The Commercial Building Integration Program will complete this section after the MYPP Integration Workshop, which will be held the week of 10 November. At that meeting, the Technology Development Managers for the component programs and for Commercial Integration will discuss the technical pathways to zero energy performance, resolve any outstanding differences on those pathways, and will develop a joint plan of action for moving forward, including clear delineation as to which program is handing off "what" and when.