Table of Contents

List of Acronyms

AC/HP: Air Conditioner/Heat Pump
AEO: Annual Energy Outlook
AET: Appliances and Emerging Technologies
AIA: American Institute of Architects
AOP: Annual Operating Plan
ARI: Air-Conditioning and Refrigeration Institute
ASERTTI: Association of State Research and Technology Transfer Institute
ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers
BED: Building Energy Data Book
BEopt: Building Energy Optimization Tool
BT: Building Technologies Program
BTS: Office of Building Technology, State and Community Program
CBECS: Commercial Buildings Energy Consumption Survey
DEER: Distributed Energy and Electric Reliability
DOE: Department of Energy
ECPA: Energy Conservation and Production Act
EERE: Office of Energy Efficiency and Renewable Energy
EIA: Energy Information Administration
EPA: Environmental Protection Agency
EPACT 2005: Energy Policy Act of 2005
EPACT: Energy Policy Act of 1992
EPCA: Energy Policy and Conservation Act of 1975
EPRI: Electric Power Research Institute
FEMP: Federal Energy Management Program
FTC: Federal Trade Commission
GPRA: Government Performance Results Act of 1993
GRI: Gas Research Institute
HUD: Housing and Urban Development
HVAC: Heating, Ventilation, Air Conditioning
ICC: International Code Council
IECC: International Energy Conservation Code
IESNA Illuminating Engineering Society of North America
LEED: Leadership in Energy and Environmental Design
MEC: Model Energy Code
MYP: Multi-year Plan
NAECA: National Appliance Energy Conservation Act of 1987
NBI: New Building Institute
NC3: New Commercial Construction Characteristic
NEMS: National Energy Modeling System
NEP: National Energy Policy
NETL: National Energy Technology Laboratory
OBCS: Office of Buildings and Community Systems

PATH: Partnership for Advanced Technology in Housing
PV: Photovoltaic
R&D: Research and Development
RESNET: Residential Energy Services Network
RO: Regional Office
SDHV: Small Duct High Velocity
TD: Technology Development
TVMI: Technology Validation and Market Introduction subprogram
WIP: Weatherization and Intergovernmental Program
ZEB: Zero Energy Buildings

Executive Summary

The next five years, as outlined in this Building Technologies Program Multi-Year Program Plan (MYP), will be an important time in improving the performance the Nation's buildings. Increasing the energy efficiency of residential and commercial buildings leads to increased energy conservation by reducing the rate of consumption of oil, natural gas, and electricity. The reduction in energy consumption decreases America's vulnerability to energy supply disruptions and energy price spikes. With our Nation's annual energy bill for residential and commercial buildings reaching $326 billion in 2004, the economic impacts of lowering energy use can be enormous.[1]

In support of the President's policies and initiatives, Building Technologies (BT) has embraced the strategic goal of developing net-zero energy buildings (ZEBs) to reduce national energy demand. We have defined our strategic goal as:

To create technologies and design approaches that enable net-zero energy buildings at low incremental cost by 2025. A net-zero energy building is a residential or commercial building with greatly reduced needs for energy through efficiency gains, with the balance of energy needs supplied by renewable technologies. These efficiency gains will have application to buildings constructed before 2025 resulting in a continuous contribution to substantial reduction in energy use throughout the sector.

Through three main areas of activity, the BT Program is structured in a way to achieve this goal. The areas are: Research and Development (R&D), Equipment Standards and Analysis, and Technology Validation and Market Introduction. While initially focused on new construction, these technologies and design approaches will have application to the buildings constructed before 2025. Important breakthroughs include the development of integrated design approaches to ZEB, as well as technology breakthroughs such as solid state lighting and electrochromic windows. Also critical is the promulgation of minimum performance standards for appliances and equipment, per the new Energy Bill. Our proven history of success, coupled with focusing of our R&D and resources through tough-minded peer review, and the identified technology pathways discussed in this MYP, positions BT well for achieving this goal. Additionally, BT is working with major private entities through Building America and the competitive solicitation process, producing significant cost-sharing by industry, a clear vote of confidence.

In order to reach the net-zero energy buildings goal by 2025, a series of intermediate goals in each area must be achieved. The following intermediate goals are expected to be achieved in the next five years:

---

[1] 2006 Building Energy Data Book, U.S. Department of Energy, Office of Planning, Budget Formulation and Analysis, Energy Efficiency and Renewable Energy. Prepared by D&R International, Ltd., September 2006.

Research and Development:

- Develop low-cost (target \$20/ft2 in 2010), durable (measured by number of cycles to failure, per ASTM standard) prototype dynamic window
- By 2010, develop solid state lighting with efficacy of 142 lumens per watt in a laboratory device
- By 2010, develop technologies and design strategies that can achieve an average of 40 percent reduction in purchased energy use for new residential buildings
- By 2011, develop technologies and design strategies that can achieve an average of 50 percent reduction in purchased energy use for new, small commercial buildings

Equipment Standards and Analysis:

- By 2007, complete energy conservation standard final rules for residential furnaces and boilers, transformers, and ceiling fan light kits
- By 2008, complete energy conservation standard final rule for packaged terminal air conditioners and heat pumps
- By 2008, complete determination for battery chargers and external power supplies
- By 2009, complete energy conservation standard final rules for incandescent reflector, fluorescent, and incandescent general service lamps; and also residential dishwashers, ranges and ovens/microwave ovens, residential dehumidifiers, and commercial clothes washers
- By 2010, complete energy conservation standard final rules for residential water heaters, direct heating equipment, and pool heaters; and also small motors
- By 2010, complete determination for high-intensity discharge lamps
- By 2011, complete energy conservation standard final rules for electric motors (1-200 HP), fluorescent lamp ballasts, residential clothes dryers, room air conditioners, and residential central air conditioners and heat pumps

Technology Validation and Market Introduction:

- By 2010, increase the market penetration of ENERGY STAR®-labeled windows to 57% (40%, 2003 baseline), and maintain 30% market share for ENERGY STAR® appliances

BT has arrived at this technology portfolio, as demonstrated in this MYP, through rigorous internal evaluations, using objective investment criteria, as well as examining key opportunities offered by external partners, including industry, universities, and other government agencies. By bringing together relevant stakeholders, BT has been able to build the critical mass necessary to address many of the barriers to increasing the energy efficiency of buildings and equipment. The path to ZEB outlined by BT will show continuous demonstrated success, focusing on incremental steps (such as 30% and then 50% for homes) and a series of technical targets.

1.0 Program Overview

1.1 Market Overview and Federal Role of the Program

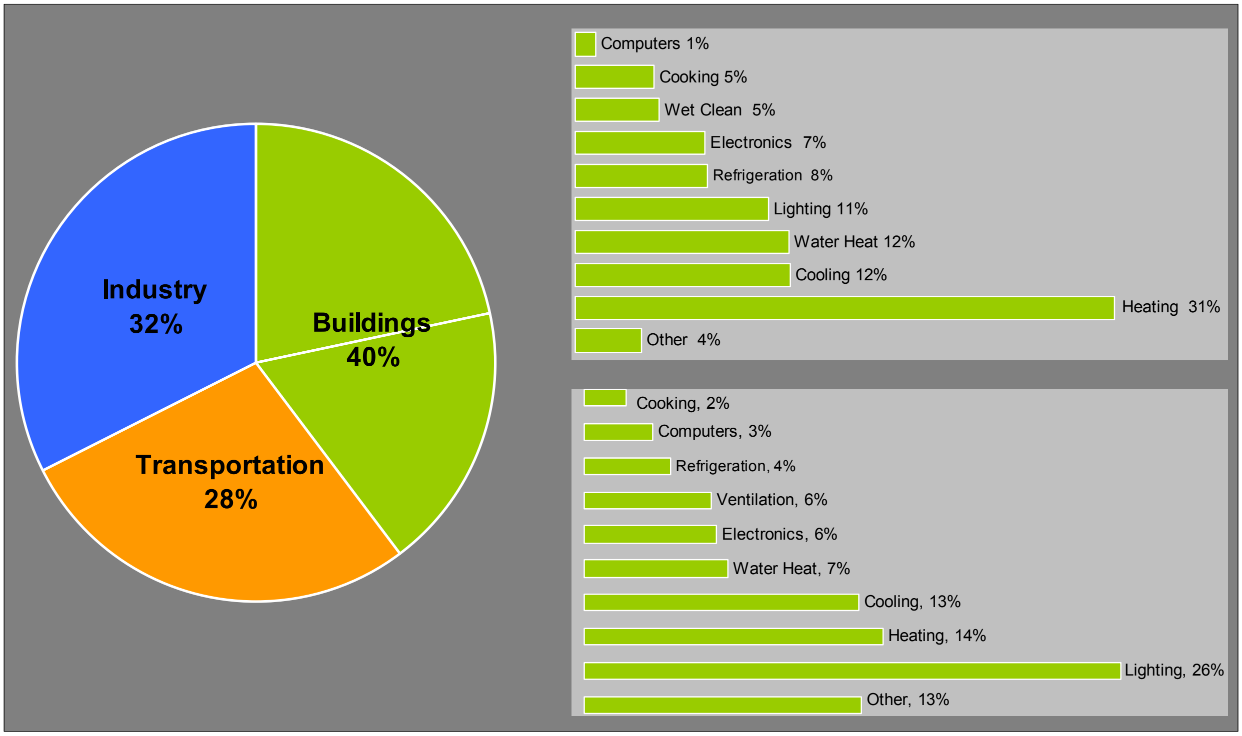
1.1.1 External Assessment and Market Overview

The Nation's 113 million households and over 4.7 million commercial buildings consume approximately 39.7 quadrillion Btu (quads) of energy annually, about 40 percent of the U.S. total, making the building sector the largest sectoral energy consumer.[2] Residential buildings use the most energy within the buildings sector with 22 percent of the U.S. total, while commercial buildings use 18 percent.

Patterns of energy use in "average" residential buildings and "average" commercial buildings differ significantly, as Figure 1-1 indicates. In residential buildings, space heating, water heating, lighting, space cooling, and refrigeration are the largest end uses. However, there is significant variation in actual end-use demand in real households, due to variation across climate zones (from Fairbanks to Key West), type of building (single family detached homes versus 20 story apartment buildings), and demographics of the household (number of occupants, patterns of occupancy, and lifestyle).

[2] *2007 Building Energy Data Book*, U.S. Department of Energy, Office of Planning, Budget and Analysis, Energy Efficiency and Renewable Energy. Prepared by D&R International, Ltd., September 2007. Hereafter, BED.

Figure 1-1 U.S. Primary Energy Consumption, 2005[3]



In commercial buildings, lighting is the most significant energy user nationally, at 4.3 quads per year. In addition to direct energy consumption by lighting, 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.[4] However, in heated buildings, the heat generated by lighting contributes to heating requirements, although this contribution is not necessarily energy efficient compared to an electrically powered heat pump or a natural gas furnace.

After lighting, the other important end-uses for commercial buildings are space conditioning (heating and then cooling) and then, with significantly lower energy demands, water heating, ventilation, and office equipment. The "other" category is an aggregation by the EIA of several distinct energy demands, and includes, for example, automated teller machines, telecommunications equipment, and medical equipment.

Therefore, the aggregated nature of this category must be considered when analyzing commercial building energy consumption.

[3] BED
[4] BED

Actual energy use demand in commercial buildings is even more variable than in residential buildings. A large end-use in one commercial building could be a small-end use or non-existent in another commercial building. For example, cooking is a major end-use in restaurants, but irrelevant in warehouses, and water heating is a major end-use in hospitals and hotels, but not in offices or retail stores. Hospitals are twenty-four hour operations, while concert halls and theaters have very concentrated energy use periods. In single-story buildings, cooling demand is partially determined by the roof; but in large multi-story buildings, cooling demand is determined by solar heat gain through windows, internal gains and by some contribution from the roof. Understanding this kind of variation is important in recognizing the actual opportunities for advanced technology and systems concepts to reduce energy demand in commercial buildings.

Energy consumption has been increasing and is expected to exceed 25 quads in the next two decades, as illustrated in Figure 1-2. The Energy Information Administration (EIA) predicts this trend to continue for three principal reasons:

1. As the population grows and the economy expands, so do the number of homes and commercial buildings. In 1970, the U.S. population was a little over 200 million; as of December 2007, it had passed 300 million.[5] By 2030, the Census Bureau projects it will be over 360 million.[6] EIA projects that the number of residential households will increase 1.1 percent per year and the total commercial square footage will grow by 1.9 percent from 2005 through 2030.[7]

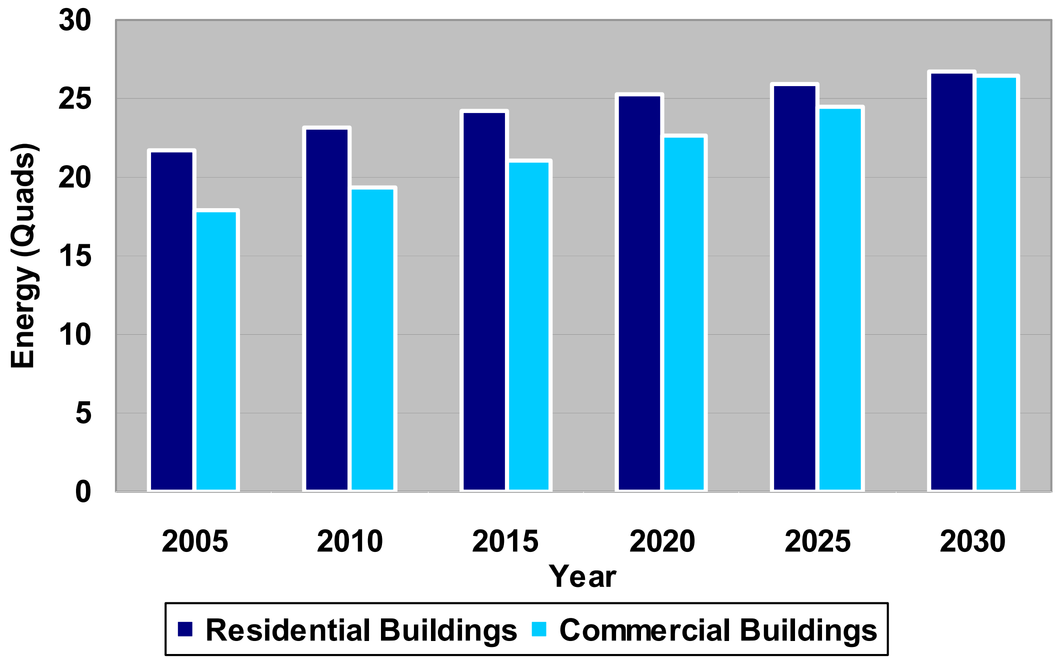
2. The amount of floor space per person has also been increasing, both due to the construction of larger homes as well as decreases in the average number of occupants per household. Average new single-family homes have increased in size by about 500 square feet since 1980. EIA projects that average house square footage will increase by over 200 square feet from 2001 through 2030.[8]

3. The demand for the services energy provides has both changed in composition and increased in scale over time. For example, air-conditioning, a novelty in the 1950s and a luxury in the 1960s, is now commonplace. The same trend is applies to household appliances like washing machines and dryers; office equipment like fax machines and computers; telecommunications equipment like mobile phones and answering machines; and entertainment devices like large screen televisions, DVD players, and digital music players. EIA projects that "other" end uses for electricity and natural gas will increase at the rate of 2.2 percent per year through

[5] U.S. Census Bureau. U.S. and World Population Clocks – POPClocks. Last revised December 11, 2007.
[6] U.S. Census Bureau. State Interim Population Projections by Age and Sex: 2004 – 2030.
[7] Annual Energy Outlook 2007, Energy Information Administration. Hereafter, AEO.
[8] AEO.

2030 in the residential sector, and by 2.4 percent per year through 2030 in the commercial sector.[9]

Figure 1-2 Projected Buildings Energy Use Growth[10]



Future energy use in buildings will include the following trends, which serve to guide our Research and Development (R&D) prioritization decisions.

- Total residential energy consumption is projected to grow at an average rate of 0.7 percent per year between 2005 and 2030, with the most rapid rate of growth projected by EIA for natural gas fueled space cooling (31.8 percent) and electricity use for personal computers (4.1 percent), color televisions and set top boxes (2.0 percent), and for the undefined and mostly electric “other” uses which EIA projects will increase 2.2 percent per year.[11]
- Commercial energy use is projected to grow at an average annual rate of 1.6 percent between 2005 and 2030. The most rapid growth rates in commercial energy use projected by EIA are for office equipment not including computers (3.9 percent), personal computers (3.2 percent), and “other” uses (3.0 percent).[12]

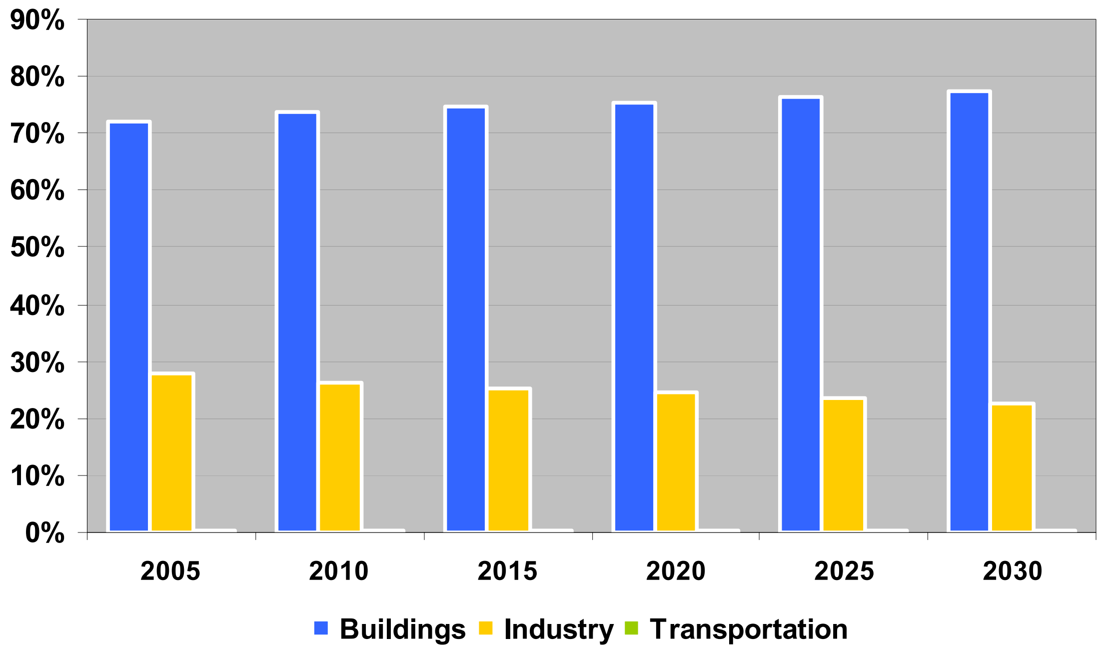
[9] AEO
[10] AEO
[11] AEO
[12] AEO

1.1.2 Description of Competing Technologies

Several options exist for reducing the environmental and national security-related consequences stemming from energy consumption in the U.S. Two important options include reducing our demand for energy in the three primary sectors: buildings, transportation and industry, and providing cleaner domestic energy generation technologies, such as renewably-generated power and renewable liquid fuels. The net zero energy goal, of course, is a combination of these two options, an "insulate then insolate" approach which lowers loads and serves remaining loads with renewable power.

Homes and commercial buildings are the dominant consumers of electricity in the U.S. at 72 percent of total consumption and will consume 77 percent of electricity by 2030, as illustrated in Figure 1-3.[13] Electric system summer peak demand, and the associated stress on transmission and distribution systems, is predominately building-related. It is largely driven by the demand for air conditioning in homes, offices, and other commercial buildings.

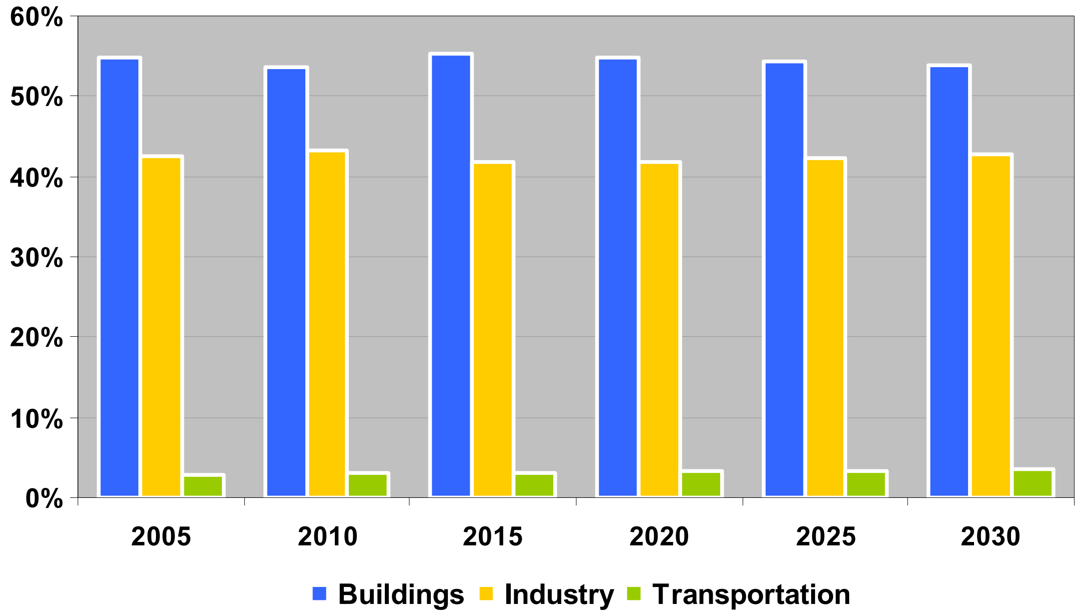
Figure 1-3 Electricity Use by Sector, 2005-2030[14]



[13] AEO
[14] AEO

Homes and commercial buildings are also the dominant consumers of natural gas, at 55 percent of total primary consumption, and will consume 54 percent by 2030 (Figure 1-4). From the standpoint of utility bills, buildings account for over $97 billion in natural gas expenditures.[15]

Figure 1-4 Primary Natural Gas Use by Sector, 2005-2030[16]



1.1.3 Overview of Market Barriers

Building industry R&D investment is 1.2 percent of revenues and building technology R&D between 0.3 and 2.2 percent; both are less than the U.S. average of 3.2 percent as a result of several factors.[17] The buildings industry is extremely fragmented, with a large number of different types of firms required to build and operate a building (e.g., manufacturers, designers, builders, subcontractors, suppliers), limiting the ability of the private sector to effectively coordinate research. With the exception of some appliances and materials, firms are typically very small and represent a small portion of their overall market (for example, the top 5 homebuilders account for only 15 percent of the market[18]) and are generally not large enough to undertake substantial research, or to realize more than a small portion of the resulting benefits themselves.

---

[15] BED
[16] BED
[17] BED
[18] BED

Building efficiency improvements entail unique market risks because they are relatively invisible and difficult to measure, making them challenging to market, especially without independent verification of savings levels. The relatively small size of building firms makes it very hard for them to absorb the costs and risks of verifying the efficiency, safety, and health characteristics of new building designs and technologies. Investment in energy R&D by private companies dropped 50 percent between 1991 and 2003.[19]

Building efficiency improvements are also impeded by the ownership structure of some commercial and residential buildings. Building occupants, who are not the owners, have little incentive to invest in building efficiency improvements. The owners are also unwilling to upgrade to high efficiency equipment and appliances because they do not see the benefit of reduced utility bills, which the occupant pays. This 'owner versus occupier' problem discourages investment in increased energy efficiency.

Another barrier is the compartmentalization of the building professions, in which architects and designers, developers, construction companies, engineering firms, and energy services providers do not typically apply integrated strategies for siting, construction, operations, and maintenance.[20]

1.1.4 National Need

President Bush's National Energy Policy (NEP) calls for "reliable, affordable, and environmentally sound energy for America's future." In order to achieve this vision, the President's plan has defined several objectives including increasing energy conservation, relieving congestion on the Nation's electricity transmission and distribution systems, and establishing energy efficiency and environmental protection as national priorities.[21]

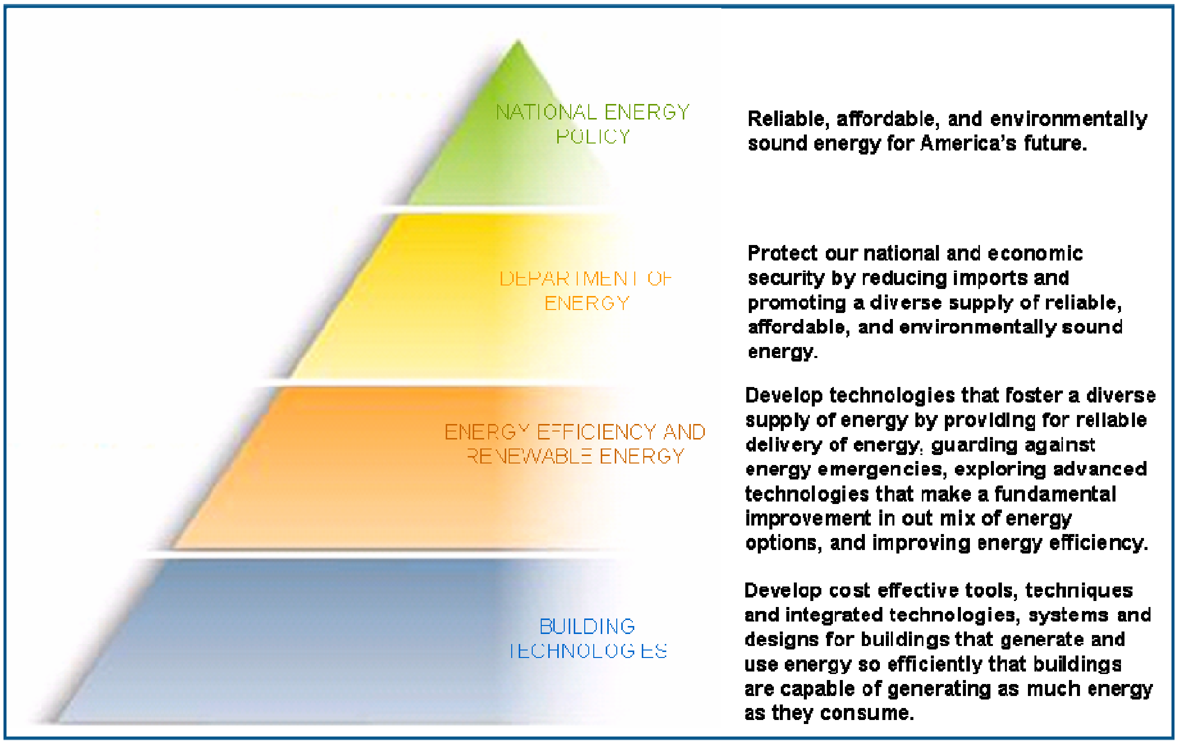
The implementation of the President's NEP is a top priority for the Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). EERE plays a critical role in achieving the NEP's goals of improving the energy efficiency of residential and commercial buildings as well as improving the energy-consuming equipment in these buildings.

Increasing the energy efficiency of residential and commercial buildings leads to reductions in the consumption of oil, natural gas, and electricity; thus, America is less vulnerable to energy supply disruptions, energy price volatility, and constraints in the Nation's electricity infrastructure. The Building Technologies Program helps to address

[19] Kammen & Nemet. *Issues in Science and Technology.* Reversing the Incredible Shrinking Energy R&D Budget.
[20] *Building Better Homes: Government Strategies for Promoting Innovation in Housing*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research and the Partnership for Advancing Technology in Housing. Prepared by Rand Corp., 2003.
[21] National Energy Policy Development Group, *National Energy Policy,* May 2001.

the NEP recommendation to reduce energy intensity and make energy efficiency a national priority (Chapter 4), modernize conservation (Chapter 4) and improve affordability (Chapter 2). Buildings also account for about a third of U.S. carbon emissions, so this program helps address the President's goal to reduce greenhouse gas emissions by 18 percent over the next 10 years.[22] EERE's and BT's role in implementing the President's energy policy is illustrated in Figure 1-5.

Figure 1-5 National Energy Policy Implementation



Increasing the energy efficiency of residential and commercial buildings leads to increased energy conservation by reducing the consumption of electricity, natural gas, and to a lesser extent, oil. With our Nation's annual energy bill for residential and commercial buildings reaching $340 billion in 2005, the economic advantages of reducing energy expenditures are significant.[23]

Buildings' power demand is the majority of peak electricity use; therefore, reducing the electricity used by buildings can also relieve congestion on the Nation's electricity distribution systems. By alleviating this congestion, buildings can improve the security of the Nation's energy production by lessening the need for larger distribution systems,

[22] EIA. Emissions of Greenhouse Gases Report, 2007.
[23] BED

reducing supply disruptions caused by overtaxed electrical distribution systems and protecting delivery infrastructure against terrorist threats.[24]

In addition, improving the energy efficiency of buildings reduces the environmental impact by decreasing the need to combust fossil fuels, either on-site (for space and water heating, or electrical power generation) or at power plants to generate electricity. In turn, this reduces the airborne emissions associated with fossil fuel combustion, including emissions of carbon dioxide, the principal greenhouse gas associated with global climate change. In 2005, U.S. buildings accounted for 39 percent of the nation's anthropogenic carbon emissions and 9.1 percent of the global carbon emissions[25], which is equal to the carbon output of Japan, France, and the United Kingdom combined.[26]

1.1.5 Federal Role

The BT Program funds research, development, and demonstration activities linked to public-private partnerships. The government's current role is to concentrate funding on high-risk, pre-competitive research in the early phases of development. As activities progress from developing technology to validating technical goals, the government's cost share will diminish as private industries and institutions begin to take on cost burdens. The government's role will bring technologies to the point where the private sector can successfully integrate them into buildings and then decide how best to commercialize technologies.

BT has assumed this Federal role because market pressures and market structures make it difficult for the building industry to earn an acceptable return on research investments as discussed in section 1.1.1, External Assessment and Market Overview. In addition, the market barriers described in section 1.1.3 make it difficult for consumers and companies to take a more active role in buildings efficiency improvements. Consumers are often unwilling to pay higher initial costs to achieve lower life cycle costs, a tradeoff inherent in some energy efficiency technologies, unless there is a resulting positive cash flow between mortgage payments and utility bills. Large corporations in the components, materials, and construction segments of the building industry spend less than the U.S. average on R&D. While this is partially due to the cyclical nature of the market, the industry is also dominated by a large number of relatively small firms that cannot afford research programs, which prevents coordinated or integrated research.

In addition to the buildings industry financial constraints, vast variability exists within buildings themselves, so that even a single community might contain hundreds of styles and sizes. One result of all this diversity is that component integration into buildings is less than optimal. Hence, buildings are typically designed and constructed as complex

---

[24] U.S. Department of Energy, *Fiscal Year 2004 - 2008 Planning Guidance*. (Unavailable)
[25] BED
[26] AEO

amalgamations of individual technologies, each of which carries out its intended function largely independent of (or even in spite of) others, rather than as a tightly integrated system of interrelated components. Inefficiencies and lost energy saving opportunities, not to mention potential reductions in construction costs, are frequent consequences of this lack of overall integration. Given this lack of "whole buildings" research in the private sector, DOE is ideally suited to bring together the component research being conducted in the private sector with best practices in the construction industry to build energy efficient buildings with minimal impact on the cost to the consumer.

In addition to compensating for the obstacles to private sector investment in building R&D, the Federal Government also has a regulatory role in protecting consumers from products that consume uneconomical amounts of energy or bring about undue environmental degradation as a result of their use. BT accordingly establishes efficiency standards for energy consuming equipment used in residential and commercial buildings under the authority of the Energy Policy and Conservation Act of 1975, as amended. BT also assists in devising and promulgating building codes targeting energy conservation that fall under state and local jurisdiction.

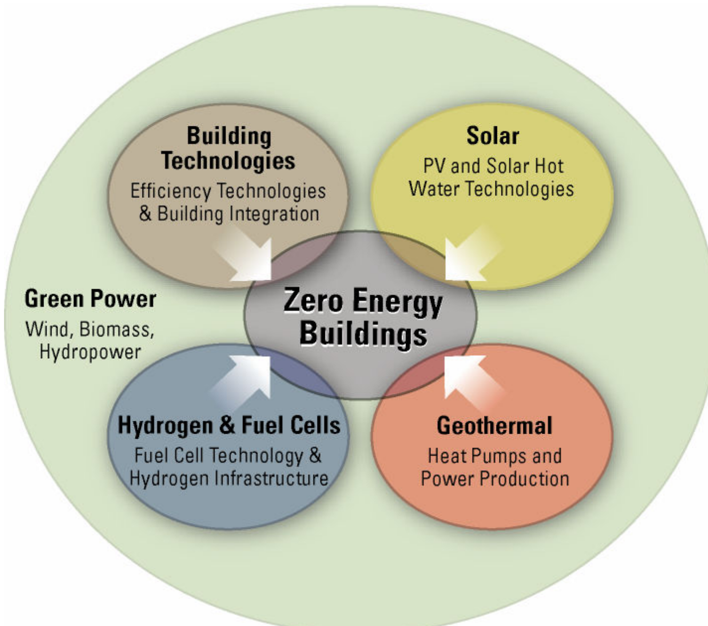
Other Federal and State Programs Complemented

Many of Building Technologies' subprograms (windows, lighting, commercial buildings, envelope, space conditioning) work closely with industry to identify pre-competitive R&D needs and prepare development roadmaps. The program coordinates with the U.S. Department of Housing and Urban Development's (HUD's) Partnership for Advanced Technology in Housing (PATH) Program and others in certain multi-agency efforts. Through the efforts of the Association of States Research and Technology Transfer Institute (ASERTTI), coordinated research agendas are developed with the counterpart State research entities. BT integrates its unique regulatory authorities within these research programs to allow full consideration of federal actions. DOE also works with the Environmental Protection Agency (EPA) on the ENERGY STAR® labeling program

Context within EERE and Other Federal Programs

Equally important, intra- and inter-agency collaboration and coordination are critical drivers of innovation. For example, EPA ENERGY STAR Homes serves as a deployment mechanism for Building America research products. The success of ZEB depends not only on the BT program itself, but also relies on the successful development of renewable energy technologies and other EERE program initiatives (see Figure 1-6).

Figure 1-6 EERE Programs Contributing to ZEB



The renewable energy technologies needed to achieve ZEB include various distributed generation technologies being developed in other parts of EERE, such as Solar, Distributed Energy and Electric Reliability (DEER), Geothermal, Hydrogen, Wind, Hydropower, and Biomass. Deployment and demonstration in Federal Energy Management Program (FEMP) and Weatherization and Intergovernmental Program (WIP) will also be needed to reach ZEB. These EERE programs must optimally align their missions and core capabilities with those of other programs, as well as reach their cost and performance goals in order for BT to achieve ZEB.

BT has a unique mission within the Federal Government of improving the energy efficiency of building equipment, subsystems, and whole buildings through research, development, demonstration and deployment; support and promotion of energy building codes; and the development and enforcement of National lighting and appliance standards. BT's Program activities focus on applied technology R&D, which includes efforts that are in our national interest and have potentially significant public benefit, but are too risky or long-term to attract private sector interest. While BT integrates research results into whole building design packages, such as the DEER and Solar Programs, it does not fund R&D topics addressed by those programs.

BT leverages internal and external resources to achieve its program goals; some of the resources and efforts required reside in other Technology Deployment (TD) programs, and BT's multi-year planning process makes these connections explicit. BT also contributes to mission goals for other TD programs and to cross-cutting goals for EERE as a whole. In both cases, BT works with the Deputy Assistant Secretary for Technology Deployment and other TD Programs to identify and manage cooperation and interrelationships in an integrated strategic-level multi-year plan.

The technology development efforts are supplemented with activities that address the needs for economically justified building energy codes and National appliance standards. Additionally, activities work to accomplish effective technology transfer and information exchange. In terms of effected energy savings, National appliance standards, which mandate the efficiency level of energy using equipment, are the most effective at obtaining energy savings due to 100 percent market penetration. Building energy codes are effective when adopted and enforced by states and local jurisdictions, but have not been uniformly adopted or enforced. In terms of technology transfer, BT works with FEMP to encourage Federal buildings to adopt appropriate innovative lighting, envelope and other technologies. However, despite BT's efforts, technologies, design tools, methods, and practices produced are subject to competitive market forces, and thus may not achieve complete market penetration.

1.2 Program Vision

BT has defined its central vision as the realization of marketable ZEH and ZEB through the development of conservation technologies and practices as well as through utilization of renewable energy technologies that are being developed by other EERE programs and industry. BT will focus on reducing the energy demand in buildings in a manner that will also allow for the successful integration of renewable energy technologies (both on-site and purchased) acceptable to the market. This strategic goal provides for the acceptance of low-energy and net-zero energy buildings in the marketplace.

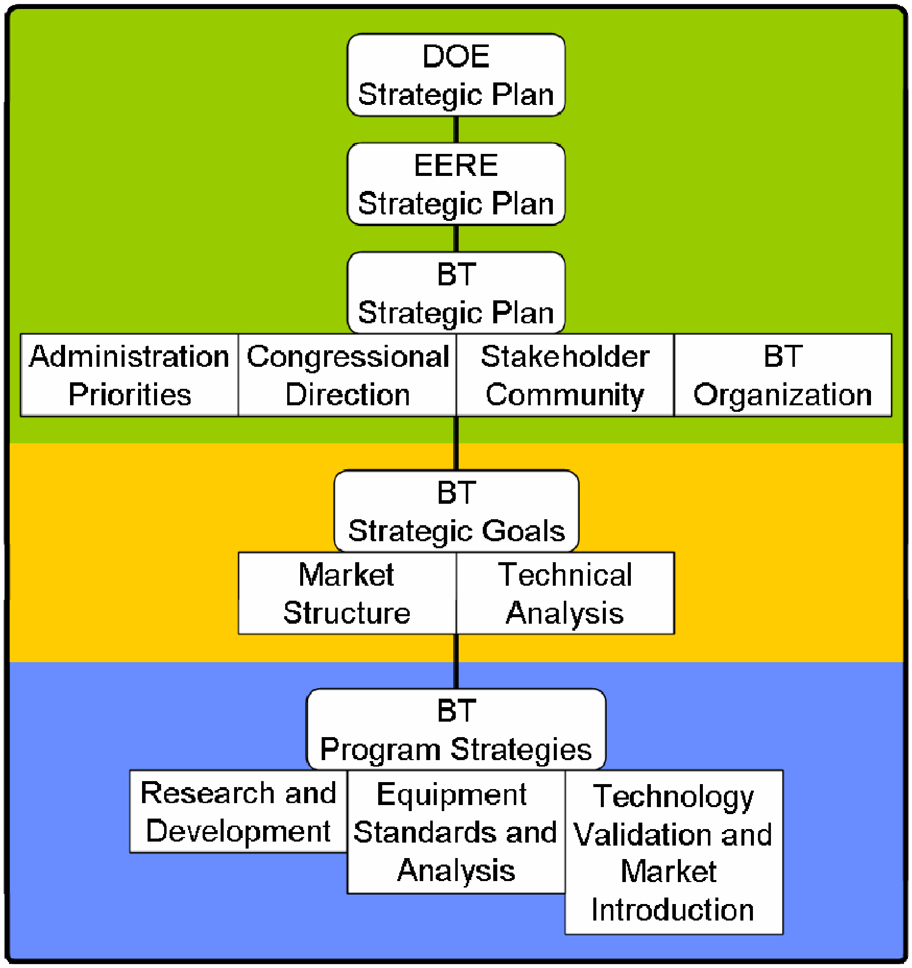
1.3 Program Mission

The mission of BT is to develop technologies, techniques and tools for making residential and commercial buildings more energy efficient, productive, and affordable. The portfolio of activities includes efforts to improve the energy efficiency of individual building components and equipment as well as their combined efficiency using integrated whole-building system-design techniques. Additionally, activities include the development of building codes and equipment standards; the integration of renewable energy systems into building design and operation; and the acceleration of adoption of these technologies and practices.

1.4 Program Design & Structure

BT is designed and structured to conduct the key activities required to meet the mission and vision of BT, marketable ZEB. The mission, vision, goals and objectives are developed in an open, consultative process that includes consideration of the priorities of the Administration, Congress, key stakeholders and the BT organization itself. The relation of these elements is depicted in Figure 1-7.

Figure 1-7 Building Technologies Program Structure

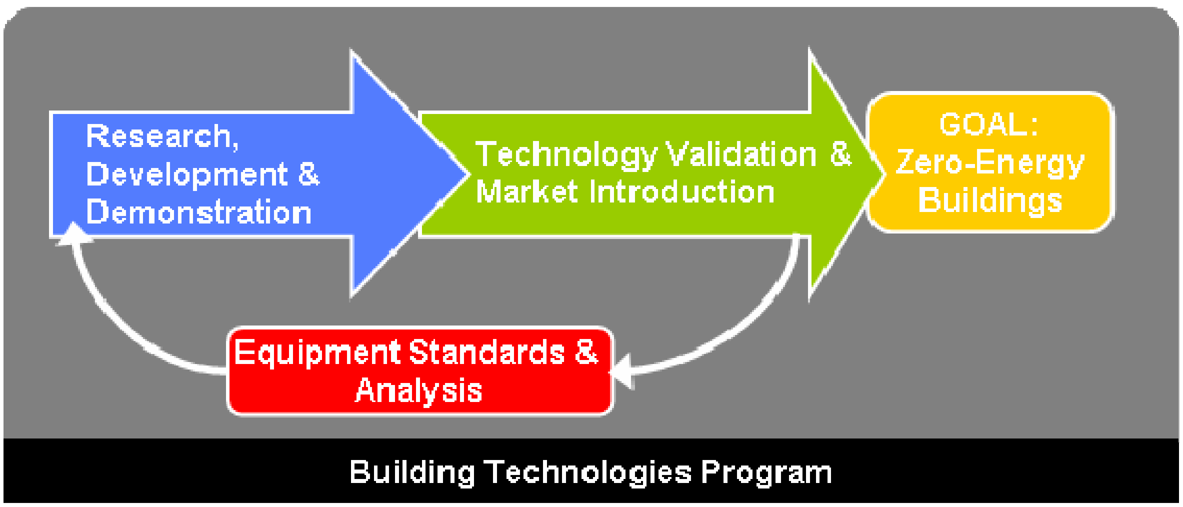


The BT strategic goals are likewise linked to the strategic objectives of EERE. That is, if BT is "…successful in meeting [its] goals and objectives… then, by definition, EERE should be successful in accomplishing its mission"[27] with respect to buildings– assuming other TD programs buildings-related goals are also accomplished. Primary direction is set through market structure and relies upon technical analysis to help set goals and to determine BT's specific activities. Strategies are developed through analysis of technical options and an understanding of the market structure (trends, barriers, institutions, consumer preferences) that are most likely to achieve the strategic goals and objectives of each activity. These strategies then form the organizational structure within the BT Program.

[27] *EERE Program Management Quick Reference Guide*, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, December 2003. Hereafter, PM-QRG.

BT has identified a three strategy approach to overcome barriers and achieve the goal of ZEB by 2025, as illustrated in Figure 1-8. The three strategies: Research, Development and Demonstration (RD&D); Technology Validation and Market Introduction (TVMI); and Equipment Standards and Analysis have evolved from careful consideration of the goal and a thorough situation analysis. BT subprograms will be designed to capitalize on the interactive, synergistic benefits of the three implementation strategies. The three strategies build upon each other, so the crosscutting approach will make the program stronger than if the strategies were pursued in isolation. A prioritized and integrated portfolio of R&D will establish the technology base for future energy savings.

Figure 1-8 Building Technologies Program Logic



In addition to the Research, Development and Demonstration of efficient technologies, the Equipment Standards and Analysis activities will eliminate the most inefficient existing technologies in the market through energy efficiency standards for equipment. Also, Technology Validation and Market Introduction activities will catalyze the introduction of new technologies and the widespread use of highly efficient technologies already on the market and provide valuable feedback for future R&D.

The three strategies combined form the complete approach to reducing energy consumption in buildings. BT's challenge is to bring the appropriate strategies to bear in order to maximize the opportunities, while designing programs that give appropriate consideration to both the market and technology barriers to energy efficiency.

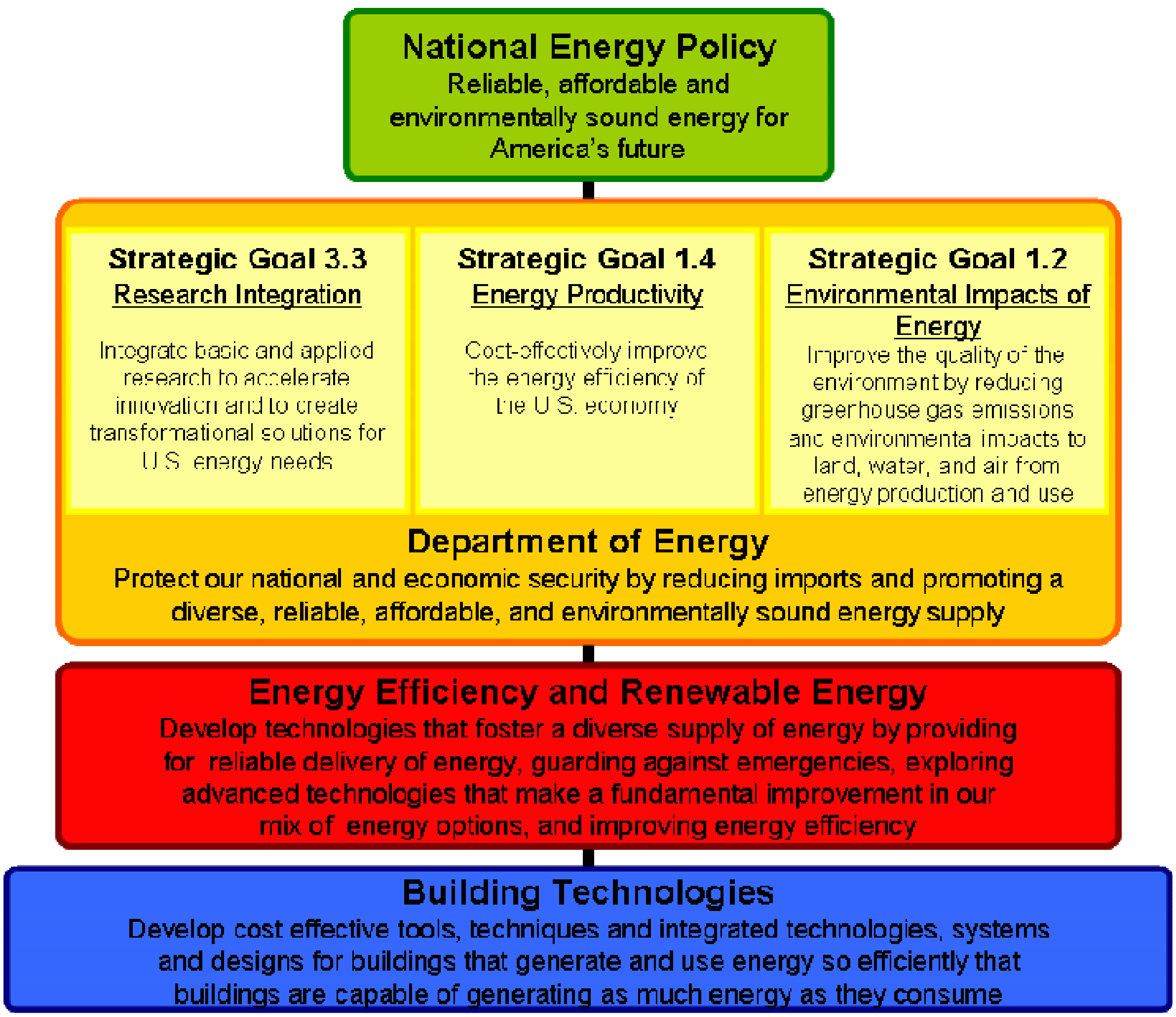
1.5 Program Goals and Multiyear Targets

The DOE Strategic Plan identifies five strategic themes (one each for nuclear, energy, science, management, and environmental aspects of the mission) plus sixteen strategic goals that tie to the strategic themes. BT's strategic and performance goals support the following DOE themes and goals, as illustrated in Figure 1-9: *Strategic Theme 1, Energy Security* and *Strategic Theme 3, Scientific Discovery and Innovation*.

The Building Technologies Program also has one GPRA Unit Program goal which contributes to Strategic Goal 1.4, GPRA Unit Program Goal 1.4.20.00: Building Technologies:

> *The Building Technologies Program goal is to develop cost effective tools, techniques and integrated technologies, systems and designs for buildings that generate and use energy so efficiently that buildings are capable of generating as much energy as they consume.*

Figure 1-9 Building Technologies Goal Cascade



1.5.1 Program Strategic Goals

In support of the President's policies and initiatives, BT has embraced the strategic goal of developing net-zero energy buildings to reduce national energy demand. The Program has defined its strategic goal more specifically as:

> *To create technologies and design approaches that enable net-zero energy buildings at low incremental cost by 2025. A net-zero energy building is a residential or commercial building with greatly reduced needs for energy through efficiency gains (60% to 70% less than conventional practice), with the balance of energy needs supplied by renewable technologies. These efficiency gains will have application to buildings constructed before 2025 resulting in a substantial reduction in energy use throughout the sector.*

1.5.2 Program Performance Goals

The principal BT contributions to Strategic Themes 1 and 3 (Energy Security and Scientific Discovery and Innovation, respectively) is improving energy efficiency and incorporating productive power technologies into the whole building infrastructure. The following key technology pathways contribute to achieving this goal, and are illustrated in Figure 1-10.

<u>*Research and Development:*</u>

- Residential Buildings Integration R&D Activities: Provide the energy technologies and solutions that will catalyze a 70 percent reduction in energy use of new prototype residential buildings that when combined with onsite energy technologies result in zero energy homes (ZEH)[28] by 2020 and, when adapted to existing homes result in a significant reduction in their energy use. By 2010, develop, document and disseminate five cost effective technology packages that achieve an average 40 percent reduction in whole house energy use. Performance indicators include the number of subsystem technological solutions developed, researched, and evaluated; technology package research reports developed, researched, and evaluated against the Building America benchmark[29] for homes; builder best practices manuals developed; and project and demonstration homes developed in the Building America (BA) Program.

[28] The zero energy building (ZEB) (referred to as zero energy homes (ZEH) in the residential sector) research initiative is bringing a new concept to homebuilders across the United States. A zero energy home combines state-of-the-art, energy efficient construction and appliances with commercially available renewable energy systems such as solar water heating and solar electricity. This combination can result in a net zero energy consumption. A ZEH, like most houses, is connected to the utility grid, but can be designed and constructed to produce as much energy as it consumes on an annual basis. With its reduced energy

- Commercial Buildings Integration R&D Activities: By 2010, collaborate with industry to develop, document and disseminate a complete set of 14 technology packages that provide builders energy efficient options to meet their complex performance demands that can achieve a 30 percent reduction in the purchased energy use in new, small to medium-sized commercial buildings relative to American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) 90.1-2004. Complete an initial technology option set that establishes a basis for achieving a 50 percent energy use reductions. Performance indicators include the number of: technology packages and option sets developed, researched, and evaluated for their demonstrated potential to contribute to the target reduction of energy use in new buildings.
- Emerging Technologies (ET) Activities: Accelerate the introduction of highly-efficient technologies and practices for both residential and commercial buildings. The emerging technologies activities support the BT goal through research and development of advanced lighting, building envelope, windows, space conditioning, water heating and appliance technologies. In the area of solid state lighting (SSL) our goal is to achieve lighting technologies with double the efficiency of today's most efficient lighting sources. Without advanced components and subsystems developed in the Emerging Technologies activities, the goal of zero energy buildings (ZEB) will not be met. The performance indicators include the number of potentially market viable technologies demonstrated each of which is expected to contribute to the ZEB based upon individual builder objectives.

Equipment Standards and Analysis:

- Increase the minimum efficiency levels of buildings and equipment through codes, standards, and guidelines that are technologically feasible, economically justified, and save significant energy. By 2010, issue 13 formal proposals, consistent with enacted law, for enhanced product standards and test procedures. Performance indicators include: product standards and test procedures proposed or issued that will result in more efficient buildings energy use.

Technology Validation and Market Introduction:

---

needs and renewable energy systems, a ZEH can, over the course of a year, give back as much energy to the utility as it takes.

[29] Building America Benchmark, Version 3.1, November 2003, National Renewable Energy Laboratory

- Accelerates the adoption of clean and efficient domestic energy technologies through such activities as Rebuild America, ENERGY STAR, and Building Energy Codes. By 2010, increase the market penetration of ENERGY STAR labeled windows to 65 percent (40 percent, 2003 baseline), and maintain 28 percent market share for ENERGY STAR appliances. ENERGY STAR activities will work to remove technical, financial and institutional barriers to the widespread awareness, availability, and purchase of highly efficient appliances, compact fluorescent lighting products, windows and other products, including new advanced products. Rebuild America activities will work to remove technical, financial and institutional barriers to the widespread awareness, availability and application of highly efficient buildings including building design, construction, retrofit and operations practices. The Building Energy Code activities will support the development and implementation of energy efficient building codes which increases the construction of more energy efficient buildings. The Solar Decathlon activities will include a high-profile university competition held biannually in Washington, D.C. (next one to be held in 2009), that promotes public awareness of highly efficient building technologies and zero-energy homes using solar energy.

Figure 1-10 Research and Development Targets

Research and Development Targets

Residential Building Integration
•Five cost effective technology packages that cut energy use 40% by 2010
•Catalyze technologies for a 70% cut in energy use of new homes by 2020

Commercial Buildings Integration
•Fourteen technology packages that cut energy use 30% by 2010
•Develop an initial technology option set that cuts energy use 50%

Emerging Technologies
•Accelerate the introduction of highly-efficient technologies and practices for residential and commercial buildings

Equipment Standards and Analysis Targets
•Issue thirteen formal proposals for enhanced product standards and test procedures by 2010
•Continue to increase efficiency levels of buildings and equipment through codes, standards, and guidelines

Technology Validation and Market Introduction Targets
•Increase the market share of ENERGY STAR labeled windows to 54% by 2010
•Maintain 28% market share for ENERGY STAR appliances
•Develop and implement energy efficient building codes
•Promote public awareness of highly efficient building technologies and ZEH using solar energy through Solar Decathlon

S

1.5.3 Means and Strategies

The Building Technologies Program will use various means and strategies, as described below, to achieve its GPRA Unit Program goal. “Means” include operational processes, resources, information, and the development of technologies, and “strategies” include program, policy, management and legislative initiatives and approaches. Various external factors, as listed below, may impact the ability to achieve the program’s goals. Collaborations are integral to the planned investments, means and strategies, and to addressing external factors. To accomplish this, the Department will implement the following means.

Research and Development:

- The Residential Buildings Integration subprogram focuses on improving the efficiency of the approximately 1.5 to 2.0 million new homes built each year and the 100+ million existing homes, including multifamily units. These improvements are accomplished through research, development, demonstrations, and technology transfer strategies. This includes efforts to improve the energy efficiency of residential energy uses such as space heating and cooling, ventilation, water heating, lighting, and home appliances. Overall the program seeks to make improvements through the application of a systems engineering approach to optimize the technologies in whole buildings and concurrently ensure health and safety of the buildings. These activities support efforts to develop strategies to integrate solar energy technologies and practices and other renewable technologies into buildings and the concept for zero energy buildings. Outputs include technology package research reports, which represent research results achieving a target level of performance. Builder Best Practices Manuals, tailored for specific climate regions, are derived from these reports.
- The Commercial Buildings Integration subprogram addresses energy savings opportunities in new and existing commercial buildings with $270.7 billion spent annually for new building construction and $168 billion spent for renovation in 2004.[30] This includes research, development and demonstration of whole building technologies, design methods and operational practices. Technology development efforts focus on crosscutting, whole building technologies such as sensors and controls. These efforts support the net zero energy buildings goal not only by reducing building energy needs, but also by developing design methods and operating strategies which seamlessly incorporate solar and other renewable technologies into commercial buildings.
- The Emerging Technologies subprogram conducts R&D and technology transfer associated with energy-efficient products and technologies, for both residential

[30] BED

and commercial buildings. These efforts address high-impact opportunities within building components such as lighting, building envelope technologies, advanced windows, solar heating and cooling, and analysis tools. The subprogram also produces design strategies to incorporate emerging technologies into building systems.

Equipment Standards and Analysis:

- The Equipment Standards and Analysis subprogram leads to improved efficiency of appliances and equipment by conducting analyses and developing standards that are technologically feasible and economically justified, under the Energy Policy and Conservation Act, as amended (EPCA). Analysis performed under this program will support related program activities such as ENERGY STAR and ensure a consistent methodology is used in setting efficiency levels for each related program.

Technology Validation and Market Introduction:

- Technology Validation and Market Introduction: Activities will accelerate the adoption of clean, efficient, and domestic energy technologies. Two major activities are: ENERGY STAR and Building Energy Codes. ENERGY STAR is a joint DOE/EPA activity designed to identify and promote energy efficient products. Building Energy Codes provides technical and financial assistance to States to update and implement their energy codes in support of Energy Conservation and Production Act, Section 304. It will also include the current building energy code activities previously conducted under Residential and Commercial Building Integration. The activity also targets residential decision makers through the Builders' Challenge project.

BT's challenge is to address the opportunities with appropriate strategies and design programs that give appropriate consideration to the marketplace and barriers to energy efficiency. To accomplish this, the Building Technologies Program will implement the following strategies:

- Focus the R&D portfolios to ensure that the most promising, revolutionary technologies and techniques are being explored, align the Residential and Commercial Integration subprograms to a vision of zero net energy buildings, and appropriately exit those areas of technology research that are sufficiently mature or proven to the marketplace, and close efforts where investigations prove to be technically or economically infeasible.

- Use a "whole buildings" approach to energy efficiency that takes into account the complex and dynamic interactions between a building and its environment, among a building's energy systems, and between a building and its occupants. Analysis suggests that this approach has achieved energy savings of 30 percent beyond those obtainable by focusing solely on individual building components, such as energy-efficient windows, lighting, and water heaters.[31]
- Investing in collaborative research with the Solar Energy Program to reduce barriers to the installation and operation of photovoltaic technology on zero energy homes and buildings.
- Develop technologies and strategies to enable effective integration of energy efficiency and renewable energy technologies and practices.
- Increase minimum efficiency levels of buildings and equipment through codes, standards, and guidelines that are technologically feasible and economically justified. BT develops standards through a public process and submits codes proposals to the International Energy Conservation Code (IECC) and the American Society of Heating, Refrigeration and Air conditioning Engineers (ASHRAE).
- Design a management strategy coordinating the inter-program cooperation required for achieving ZEB. Developing affordable net zero energy buildings requires a high level of coordination with other programs in EERE. These include the Solar Energy Technology Program, Biomass Program, Wind Energy Program, Hydrogen Technology Program (fuel cells), Federal Energy Management Program and the Weatherization and Intergovernmental Program that may have important technologies to contribute. BT also invests in technical program and market analysis as well as performance assessment in order to direct effective strategic planning.
- Provide technical information to customers through deployment of cost-effective energy technologies and partnerships with private and public sector organizations. ENERGY STAR utilizes partnerships with more than 7,000 private and public sector organizations, delivering the technical information and tools that organizations and consumers need to choose energy-efficient solutions and best management practices. The Building Energy Code activities provide technical and financial assistance to the States to update and implement their energy codes in support of Energy Conservation and Production Act, section 304.

[31] Building Science Corporation, Final Report: Lessons Learned from Building America Participation, February 1995 – December 2002, February 2003, NREL/SR-550-33100

BT strategies will result in significant cost savings, reduction in the consumption of energy, increase in the substitution of clean and renewable fuels, and cost-effective reduction of America's energy demand. Thus, these strategies will lower carbon emissions and decrease energy expenditures.

2.0 Research and Development

Under our Research and Development (R&D) activities, BT will conduct a balanced portfolio of high-risk and applied research to accelerate the introduction of energy-efficient building technologies and practices.

Research is conducted in two areas: systems integration and component R&D. Systems integration research and development activities analyze building components and systems and integrate them so that the overall building performance is greater than the sum of its parts, often using the components developed by BT. In turn, research and development of individual building components (envelope and equipment/appliances) provides the technical basis for significant contributions to achieving net-zero energy performance in buildings.

BT's challenge is to address the opportunities with appropriate strategies, and design subprograms that give appropriate consideration to the trends in the marketplace and barriers to energy efficiency. To accomplish this, the BT will implement the following strategies:

- Use a "whole buildings" approach to energy efficiency that takes into account the complex and dynamic interactions between a building and its environment, among a building's energy systems, and between a building and its occupants. This is often referred to as building systems integration
- Focus the R&D portfolios using Stage-Gate methodology[32] to ensure that the most promising, revolutionary technologies and techniques are being explored, and close efforts where investigations prove to be technically or economically infeasible; align the Residential and Commercial Integration subprograms to a vision of net-zero energy buildings; and appropriately exit those areas of technology research that are sufficiently mature or proved to the marketplace.

Stage-Gating provides specific evaluation points, gates, where a project is evaluated on pre-determined criteria and, approved for the next phase, rejected, or recycled to resolve issues. Each phase has must-meet and should-meet criteria. The project is required to address the should-meet criteria to receive additional funding, then proceeding to the next phase where the project is typically held to the previous phase's should-meet criteria.

Through BT's multi-year planning and the Stage-Gate process, key priorities were developed for selection of the portfolio of activities. These priorities are (in order of importance):

1. Research and development to create systems integration solutions to enhance the technical energy efficiency of whole residential and commercial building new construction (including substantially new commercial construction) leading to marketable zero energy homes in 2020 and commercial zero energy buildings in 2025.

2. Research and development to create technical solutions to component and equipment advancement needs identified through system integration research activities conducted in priority.

3. Research and development activities of an enabling nature (including simulation software and design guides) that enhance and support the activities conducted in support of priorities 1 and 2.

32 Adapted from Robert Cooper, "Winning at New Products, Accelerating the Process from Idea to Launch." Perseus Books Group. 3rd Edition. 2001. ISBN: 0738204633

4. Research and development in systems integration, components and practices that when implemented primarily improve the technical efficiency of existing homes or commercial buildings through equipment replacement or retrofit.

Through the BT portfolio analysis and multi-year planning, technical targets were developed for Research and Development activities, including both top-down and bottom-up approaches:

- The top-down approach (from the integrated whole building perspective) establishes the component-by-component cost and performance needed to get to the optimized economic and performance result.

- The bottom-up approach (from the component perspective) informs the top-down perspective by establishing the baseline (standard current practice), best current available, projected improvement, and max potential performance of components.

Reconciling the two approaches yields the identification of gaps between the top-down performance needs and the bottom-up technologies, and this process also identifies the "good enough" states for the components in the optimized whole buildings context.

The individual component subprograms of Research and Development identify a time-specific target for providing the cost-performance solutions identified in the integration activities (residential and commercial). Further, the component research subprograms identify the maximum technical potential as an exit criteria past the target associated, which satisfies the whole building need, only if a strong enough justification for going beyond the optimized need can be made. Setting component targets in excess of the identified needs is prudent given the uncertainty that every component would exactly meet the stated need and thus higher performance component research goals would allow for trade-offs and flexibility in meeting the zero energy building (ZEB) goal.

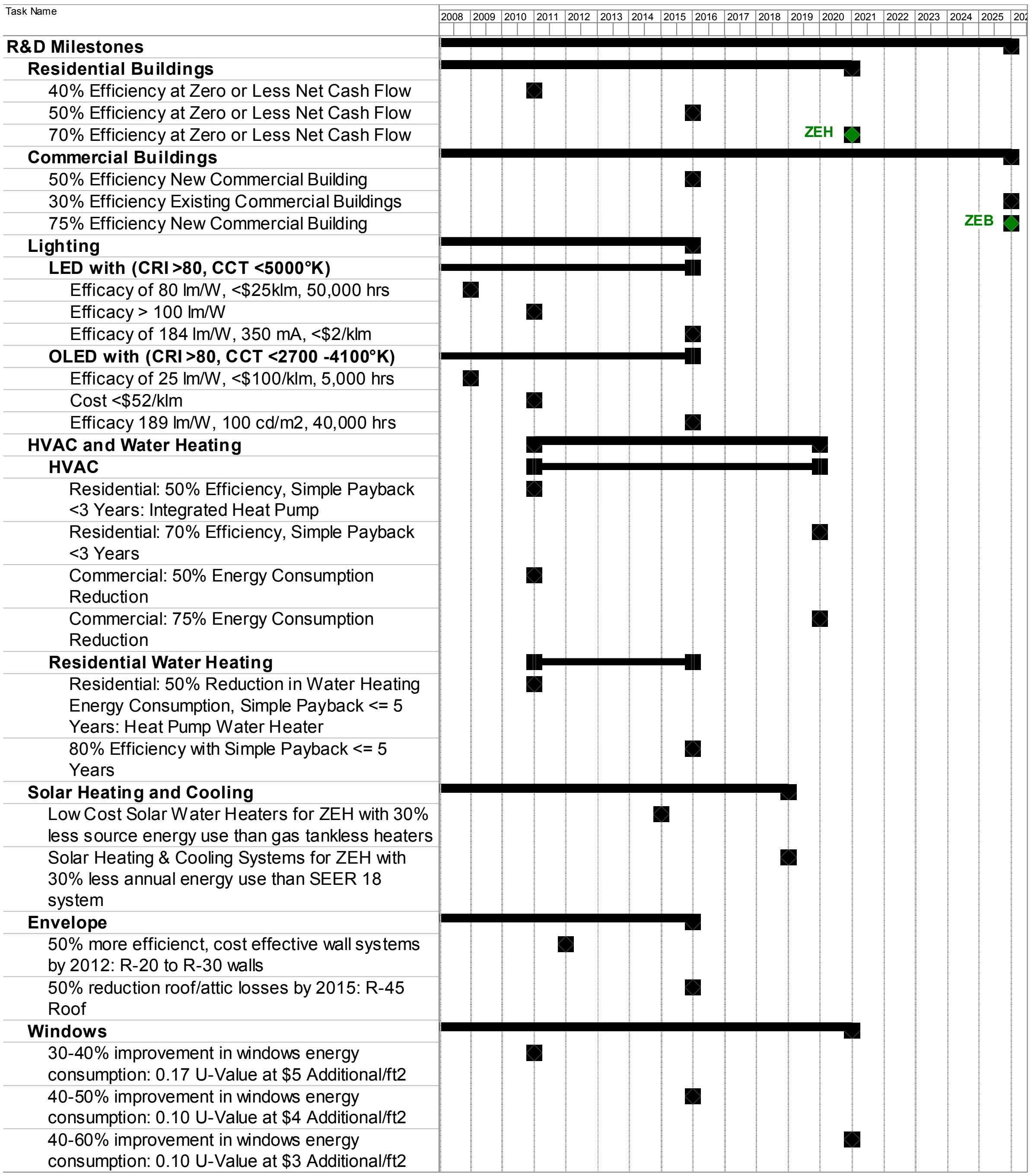
With the long-term ZEB goal in mind, BT has developed the following key Research and Development targets to be achieved over the next five years.

- By 2010, develop technologies and design strategies that can achieve an average of 40 percent reduction in purchased energy use for new residential buildings.
- By 2010, develop five or more cost-effective design technology packages that can achieve an average of 30 percent reduction in purchased energy use for new, small commercial buildings.
- By 2012, develop Solid State Lighting laboratory devices with 125 lumens per Watt.

- By 2010, develop heating and cooling systems with the technical potential to reduce annual HVAC, dehumidification, and water heating energy consumption by 50 percent.
- By 2010, develop attic/roof systems with dynamic annual performance equal to conventional R-45
- By 2010, develop wall systems with dynamic annual performance equal to conventional R-20
- By 2010, Develop low-cost (target $20/ft2 in 2010), durable (measured by number of cycles to failure, per ASTM standard) prototype dynamic window with 30-40% energy consumption improvement.

These intermediate goals over the next five years are part of BT's critical path to achieving the ZEH strategic goal by 2020 and ZEB by 2025. The following Gantt chart summarizes the major R&D milestones and decision points on the path to ZEB.

Figure 2-1 Major ZEB Milestones



As shown in this MYP, we have arrived at our technology portfolio through rigorous internal evaluations, using objective investment criteria, as well as examining key opportunities offered by our external partners, including industry, universities, and other government agencies (see Chapter 5 for more detail). By bringing together relevant stakeholders, the BT has been able to build the critical mass necessary to address many of the barriers to increasing the energy efficiency of buildings and equipment. The path to ZEB outlined here will show continuous demonstrated success, focusing on incremental steps (such as 30 percent then 50 percent for homes) and a series of technical targets.

The following sections describe the results of this planning as well as the priority activity areas for BT Research and Development to meet the ZEB goal.

2.1 Residential Integration

Table 2-1 Residential Integration Summary

Start date	1995
Target market(s)	New, single-family residential buildings
Accomplishments to date	• Developed the Building America Benchmark Definition • Developed protocols for validating whole house energy tools • Documented research and publishing Houses That Work, Builder Guides, and Best Practices manuals • Increased the number of ENERGY STAR® Homes • Completed 15% whole house Best Practices • Completed 4 climates at 30% energy savings compared to Building America benchmark • Developed Building America benchmark for whole house energy use • Completed 40,371 Building America houses • Developed advanced duct systems for factory built housing • Completed Nightcool
Current activities	2008 activities: Developing integrated cost-effective, whole building strategies to enable new, single-family residential buildings to use 40% less total energy than the Building America Benchmark in the Mixed-Humid climate. Also working towards 40% reductions in Marine and Cold climates in 2009.
Future directions	Continuing to develop the strategies, technology packages, and training packages for new, single-family residential buildings to use 40-100% less energy than the Building America Benchmark in the Marine, Hot-Humid, Hot/Mixed-Dry, Mixed-Humid, and Cold climate regions.
Projected end date(s)	2020
Expected technology commercialization dates	See Table 2-4 Residential Integration Efficiency Performance Targets by Climate Region

The Residential Integration (RI) subprogram, primarily Building America activity, focuses on improving the efficiency of the approximately 1.5 million new homes built each year.[33] These improvements are accomplished through research, development,

[33] National Association of Home Builders, *Annual Housing Starts (1978-2006)*, 2006. http://www.nahbregistration.com/generic.aspx?sectionID=130&genericContentID=554

demonstrations, and technology transfer of system-based strategies. The system-based strategies improve whole house source energy efficiency through integrating technologies to achieve reductions in all residential energy uses, including space heating and cooling, ventilation, water heating, lighting, and home appliances. These activities support efforts to develop strategies to integrate solar energy applications and other renewable technologies into buildings, and increase energy efficiency to achieve net-zero energy homes (ZEH). Working with various partners, Building America will achieve ZEH by 2020 for six climate zones by increasing energy efficiency, with intermediate efficiency goals, and incorporating renewable energy technologies. Outputs from the subprogram include technology package research reports, which represent research results achieving a particular level of performance. These reports, as well as other research reports, form the basis for Best Practices manuals tailored to specific climate regions. Table 2-1 summarizes the subprogram's history, including past accomplishments and future direction.

There are currently thirty-six states working with Building America on 40,371 total projects, resulting in over 989 Billion BTUs saved.[34] In addition to the state programs, Building America has projects in 36 states involving 318 builder partners.[35] Building America directly benefited 648 houses in 2007 and a total of 40,371 houses over the 10 year program duration. The ENERGY STAR® new homes program has also directly benefited from Building America research and continues to utilize and promote the research results. Due to the program's outreach efforts at professional and builder conferences as well as with trade press media, the number of homes indirectly built with Building America best practices is far greater, up to the hundreds of thousands.

Unlike other building types, residential buildings include a limited number of different end uses with many similarities in a particular climate region. Therefore system solutions can be replicated on a regional basis. Figure 2-2 shows the climate regions defined by Building America and Table 2-2 lists the number of research houses by region.

[34] http://www.eere.energy.gov/buildings/building_america/cfm/project_locations.cfm, accessed Sept. 26, 2007.
[35] NREL, Bob Hendron. Email Communication.

Figure 2-2 Building America Climate Regions[36]

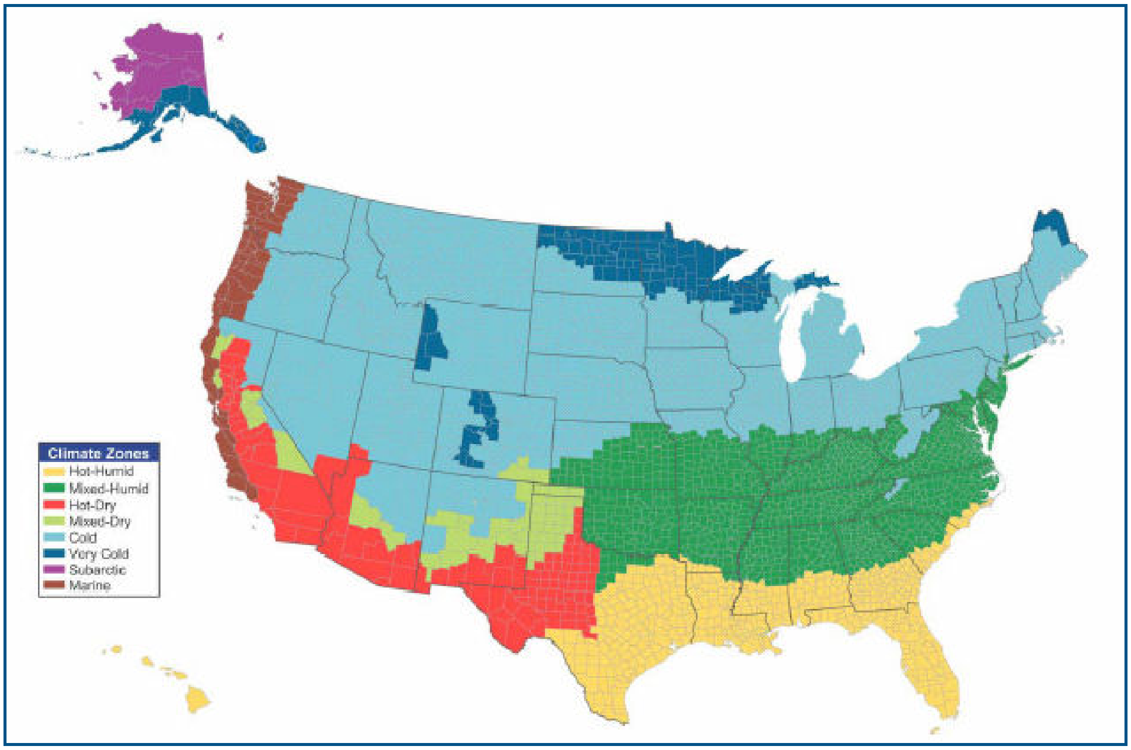


Table 2-2 Total Research Houses by Climate Region[37]

Climate Region	Number of Houses
Hot-Dry	23,661
Hot-Humid	4,024
Mixed-Dry	1,524
Mixed-Humid	921
Cold	5,073
Very Cold	14
Subarctic	1
Marine	1,641

Building America currently focuses on six of the eight climate regions: Marine, Hot-Humid, Hot-Dry/Mixed-Dry, Mixed-Humid, and Cold. Very Cold and Subarctic were addressed in the past, but due to a lack of growth, they are currently omitted from

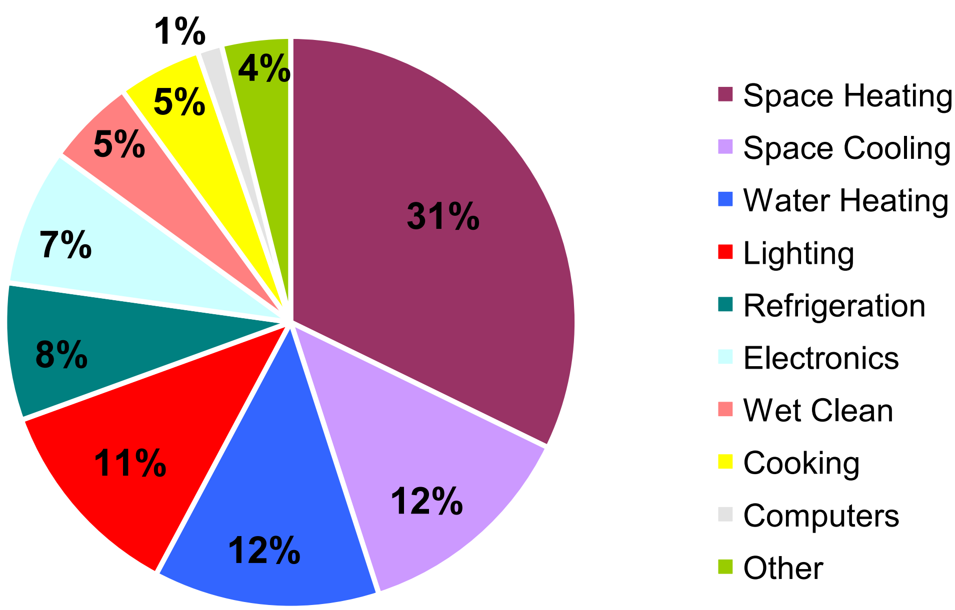
[36] Anderson, Ren, et all, Analysis of System Strategies Targeting Near-Term Building America Energy-Performance Goals for New Single-Family Homes, November 2004, National Renewable Energy Laboratory. Report No. TP-550-36920.
[37] Source: NREL 2007

development. The majority of the prototype home activity is in the Hot-Dry and Cold regions due to the relative number of housing starts in these climates.

2.1.1 Residential Integration Support of Program Strategic Goals

In 2005 the US consumed 100.2 Quads and the buildings sector represented 40% of the total energy consumed. Within the buildings sector, residences used the majority of the energy, representing 55% of the total energy consumed and accounting for 21.8 quads in 2005.[38] The largest end uses of energy in a home are space heating and cooling, water heating, and lighting as shown in Figure 2-3.

Figure 2-3 2005 Residential Buildings Primary Energy Use [39]



Note: The percentages may not sum to 100% due to EIA adjustments used to relieve data discrepancies

The Residential Integration subprogram goal is to develop integrated energy efficiency and onsite renewable power solutions that will be evaluated on a production basis in subdivisions to reduce whole-house energy use in new homes by an *average*[40] of 50% by 2015 and 70% by 2020 compared to the Building America Benchmark[41,42] at neutral cash

[38] BED
[39] BED
[40] The distinction between the average savings and the range of savings is important because it is not cost-effective (or even possible without wasteful over engineering) to design a net-zero energy home for every possible potential occupant. Because the range of possible occupant behavior is large, the average savings target in 2020 is 95%. This average will include a significant number of homes that achieve 100% savings, ensuring that the goal of net-zero energy homes is met.
[41] *Building America Research Benchmark Definition*, 2006, National Renewable Energy Laboratory.
http://www.eere.energy.gov/buildings/building_america/pdfs/40968.pdf

flow.[43] These efficiency solutions will help to achieve the strategic goal of ZEH by 2020 when combined with on-site renewable energy generation.

2.1.2 Residential Integration Support of Program Performance Goals

Building America developed the following performance goals for each phase of the systems approach. The performance targets show the energy savings from improvements in efficiency that will be reached on the path to net-zero energy homes in 2020, under the base research schedule. It is feasible to accelerate achievement of these goals by three to four years if additional resources are available.

Table 2-3 Residential Integration Efficiency Performance Goals[44]

Characteristics	Units	Year			
		2008	2010	2015	2020
Average Energy savings	%	30	40	50	70
Home Owner Cost	$	Neutral Cash Flow			

Building America has also specified the following interim performance targets for each climate region, which also serve as the annual Joule milestones for the subprogram.

Table 2-4 Residential Integration Efficiency Performance Targets by Climate Region

Target (Energy savings)	Marine	Hot-Humid	Hot-Dry/ Mixed- Dry	Mixed-Humid	Cold
40%	2009	2010	-	2008	2009
50%	2011	2015	2012	2013	2014
70%[45]	2020	2020	2020	2020	2020

[42] The Building America Research Benchmark Definition consists of the 2000 IECC envelope requirements plus, HVAC, lighting, appliances and plug load energy levels derived from best available research studies and energy use data for 1990's housing stock.

[43] Net cash flow is the monthly mortgage payment for energy options minus the monthly utility bill cost savings. "Neutral" means that monthly utility bill cost savings are equal to the monthly mortgage payment for energy options. In other words, the increase in a 30-year mortgage payment is offset by the energy savings.

[44] Year of completion of annual Joule targets in six climate regions. Energy savings are measured relative to the BA Research Benchmark. This schedule assumes that funding for the systems research activities will remain at FY 2008 levels.

[45] The current Building America target year for completion is 2020. Climate zone target dates for the 70 percent level are dependent upon progress at lower target (energy savings) levels and will be determined in a future planning cycle; some climate zones may be completed before 2020.

The performance targets are incremental percentages to manage research risks, closely track progress, and allow early identification and targeting of barriers to achieving the strategic goal. Hence, the Building America systems research strategy increases the performance targets leading toward long-term strategic goals based on the successful development of system solutions at the previous performance level. These goals are adjusted and reviewed on an annual basis relative to current year technical progress and barriers.

2.1.3 Residential Integration Market Challenges and Barriers

Building America targets single-family homes because they are the most significant home sector from an energy use and growth in energy use perspective. Technologies developed for single-family homes can often be applied to multi-family and to existing homes.

The residential sector is the largest user of energy for buildings, and single-family homes currently consume approximately 80% of the energy used for residential buildings. New homes are significant contributors to the growth of peak electric demands during the cooling season because of the high penetration of air conditioners. Not only do single-family homes account for four-fifths of the residential energy use, but over the next decade the single-family home sector is projected to grow and account for over 70% of new housing units.[46] The remainder includes both multi-family and manufactured homes.

Construction of new homes requires the combined efforts of a numerous suppliers and contractors whose efforts are coordinated by a large number of builders. Because of the high costs of failure, the residential construction industry is highly risk-intolerant and first-cost sensitive.

The key market barriers to development of advanced residential energy systems are the large number of market players, the relatively low level of investment in R&D relative to other sectors of the economy, and the strict requirements for market acceptance based on achievement of low incremental costs and high reliability. The market barriers to meeting the strategic goal and performance goals are summarized in Table 2-5.

[46] Berson, David, et al, *America's Home Forecast: The Next Decade for Housing and Mortgage Finance*, 2004, Homeownership Alliance.
http://www.homeownershipalliance.com/documents/americas_home_forecast_005.pdf

Table 2-5 Residential Integration Market Challenges and Barriers

Barrier	Title	Description
A	Identification of cost neutral system solutions	Evaluation and validation of most cost-effective options needed to achieve target energy savings
B	Integration of advanced components	Identification of performance gaps and advanced component cost and performance requirements
C	Acceptance of new building practices by industry leaders	Evaluation of new system options on a cost shared basis with lead builders, manufacturers and contractors is required for acceptance
D	Identification of code issues limiting adoption of advanced systems	Identification of issues where additional performance information is required by local and national code officials to facilitate broad use of advanced systems require
E	Quality management tools and practices	Development or quality management practices in order to gain market acceptance of high performance homes

2.1.4 Residential Integration Technical (Non-Market) Challenges/Barriers

The key technical barriers are the large number of technical performance requirements that must be met before a new system can be implemented on a production basis. These technical performance requirements are driven by regional differences in building energy loads and construction techniques. For example, systems that work well in cold climates may not be applicable in hot climates. The technical barriers to meeting the strategic and performance goals are described in Table 2-6.

Table 2-6 Residential Integration Technical Challenges/Barriers

Barrier	Title	Description
F	Self-drying high R-wall assemblies	Identification of flashing and drainage plane details required to block wind-driven rain and smart vapor barriers to permit drying in both directions Development of integrated framing, insulation, air barrier, and vapor barrier details required to construct durable high-R walls
G	Advanced foundations subsystems, tools, and practices	Development of advanced durable, energy efficient foundation systems needed to address moisture, termites, durability, and energy efficiency issues
H	High performance hot water systems for cold climates	Reduction of distribution losses, recovery of waste heat, integration of tankless hot water systems, and integration of simple, durable, low cost solar hot water systems are required for cold climates
I	Miscellaneous electric loads	Improvement of miscellaneous electric end-uses' energy efficiency of and reduction of standby losses
J	Supplemental dehumidification systems for Humid climates	Development efficient, reliable, low cost supplemental dehumidification systems for hot humid climates that are capable of maintaining internal RH below 50% during periods that the demand for sensible cooling is low
K	Efficient low capacity space conditioning systems	Development of cost effective and efficient space conditioning systems with capacities 50% less than current systems, including integration with night cooling, and evaporative cooling options, as well as development of efficient/low cost ground coil systems
L	Air distribution study	Evaluation of systems that can provide uniform mixing of air with low-tonnage HVAC in heating and cooling climates while minimizing duct thermal and pressure losses

M	Supplemental ventilation strategies	Development of reliable energy-efficient ventilation systems for very high performance homes
N	High performance windows for Cold climates	Development of a window with an overall performance of R-10 or better
O	Modeling for ground source heat pumps	Modeling of thermal load profiles in soil conditions for ground source heat pump design and energy analysis
P	Electric and thermal storage	Feasibility testing for peak heating reductions using electric and thermal storage
Q	Desiccant cooling	Development of energy-efficient advanced direct expansion systems to improve latent load fraction

2.1.5 Residential Integration Approach/Strategies for Overcoming Challenges and Barriers

Building America conducts a systems research approach for single-family homes in six climate regions to meet the stated goal of developing integrated energy efficiency and onsite/renewable power solutions to reduce whole-house energy use in new homes by an average of 50% by 2013, with the ultimate goal of ZEH by 2020.[47] In order for energy-efficient solutions to be viable candidates over conventional solutions, they must cost-effectively increase overall product value and quality, while reducing energy use. Building America's systems research approach provides opportunities for cost and performance trade-offs that improve whole building performance and value, while minimizing increases in overall building cost. Alternately, a component research approach would not account for system interactions, creating integration barriers and additional risk in meeting energy savings goals cost-effectively.

Building America performs systems research by combining operations research and systems engineering in the Stage-Gate process. The first step utilizes operations research techniques to identify the technology pathways that will achieve the target energy savings in each climate region for the lowest installed cost. From these results, the optimal efficiency targets can be identified and technologies can be developed that will meet the energy savings needs cost-effectively in all climate regions. The second step in the systems research is to implement the optimal technology pathways through systems engineering in prototype homes. The step identifies challenges and barriers unanticipated by the optimization. The combination of operations research and systems engineering

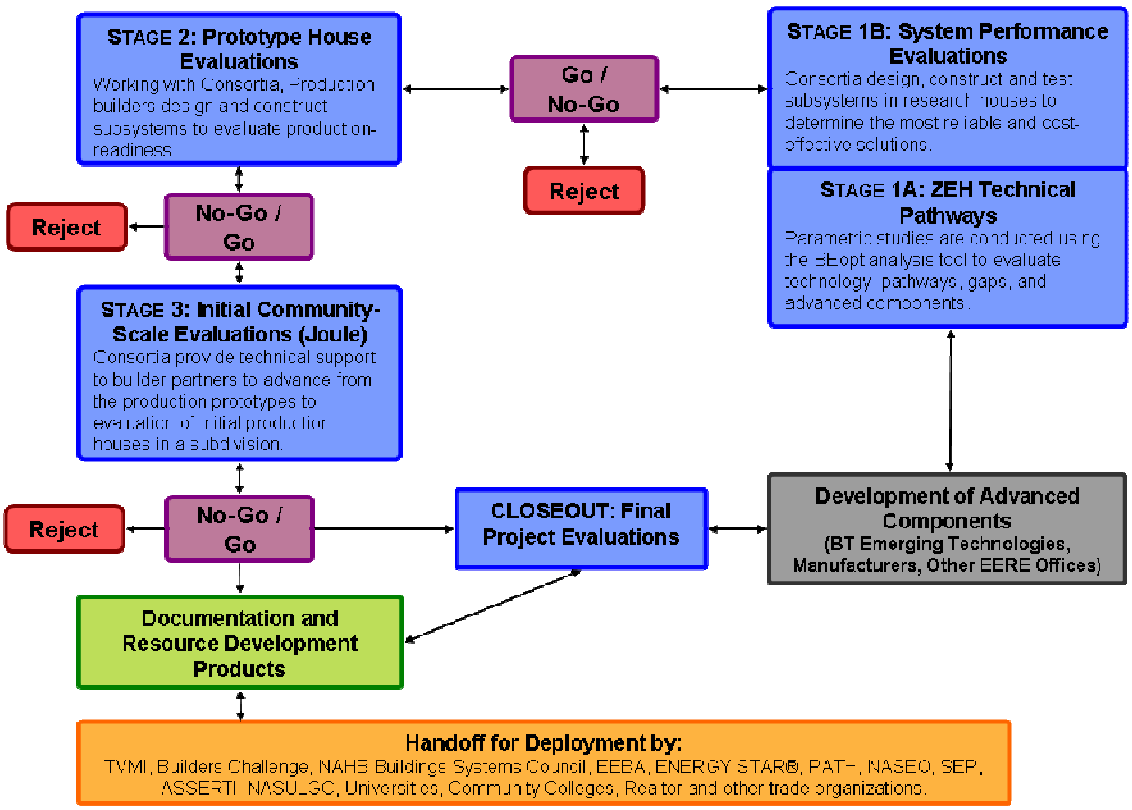
[47] 2011 target assumes level funding for Building America systems research activities.

ensures that the solutions created will meet the energy savings and cost goals, and can be used on a production basis.

The systems research described above is applied in three stages (with a final closeout stage) for each climate zone and a stage gate planning process is used to review the project status after each stage is completed (Figure 2-4). Building America acts as a national residential energy systems test bed where homes with different system options are evaluated, designed, built and tested during the three stages. To accelerate progress towards multi-year goals, research is conducted in parallel at different performance levels, facilitating rapid use of new system solutions at all performance levels. System performance evaluations, prototype houses, and evaluations in community scale housing validate the reliability, cost-effectiveness, and marketability of the energy systems, when integrated in production housing. After completion of the initial community evaluations in Stage 3, a low level of technical support may be provided as needed to ensure successful implementation of systems research results.

The stages and closeout activities are linked to quickly resolve issues as they are identified. These research stages currently take about 3 to 4 years per climate region, but for more advanced energy efficiency levels (at and above 40% savings), the process is expected to take additional iterations of whole house testing before implementation in production ready homes. At and above the 50% level, the systems research stages will probably take 4 to 6 years to complete for each climate region.

Figure 2-4 Residential Systems Research Stage-Gates



The systems research approach is best suited to meet the stated goals because the three stages allow for the early identification of performance gaps and allow for reallocation of resources to other high-priority areas when required. Building America identifies and resolves the barriers through the series of design and test studies at each stage of development. By identifying inefficiencies early, Building America has created a streamlined process for introducing higher energy efficiency to prototype housing by Stage 2.

The Residential Integration strategies to overcome market and technical barriers and challenges are described in Table 2-7.

Table 2-7 Residential Integration Strategies for Overcoming Barriers and Challenges

Barrier	Title	Strategy
A	Identification of cost neutral system solutions	Develop a systematic design and performance analysis method with integrated systems to lower cost and energy use

B	Integration of advanced components	Work with lead builders and contractors to accelerate adoption of advanced technologies and systems
C	Acceptance of new building practices by industry leaders	Use an industry driven, cost shared, team-based systems research approach to involve all participants in the residential construction industry in the development of new system solutions for high performance homes; communicate research results through Best Practices and other documentation then share results with implementation partners
D	Identification of code issues limiting adoption of advanced systems	Provide research results and performance validation required to ensure broad acceptance of advanced systems by code officials
E	Quality management tools and practices	Develop trade construction documentation (trade scopes of work, specifications, checklists, etc.) and test with several builders Develop additional quality management products such as "hot spot" training packages, quality management guidelines, and an evaluation of builder quality processes and economics (analysis and methodology)
F	Self-drying high R-wall assemblies	Develop "moisture-proof" walls and evaluate alternative framing, insulation, vapor barrier and air barrier strategies
G	Advanced foundations subsystems, tools, and practices	Build and evaluate advanced durable, energy efficient foundation systems in whole house experiments
H	High performance hot water systems for cold climates	Move water heaters and hot water distribution into conditioned space, reduce piping runs using smaller pipe diameter with thicker insulation, define hot water draw profiles required to evaluate and compare the performance of alternative system designs, improve part load performance of tankless hot water heaters, and integrate low cost solar hot water systems
I	Miscellaneous electric loads	Reduce the energy used to meet plug loads by integrating best available technologies and supplement with renewable technologies

J	Supplemental dehumidification systems for Humid Climates	Work with laboratories and industry to develop and integrate supplemental dehumidification systems for hot humid climates
K	Efficient low capacity space conditioning systems	Work with national labs and industry to develop low capacity space conditioning systems
L	Air distribution study	Conduct research using modeling, laboratory testing and field testing to determine configurations that will provide satisfactory uniform mixing of the air in homes; reducing duct pressure and thermal losses
M	Supplemental ventilation strategies	Integrate delivery of outside air with home space conditioning systems, and provide technical support to ASHRAE Standard 62.2 as needed
N	High performance windows for cold climates	Work with laboratories and industry to develop an R-10 window that is no more than 25% higher in cost than current low-e window
O	Modeling for ground source heat pumps	Conduct soil monitoring to ensure optimum performance of ground source heat pumps
P	Desiccant cooling	Refine and test advanced vapor compression systems.

2.1.6 Identification of Component Development Needs

The stage gate approach requires early identification of future system needs to allow for sufficient lead time necessary for developing and evaluating new options to meet those needs. Prior to starting Stage 1b systems evaluations, components must be developed and then evaluated to determine if they can fill gaps between current systems' performance and future whole house performance goals. These components are developed in collaboration with industry partners, BT, and other EERE offices. The component research requires significant lead time in some cases and focuses on communication of system integration needs and requirements to component developers. Building America's role is providing inputs to component developers that help to identify residential system integration needs, requirements and gaps based on annual residential cost/performance studies using the BEopt analysis method.[48,49] Components that move from development to Stage 1b system evaluations must meet minimum requirements for

[48] Anderson, R., Christensen, C., Horowitz, S., Analysis of Residential Systems Targeting Least-Cost Solutions Leading to Net-Zero Energy Homes, ASHRAE Transactions, 2006.
[49] Anderson, R., Christensen, C., Horowitz, S., Program Design Analysis using BEopt Building Energy Optimization Software: Defining a Technology Pathway Leading to New Homes with Zero Peak Cooling Demand, ACEEE Summer Study, 2006.

energy performance, reliability, and cost-effectiveness before they are included as part of the residential integration activities in Stages 2 and 3.

2.1.7 Documentation and Resource Development

At the completion of Stage 3, the research results are documented in technical research reports that serve as references for students, educators, building scientists, architects, designers, and engineers. For the research results to be successfully transferred to key stakeholders in the housing industry, they must be translated into a format appropriate for dissemination to developers, builders, contractors, homeowners, realtors, insurance companies, and mortgage providers.

During and upon the completion of closeout activities, BT fosters market implementation of Building America research and building techniques, and establishes voluntary collaborations with housing and financial industries to make the nation's houses more energy-efficient and affordable. The final activities of the research process include documentation of Best Practices manuals as well as development and evaluation of resources to provide BT research findings to private and public sector implementation programs. This work supports activities that improve the energy efficiency of public and privately owned single-family housing. The subprogram coordinates presentations at technical conferences on peer reviewed and validated research results and facilitates validation, field-testing, and final project evaluations.

The Building America resource development effort creates "Best Practices" manuals from Stage 1-3 research results that are designed for builders, manufacturers, homeowners, realtors, educators, insurance companies, and mortgage providers. These manuals summarize best practice recommendations in illustrated text that is targeted to a specific audience, synthesizing research findings into energy-efficient processes for the building industry. To facilitate construction of affordable homes designed for non-profit organizations and small builders, BT has floor plans and section details available through the BT website and other means.[50]

These post-Stage 3 efforts document Building America's best practices and lessons learned in over 40,000 energy-efficient new houses of all sizes, styles, and price points, constructed to date by Building America partners. Key Building America research results have also been incorporated in over 781,559 additional homes via coordination with deployment partner ENERGY STAR® New Homes Program and 700,000 additional homes via coordination with MASCO Environments for Living Program. The first Best Practices volume has documented practices for construction of energy-efficient houses at the 15% savings in all climate regions and has illustrated the results through case studies. As Building America efficiency goals increase between now and 2011,

[50] See www.buildingscience.com/doctypes/primer/.

similar documentation packages will be developed for whole-house conservation and renewable energy generation levels of 40% and 50%. The current schedule for development of Best Practices is shown in **Error! Reference source not found.** The documents allow a handoff of BT's building research findings to the private sector.

Table 2-8 Residential Best Practices Schedule

Target	Marine	Hot-Humid	Hot/Mixed Dry	Mixed Humid	Cold
40% Best Practices	2009	2011	2008	2009	2010
50% & beyond Best Practices	2012	2016	2013	2014	2015

In addition, Building America provides train-the-trainer course reference materials to be used by existing training programs throughout the building industry. BA provides these reference materials in partnership with ongoing training programs sponsored by professional organizations, universities, community colleges, vocational schools and others involved in the education and training of those associated with the design and construction of homes.

2.1.8 Residential Integration Milestones and Decision Points

Residential Integration subprogram will undertake the tasks in the Table 2-9 to address the market and technology barriers and to meet the performance targets. The tasks are listed by stages and duration.

Table 2-9 Residential Integration Whole House Tasks[51]

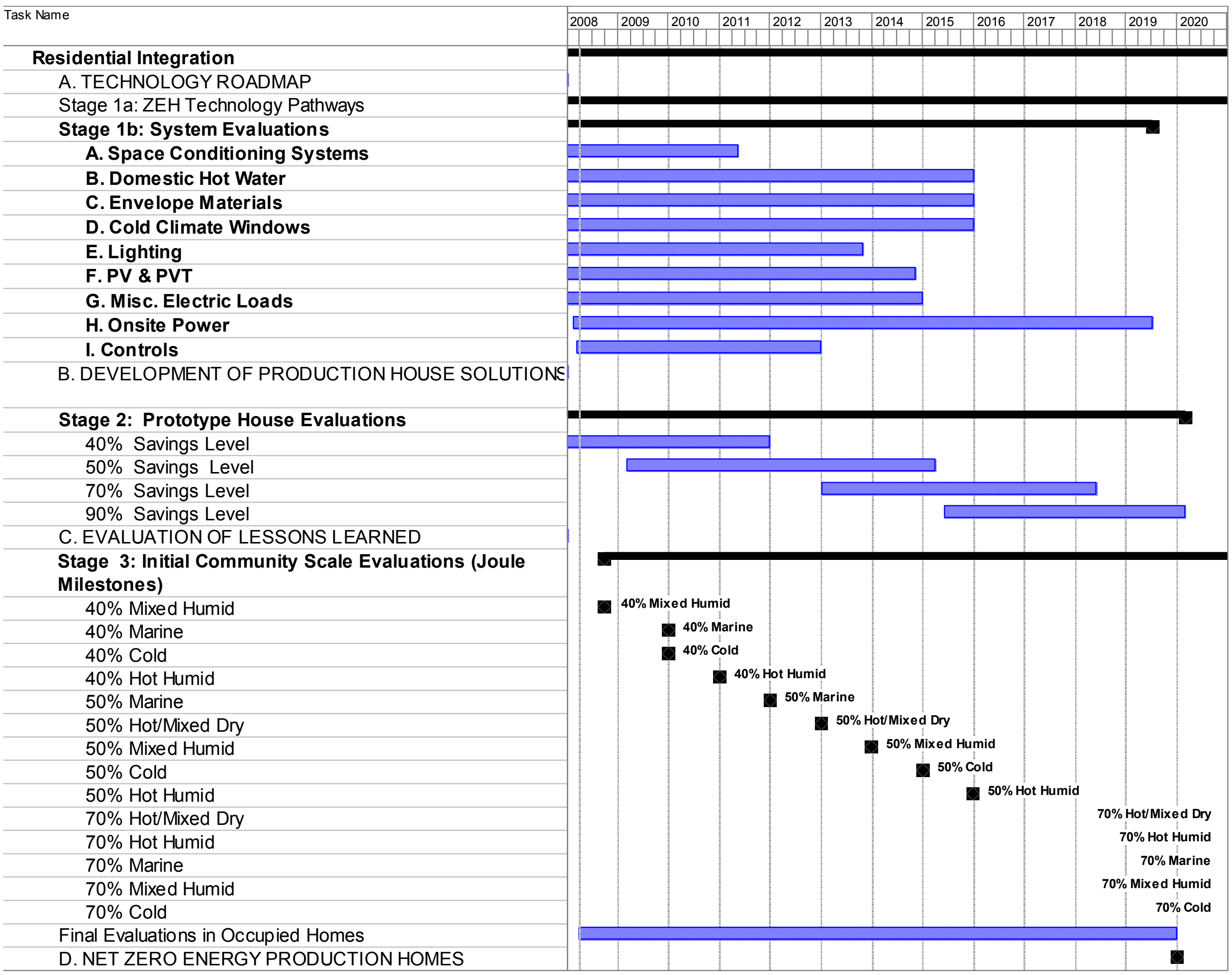
Task	Title	Duration	Barriers
1	Stage 1A – ZEH technology pathways	2008-2020	A
2	Stage 1B – System performance evaluations	2008-2019	B, F-O
3	Stage 2 – Prototype house evaluations	2008-2020	B, F-O
4	Stage 3 – Initial community-scale evaluations (Joule)	2008-2020	C
5	Closeout: Final project evaluations	2008-2020	D, E

The Residential Integration performance targets and tasks can be translated into a schedule that incorporates the Stage-Gate process. Figure 2-5 below shows the schedule for whole house and component tasks. The end of each task is the milestone and also

[51] Completed activities: "Advanced duct systems for factory built housing" and "Nightcool"

where the Go/No-Go decision occurs for the next stage. The completion of Stage 3 is the point where Best Practices documentation and training materials are developed and tested prior to distributing to implementation partners.

Figure 2-5 Residential Integration Gantt Chart



2.1.9 Residential Integration Unaddressed Opportunities

The Residential Integration subprogram has identified several areas of unaddressed opportunities. The current research could be expanded to address existing homes since approximately 1 – 2 million new homes are built each year, while 110 million existing homes consume the vast majority of the energy in the residential sector. Current activities could also be accelerated to achieve targeted performance goals in the climate zones sooner and thus realize the energy savings sooner. Both would allow for meeting ZEB goals in an accelerated manner. Particularly attractive is existing homes whole building research, which would begin to address the remodeling market's incorporation of energy efficiency techniques and solutions.

2.2 Commercial Integration

Table 2-10 Commercial Integration Summary

Start date	1995
Target market(s)	New and existing commercial buildings
Accomplishments to date	• **Established the First of Several Planned National Energy Alliances.** Commercial Integration developed a new strategic, market-focused, approach to addressing energy use in the commercial sector. The first of these alliances, the Retailer Energy Alliance (REA), was lestablished in February 2008. The REA is designed to aid retailers in improving their bottom lines and saving energy. Members include A&P, Best Buy, Food Lion, JC Penny, John Deere, Kohls', Macy's, The Home Depot, McDonalds, Staples, Target, Walgreens, Wal-Mart, and Whole Foods, in addition to ASHRAE and IESNA.[52] • Technical and financial support for the **three Advanced Energy Design Guides published by ASHRAE**, and also available for free download. (To date, 34,000 have been downloaded.)[53] The guides, which provide recommendations for achieving 30% energy savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999, focus on Small Retail, Small Office, and K-12 School Buildings, with a fourth guide on unrefrigerated Warehouses forthcoming in Spring 2008., and fifth on Highway Lodging due in another year. • **Technical Potential of ZEB.** Commercial Integration completed fundamental analysis of the technical potential of zero-net energy commercial buildings at the National Renewable Energy Laboratory. • **Web-Accessible Web Database on High Performance.** Commercial Integration has supported the development of a Web-Accessible High Performance Buildings database,[54] which currently features nearly 100 projects. • **High Performance Building Field Studies.** Commercial Integration has conducted detailed case study evaluations of

[52] See http://www1.eere.energy.gov/buildings/retailer/index.html for more information about the REA.
[53] Email, dated 4 March 2008, from Kent Peterson, ASHRAE President.
[54] http://www.eere.energy.gov/buildings/database/

	six recently built high performance buildings, and has summarized the "lessons learned" in a formal NREL report.[55] Lessons learned inform Commercial Integration's future research portfolio in areas, such as whole-buildings, including supporting technology option set portfolio. • **Ultra-Violet Photocatalytic Oxidation (UVPCO) for Indoor Air Applications.** LBNL has completed laboratory testing of UVPCO air cleaners for efficient removal of indoor generated airborne particles and volatile organic compounds (VOCs) in office buildings and other large buildings. • **Demand-controlled ventilation.** A review of demand controlled ventilation (DCV) performance and research needs was completed and documented in a technical report. While this study showed that current DCV sensor technologies needed adjustments, the energy saving opportunity for these systems is significant. • **Energy Efficient Portable Classrooms.** LBNL developed specifications and validated substantially improved portable classroom HVAC energy efficiency with a major manufacturer. These classrooms saved over 30% of the normal energy consumption and provided a cleaner, quieter and more comfortable indoor environment for learning. • **Commercial Building Benchmarks.** LBNL, NREL, and PNNL worked collaboratively to update a set of commercial building benchmarks for existing and new buildings. This set covers 15 building types in all the DOE climate zones. The benchmarks will be used as to help to assess progress towards goals through the National Energy Alliances, and also provide a firm baseline against which to measure programs towards net-zero energy performance. • **Building Controls Virtual Test Bed (BCVTB)**. BCVTB, developed at LBNL, makes it possible to develop, debug and validate building controls strategies and systems virtually before buildings and controls systems are completed. • **Low-Lift Cooling**. DOE completed a technical scoping study to evaluate the national energy savings potential of systems integration involving low-lift cooling in combination with other elements.

[55] The case studies are available at http://www.eere.energy.gov/buildings/highperformance/research_reports.html

Current activities	• Establishing the National Energy Alliances and National Accounts to develop and replicate building design prototypes at 50% and beyond energy savings. • Developing design guides, decision tools, and technology option sets. Three Technical Support Documents will be completed in FY08: Warehouse and Lodging, 30% savings; General Merchandise Stores,50% savings; and Grocery Stores, 50% savings. • Reprioritizing integrated systems research and analysis to support decision making. • Field testing, by LBNL, in an occupied building the UVPCO air cleaner with a chemisorbent added to determine the in-situ operating performance of the system and to prove the benefits.
Future directions	50-70 percent whole building energy improvements, relative to Standard 90.1-2204, through better than code flexible design guides and buildings constructed through National Accounts.
Projected end date(s)	2025
Expected technology commercialization dates	2009: Wireless controls and diagnostics for rooftop HVAC 2010: Automated commissioning; Ultra-Violet Photocatalytic Oxidation (UVPCO) advanced air cleaning

The goal of the Commercial Buildings Integration (CBI) subprogram is to achieve significant energy savings in new and existing commercial buildings. The subprogram includes research, development, and demonstration of whole building technologies, active engagement with significant market actors, design methods, and operational practices. Technology development efforts focus on cross-cutting, whole building technologies, such as controls and ventilation systems. These efforts support the zero energy building goal, not only by reducing building energy needs, but also by developing design methods and operating strategies which seamlessly incorporate solar and other renewable technologies into commercial buildings. DOE's National Energy Alliances and close technical support of National Accounts will be the vehicle for evaluating, testing, and ultimately implementing these approaches.

A building's key energy-related characteristics– aspect ratio, orientation, glazing fraction and core envelope –are all determined at the time of construction, and once set in metal and concrete, are not economically (and in many cases are not physically) alterable. This means that new construction represents a tremendous "once only" opportunity to apply high performance and net zero energy principles. A building can cast a relatively small and sustainable "energy shadow" if opportunities are seized with daylighting techniques, building orientation and optimized HVAC. However, if these sustainable practices are not adopted, the negative implications will last the lifetime of the building (up to 75 years). At the beginning of a project, it is essential to set aside sufficient time for design team development, goal setting, and project planning. A sustainable building can only be accomplished when everyone (the building owner, future occupants, and design team) share the same energy and environmental goals from the start. Ultimately, the building owner is responsible for setting and implementing the building's goals. It is the design team's responsibility to translate the building's goals and the project's budget into measurable benchmarks for design, construction, and operations to optimize the building's performance and characteristics.

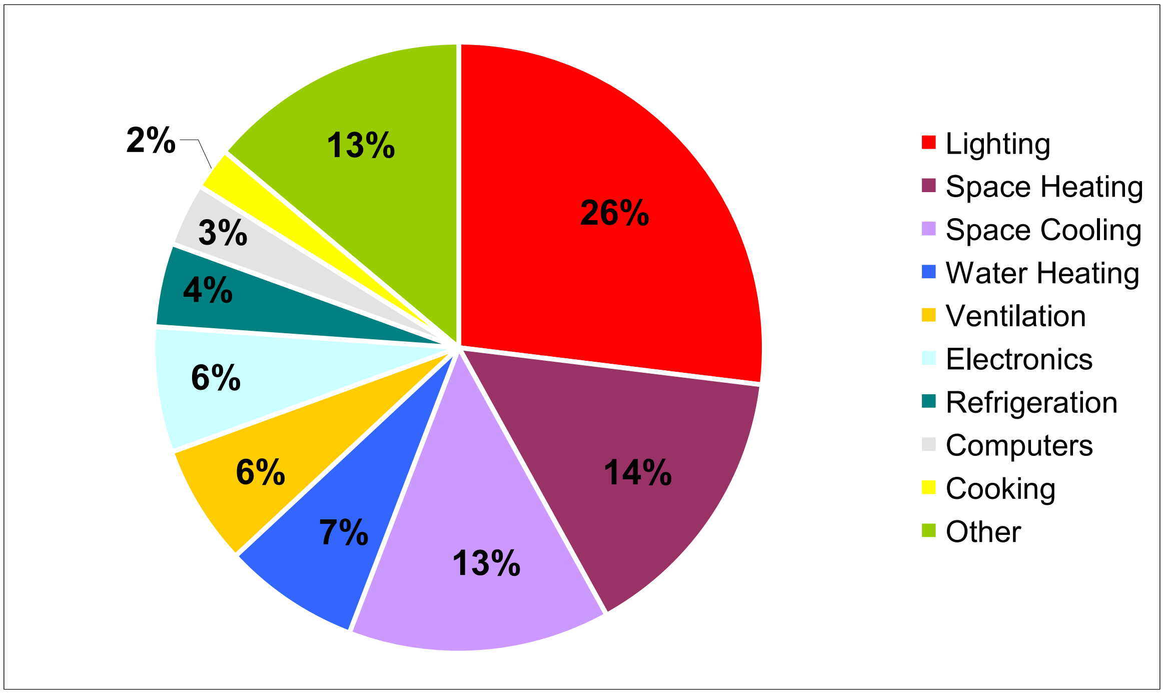
The very long lifetimes of commercial structures, combined with extraordinary growth in commercial floorspace, explains Commercial Integration's strong focus on new construction.[56] The National Energy Alliances are further focused on those sub-sectors which are both growing fastest, and that have the largest opportunity for deep energy savings. At the same time, the large stock of existing buildings will be addressed through these Alliances. Today's existing buildings will dominate the total building stock in 2025, largely because of the longevity of commercial structures. Careful attention to operation and maintenance practices, through benchmarking and sharing best practices, as well as renovation and upgrade opportunities with Alliance members will result in significant energy savings at scale for existing buildings.

2.2.1 Commercial Integration Support of Program Strategic Goals

The Commercial Buildings Integration subprogram addresses whole-building opportunities in both new construction and existing buildings. The Nation's 4.7 million buildings have a collective footprint of about 74 billion square feet.[57] The nation spends $286 billion on new capital construction and $177 billion for building renovation.[58] Commercial buildings' energy demand, including lighting, heating, cooling, water heating, ventilation, and electronics, consume 18 percent of the Nation's total primary energy, and 35 percent of its electricity. Commercial buildings, in the United States, consume 18 quads annually. This results in a total annual "utility bill" of about $155 Billion. The energy consumed by commercial building end-uses is shown in Figure 2-6; labeled end uses are addressed by BT component R&D. Lighting comprises over 25 percent of energy use and HVAC totals one third of commercial buildings' primary energy expenditures. Other loads are also significant as commercial buildings have high plug and process loads.[59]

Figure 2-6 Commercial Building Energy End Use Splits in Quads[60]

[56] BED
[57] BED
[58] BED
[59] BED
[60] BED



Note: The percentages may not sum to 100% due to EIA energy adjustments used to relieve discrepancies

Considering construction, renovation, and energy expenditures, the U.S. invests over *half a trillion dollars per year* in the commercial built environment.[61] Commercial Integration works to reduce these energy expenditures, which supports the BT strategic goal for commercial buildings: *To create technologies and design approaches that enable net-zero energy buildings at low incremental cost by 2025.*

In order to reach ZEB by 2025, BT has implemented a new market-focused strategy based on National Energy Alliances with the private sector. These Alliances, and actively interested National Accounts within the alliance, will evaluate, test, and ultimately implement integrated whole building strategies to enable commercial buildings to use up to 75 percent less energy relative to ASHRAE Standard 90.1-2004. DOE will develop the tools and Technology Option Sets which will be evaluated and implemented by the Alliances through design, construction, and operation of commercial buildings. The balance of the buildings' energy requirements will be met by renewable energy sources to achieve a net-zero energy building.

2.2.2 Commercial Integration Support of Program Performance Goals

Commercial Integration supports BT performance goals, in new construction, with its goal of whole-building improvements of 50% by 2015 and 75% by 2025 (Table 2-11).

[61] BED

In addition to focusing on new construction, the Commercial Integration subprogram's new strategic approach will also increase efforts to improve the energy performance of buildings in the existing stock. BT's existing building goals are to provide the technical capability to improve energy performance 30 percent over the Commercial Buildings Energy Consumption Survey (CBECS) 2003 baselines for existing buildings by 2025.

Once Commercial Integration has determined solutions at savings targets, the subprogram will collaborate with the National Energy Alliances to implement these solutions. DOE is completing work with ASHRAE, AIA, IESNA, and the USGBC to develop advanced energy design guides at 30% for five commercial building types: Small Retail, Small Office, K-12 Schools, Warehouses, and Highway Lodging. Having proved the feasibility of 30% energy savings across a variety of building types, DOE will then exit the 30% design guide area and focus on other areas in FY 2009.

Table 2-11 High Performance Buildings Performance Targets

Characteristics	Units	Calendar Year		
		2008	2015	2025
New Commercial Building Energy Use – Whole Building	% Energy savings	30	50	75
Existing Commercial Building Energy Use – Whole Building	% Energy savings			30
Advanced Energy Design Guides	Guides	5	TBD	TBD

2.2.3 Commercial Integration Market Challenges and Barriers

The key market barriers to high performance commercial buildings have traditionally been relatively low energy prices, the inconsistency in building design verses building construction, the difficulty of verifying building operations and the lack of fees and education for high performance building design (Table 2-12).

Table 2-12 Commercial Integration Market Challenges and Barriers

Barrier	Title	Description
A	As-built versus design	When construction changes are needed (for scheduling or product availability), the solutions must be evaluated consistent with the design goals and design process flaws can lock in building designs before energy is considered.
B	Building commissioning not common practice	Building commissioning should make the building operate according to the design intent and examine the entire building system.

C	Best practices in O&M are not widely used	Current Operations and Maintenance (O&M) practice of new and existing commercial buildings is frequently poor and can increase building energy use by as much as 30 percent
D	Unsubstantial design fees	Current low design fees do not support innovative designs and related energy analysis.
E	Minimal education on benefits of high performance buildings	Economic value proposition for high performance buildings is not well known by industry leaders.
F	Large variations due to occupant behavior	Energy use patterns are not always controlled by design; they are highly influenced by occupant behavior.

2.2.4 Commercial Integration (Non-Market) Challenges/Barriers

The key technical barriers are the complexity of high performance designs and building controls, the lack of a definition for high performance building and the need for building ventilation above current building codes (Table 2-13). Approaching ZEB, plug and process loads (in some buildings, such as 24/7 hospitals, these are really process loads) become increasingly important, and must be addressed to attain exemplary energy performance. However, this is a research challenge; BT does not have a programmatic focus in this area.

Table 2-13 Commercial Integration Technical Challenges/Barriers

Barrier	Title	Description
G	Inherent complexity of daylighting practices	Daylighting is inherently complex and a number of elements must be carefully integrated to ensure savings.
H	Integrated building control systems have poor user interfaces	Capabilities of energy management and control systems are often neither fully utilized nor even understood by the operators due to poor user interfaces.
I	No single definition of "good" building energy performance	Standard metrics for fuel economy exist for vehicles, allowing for comparisons of energy performance and annual energy costs between models. Similar metrics for commercial buildings do not exist, so most building managers have no idea if they are operating their buildings well.

J	Indoor environmental quality (IEQ) requires more than code ventilation requirements	Recent studies suggest that human health, and performance depends on providing clean air (good IEQ) in buildings. Currently minimum ventilation standards are based on anecdotal experience because there are few studies indicating how ventilation rates affect health, performance, and learning.
K	Additional analysis techniques needed	Complex buildings require sophisticated analysis beyond average practitioners' capabilities.
L	Plug and process loads are unaddressed	Getting beyond 50% savings requires addressing plug and process loads, where there is currently little research.

2.2.5 Commercial Integration Approach/Strategies for Overcoming Challenges and Barriers

The challenges inherent in designing and operating high performance buildings and ZEBs demand a number of breakthroughs, both in technology, including software and information technology, and in the fundamental knowledge of optimizing whole building performance through integration and component operation. Systems integration and improved component technology (HVAC, lighting, windows, etc.) are required in order to achieve progressively higher levels of energy performance.[62]

Development of marketable ZEBs also requires a much richer understanding of the commercial buildings market. Commercial buildings vary widely by size, surface-to-volume ratio, construction vintage, function complexity, owner-lessor role, and energy use. Also important is a keen understanding of the market structure *within* market subsectors, such as the degree of market concentration in ownership of grocery stores and big box retail, as well as insight into who the key decision makers are. Understanding this market is necessary to target R&D and achieve large energy opportunities for saving energy in commercial buildings.

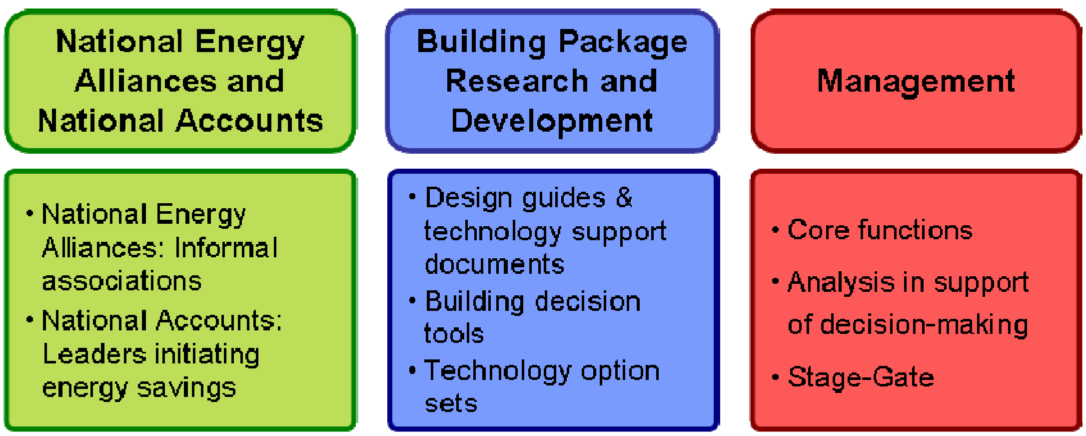
Beginning in FY08, the Commercial Integration subprogram has initiated a wholly new set of strategies to overcome challenges and barriers, which are shown in Figure 2-7.

---

[62] Buildings "systems integration," means the design, construction and operation of the commercial building as an integrated system so as to maximize energy performance and occupant satisfaction. Careful daylighting design – for example – involves care in the specification of building orientation, window area, the performance of windows, interior design, and the control of electric lighting systems so as to maximize the use of natural light. A systems approach, as embedded in the technology option sets will carefully integrate all these factors to optimize building energy performance, including lighting and space heating and cooling.

- *National Energy Alliances and National Accounts* are strategic alliances with businesses and organizations to achieve strong market demand-pull for new buildings with exemplary energy performance (50% and higher);
- *Building Package Research and Development* are information packages and tools developed by Commercial Integration to support realization of 50% and better buildings; and
- *Management* involves transparent management of the portfolio and development of supporting analysis and materials; development of contractor solicitations to support program activities; provision of performance requirements to the BT component subprograms.

Figure 2-7 Commercial Integration Strategies



National Energy Alliances & National Accounts

The National Alliances strategy consists of two key components. The first is the overarching alliance which combines businesses and organizations with similar building types (e.g., "big box" one-story, high ceiling) and business sectors (e.g., retail, office, lodging) which results in groupings with similar energy use profiles, business case needs, and potential solution sets. The second aspect of the strategy is the use of National Accounts, which are companies within these National Energy Alliances who choose to lead efforts through implementing energy saving strategies, and then share these results with Alliance members.

National Energy Alliances

National Energy Alliances (NEA) combine businesses and organizations with similar building types (for example, "big box" one-story, high ceiling) and business sectors (for example, retail, office) and hence similar energy use profiles and potential solution sets.. The members share a common goal in reducing energy consumption by significant levels in their buildings and commit to actively participate and when possible, take the lead as a National Account. The NEA strategy includes tasks which are specifically designed to improve design and operation of new and existing buildings. The Alliance will be open to broad participation (including independent associations, code bodies, and research institutions) but the benefits of participation will be fully realized by those organizations with a sustained commitment, strong involvement, and ultimately agreement to engage as a National Account. The Retail Energy Alliance was launched in February 2008 and another Alliance is planned for later in FY08.

Using market sectors and energy impacts from CBECS as well as ZEB potential from NREL, Commercial Integration prioritized target building sectors for NEA. The sectors are retail, office, institutional, and lodging. The initial NEA will focus on retail; however, a technical and market assessment in FY08 will shape future priorities.

The "Retail" sub-market itself is not monolithic. Commercial Integration has identified several important building types within the retail sub-market:

- Food Sales/General Merchandise (e.g., Wal-Mart, Target, or "Big-Box")
- Food Only (e.g., Whole Foods, Food Lion)
- General Merchandise Only (e.g., Home Depot, Petco)
- Food Service (e.g., McDonald, Starbucks, Olive Garden)

Working with retail building owners initially, BT will establish baseline energy consumption and undertake a series of technology procurements. The energy consumption information will be used to develop strategies for reduction and evaluate the effect of the NEA. Technology procurements by the NEA will bring down the price for energy efficient technologies.

BT will ask members with buildings that represent energy outliers to participate in a more detailed "Best Practices" study. Members will document basic data such as buildings size, location, age, energy use with fuel type, and energy service equipment (HVAC, Lighting, refrigeration). The data will be used in a baseline analysis that forms the primary measure for determining if Commercial Integration is reaching its 30 percent savings goal for existing buildings.
A second series of activities managed under the auspices of the NEAs are Technology Procurements. Alliance members will join together to "move the market" specifying equipment with energy performance characteristics which are beyond what the market might offer, or to help reduce the cost of "cutting-edge" equipment through a mass buy.

Commercial Integration will create a prioritized list from NEA input that will be used to establish several succeeding rounds of technology procurements. Further analysis will focus on the market impacts of the procurement process to determine whether the process has significantly "moved the market" by increasing the number of manufacturers who are offering equipment at the higher efficiency levels specified in the procurement.

National Accounts

The use of National Accounts is the other key aspect of the overall NEA strategy. A National Account is a company or organization that designs, builds, owns, and operates its own stock of buildings. Within each National Energy Alliance, companies or organizations (National Accounts) wishing to take a leading role in designing, constructing, analyzing, retrofitting and replicating energy efficient buildings using their current building construction schedule will be identified. Each National Account will enter into a formal Memorandum of Understanding (MOU) with DOE that specifies the roles, goals, and commitments of both DOE and the National Account.

The National Account will submit the current design drawings and specifications for analysis. A Technical Team will work with the National Account to determine an acceptable set of design and operational changes that will achieve over 30% energy use savings over the current standard. While the National Account may choose a level of efficiency consistent with operational goals, the Technical Team will analyze a full range of options up to and beyond 50% energy savings. The National Account will agree to build at least one building which will be monitored for at least three years. The National Account will pay for and install an Energy Management System and allow interoperability and communication with sensors to facilitate CBI analysis. Additionally, the National Account will conduct an analysis and retrofit of at least one of their most energy inefficient existing buildings.

In addition to design analysis, the Commercial Integration subprogram will provide the tools to develop the most energy-efficient design that meets business needs and cost targets of the National Account. The designers for the National Account will receive Building Decision tool training, which can be used to decrease the energy consumption of additional buildings. After monitoring, verifying, and reporting the energy savings, the Technical Team will support the National Account in acquiring tax or carbon credits from the energy reduction. Existing buildings may also be addressed through these energy efficiency measures.

Both Commercial Integration and the National Account will share the results of the re-design with the NEA and potentially more broadly. The data sharing, at a minimum, will include the building option sets chosen as well as the full spectrum of options analyzed and put forward for consideration (30-50 percent savings or more).

The ultimate goal is to develop prototype designs for each building type that achieve 50% or greater energy savings. It is recognized, 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 Design Tool, from 30 to 50% energy savings, or greater, will be analyzed and documented so that other members of the Alliance have the ability to make alternative choices.

The next step will be for the Technical Assistance Team to re-simulate the "As Built" building to determine the new energy savings level. This fully documented design will then be recommended to the collective National Energy Alliance as the "Best Practice" for achieving the current energy savings level. The National Account will then adopt the new design as the standard for all future buildings.

The National Account partner will monitor and verify energy savings in the newly constructed prototype. Energy usage and incremental cost for energy efficient approaches will be reported. If the energy savings level is less than 50% in the new Design Prototype, which is initially expected, Commercial Integration will initiate a new design-build cycle. BT will work with the existing National Account, or other National Accounts to develop higher levels of efficiency for the next design prototype. Alternative Building Packages will be developed and analyzed and put forward for consideration.

Building Package Research and Development

Building Package R&D is the research element in Commercial Integration, developing the decision tools, guides, and underlying technology options necessary to realize 50 and 70 percent energy savings levels across a variety of building types, energy intensities and sizes. Building Package R&D features three core elements:

- *Advanced Energy Design Guides 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;
- *Building Decision Tools* are tools enabling 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 building energy efficiency solutions for achieving the desired energy target, based on user inputs, costs and constraints.
- *Technology Option Sets* are defined as specific energy efficient solutions for a specific building type or process-specific design. Technology Option Sets may include equipment, strategies, algorithms, methods, and systems. Specific examples of TOS include various 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.

Advanced Energy Design Guides & Technical Support Documents

There are three distinct but related products under this element. An Advanced Energy Design Guide (AEDG) is a publication targeted at architects and other practitioners that provides specific guidance on how to achieve certain levels of high energy performance in buildings. A Technical Support Document (TSD) is a background document describing the assumptions and methodologies used to achieve particular levels of energy performance. AEDGs invariably have concomitant TSDs (to document the rationale behind the design decisions), but not all TSDs are necessarily associated with AEDGs. After the AEDGs have been released, Commercial Integration will commission market evaluations to determine the impact of these information resources with practitioners and decision makers, which will help guide future program resources.

One way to achieve "above-code" exemplary energy performance in new construction is to provide a prescriptive guide that indicates specific designs and features of a building. To this end, Commercial Integration has actively supported development of a series of *Advanced Energy Design Guides* (AEDG). These are hardcopy publications designed to provide recommendations for achieving 30 percent energy savings over the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1-1999. The guides have been developed in collaboration with ASHRAE, AIA, IESNA, and USGBC. Having proved the feasibility of achieving 30% energy savings levels in these buildings, Commercial Integration does not plan to support the development of any more 30% guides. However, the subprogram is considering developing further AEDGs targeting 50% energy savings and is undertaking Technical Support Documents (analysis) to support future publications. The anticipated release dates for AEDGs and other resources are listed in Table 2-14.

Table 2-14 Building Package R&D Publications Dates

	30% AEDG	50% TSDs	Decision Tools	50% AEDG
Retail	2007 (small)			
Food Sales/ General Merchandise	NA	TBD	2009	2015?
Food Only	NA	TBD		2015?
General Merchandise	NA	TBD		2015?
Food Service	NA	TBD		
Warehousing & Distribution	2008	TBD		
Office	2005 (small)	TBD		
Institutional (Schools, Hospitals)	2008 (K-12 schools, hospitals)	TBD		
Lodging	2008	TBD		

The Technical Support Documents (TSDs) describe the process and methodology for developing the guides.[63] TSDs typically describe the following:

- Charge given to the committee in developing the AEDG
- Development of prototype buildings to represent the class targeted by the AEDG
- Rationale for the measures selected
- Simulation approach used to meet the energy savings target
- Energy savings results by climate region

The FY08 50 percent TSDs do not support ASHRAE-published AEDGs, but are intended to be stand-alone reports documenting the technical feasibility of achieving a 50% reduction in whole-building energy use. These reports will demonstrate to National Accounts that exemplary energy performance is feasible today with available technology.

By early FY09, Commercial Integration, ASHRAE, and other key partners will have completed five 30 percent-savings AEDGs. The subprogram will conduct analysis to determine the impacts of AEDGs in the new construction market. To answer such questions, Commercial Integration has commissioned an evaluation of the currently available AEDGs, as well as of alternative guide products.

Decision Tool for Evaluating Technology Packages

Commercial Integration will develop Building Decision Tools to support building prototype redesign for National Accounts, which integrate across the TOS to help select solutions appropriate to the building type and the owners/designer performance target. The tools will present a continuum of efficiency levels from 30 to 50 percent and beyond. While a National Account may select a particular level of performance for prototype design and construction (see National Accounts below), other Alliance members can use this tool to pick alternative energy efficiency performance levels based on their design needs, costs, and other constraints.

Beginning in FY08, Commercial Integration is introducing a new strategy to develop simplified decision tools that enable design practitioners to evaluate quickly and efficiently the energy saving contributions of various technology "packages." These tools will be less intensive than EnergyPlus simulations but more complex than prescriptive, single-solution (and hard-copy) AEDGs. By using EnergyPlus as the background calculation engine, the tools will essentially present pre-packaged results tailored for a specific building type and location, and will feature a selection of technology packages. The user will then be able to quickly evaluate the various pathways for a specific energy savings target. The decision tool is much simpler to use than

---

[63] For example, PNNL has developed TSDs for both the small-retail and small office AEDGs which are available from the PNNL publications website at http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16031.pdf and http://www.pnl.gov/main/publications/external/technical_reports/PNNL-16250.pdf

performing many multiple building simulations; yet still has the capability to explore various pathways.

In line with Commercial Integration priorities, as reflected in the preliminary ranking of NEA launches by building type, the subprogram will first develop a decision tool for Retail buildings, specifically General Merchandise stores and Food-Only Grocery stores, with a 50% energy savings target.

Technology Option Sets
Commercial Integration will be developing or adopting Technology Option Sets (TOS) for consideration by Alliance members. These TOSs will address specific energy efficient solutions (such as illumination) for a specific building type or process-specific design. TOSs provide multiple pathways for designers and builders to achieve advanced energy savings with the flexibility to mix and match energy-efficient technologies. The Commercial Lighting Initiative (CLI) managed in the Technology Validation and Market Introduction (TVMI) sub-program is an example of a TOS that is being developed for the retail "Big-Box" market.

As of FY08, Commercial Integration will include all of its "technology" research and development work under this element. The core objective of this element is to develop technology option sets that directly support the 50% to 70% whole-building energy savings targets in new construction, and where applicable, the 30-50% targets in existing buildings. Technology options or research endeavors that are not integrally related to realization of these goals will no longer be supported.

Within this category, Commercial Integration will manage its work across two elements. The first element will produce a prioritized list of TOS that the subprogram can then execute as part of its Annual Operating Plan. The second element will align the current research portfolio directly to support those priorities.

Prioritized List of Technology Option Sets
The purpose of this annual activity is to produce a rank-ordered list of technology option sets, and then fund top priorities as part of the Annual Operating Plan solicitation to national laboratories and contractors. Commercial Integration will systematically list all possible TOSs applicable to its priority building markets, namely Retail, Office, Institutional and Lodging. This listing will favor inclusion and comprehensiveness over any detailed description of TOS; the purpose is to identify as many candidates as is practicable. Then, the subprogram will actively seek input from the NEAs, National Accounts, and others external to the subprogram. Commercial Integration will synthesize this input, draw insights from relevant analyses and studies[64] and proceed to rank-order the candidates using the following criteria:

[64] Including NREL's Assessment of Opportunities

- Contribution to new construction and existing building savings targets;
- Likelihood of future adoption by Retail Alliance partners in their buildings;
- Amount of research in the area conducted by other; and
- Appropriateness of the BT research role.

After identifying top-priorities, Commercial Integration will issue a call for proposals in these select areas annually to reflect changing technology and market conditions, and to reflect in the status of the national energy alliance cycle.[65] This process differs greatly from the subprogram's past practice in calling for TOS because Commercial Integration is *first* determining priorities, and *then* requiring national laboratories to propose in these priority areas.

Align Current R&D Portfolio with TOS Priorities

Commercial Integration will align the existing portfolio of Integrated Systems Research so that it *directly targets* the TOS prioritizations described above. Integrated Systems Research includes daylighting, integrated building controls, commissioning and O&M, and Ventilation to support good Indoor Environmental Quality (IEQ). The desired outcome from the prioritization will be a prototype TOS that can be tested and validated in real buildings in target building markets. This process of "rationalizing" the current portfolio of research within an operational TOS context will occur in FY08, with Stage-Gating, for the four Integrated Systems Research elements. In the case of IEQ/V, Commercial Integration will draw upon the forthcoming NREL report on Ventilation to inform the discussion.

With the alignment complete, the subprogram's activities in IEQ/V and Daylighting will be "migrated" to a resolute TOS focus by FY09 and its activities in controls and commissioning to similar TOS focus by mid FY10, at the latest. Future areas of research needed to progress beyond 50% are MELs reduction, refrigeration, lighting, thermal insulation, very high SEER/EER AC, High R windows, and Daylighting/passive solar.

Stage – Gate

Commercial Integration uses the Stage-Gate methodology to manage decision-making in the following areas: technology procurement, NEA prioritization decision tools, and others. The Stage-Gate decision for continuation of the technology procurement effort will be made after three rounds. As this is a new approach, Commercial Integration, with the REA, will conduct an evaluation at the end of one year of operation by end of Q1 FY09.

In Q2 of the applicable years, just prior to the launch of new alliances, the subprogram will conduct technical and market analysis to determine two aspects of the NEA. The

[65] A list of TOS for hospitals will be different than for General Merchandise, so the TOSs reflect NEA priorities.

first is to confirm Commercial Integration's priority order for National Energy Alliances, by building type (or sub sector). Second, the subprogram will update its understanding on the feasibility of achieving 50% savings in the selected building type or sub sector. The purpose of this analytical update is to establish BT's "corporate" knowledge of the sub sector and guide discussions with Alliance members.

In FY08, the decision tool for technology packages will be refined to produce a prototype tool by Q1, followed immediately by a Stage-Gate Decision, which shall determine: whether the prototype looks to be a truly promising line of inquiry and deserves further support; whether it is useful (or might prove useful) to Retail Energy Alliance members; and, most critically, whether the process should be repeated for additional building types.

Assuming the resulting gate decision is a "Go," Commercial Integration will produce a "public release" version of the tool in Q2 of FY09, Stage-Gate that release in the next quarter[66], release a revision to the public the following quarter and commence work on a decision tool for offices in Q1 of FY09, and then commission subsequent tools for other building types.

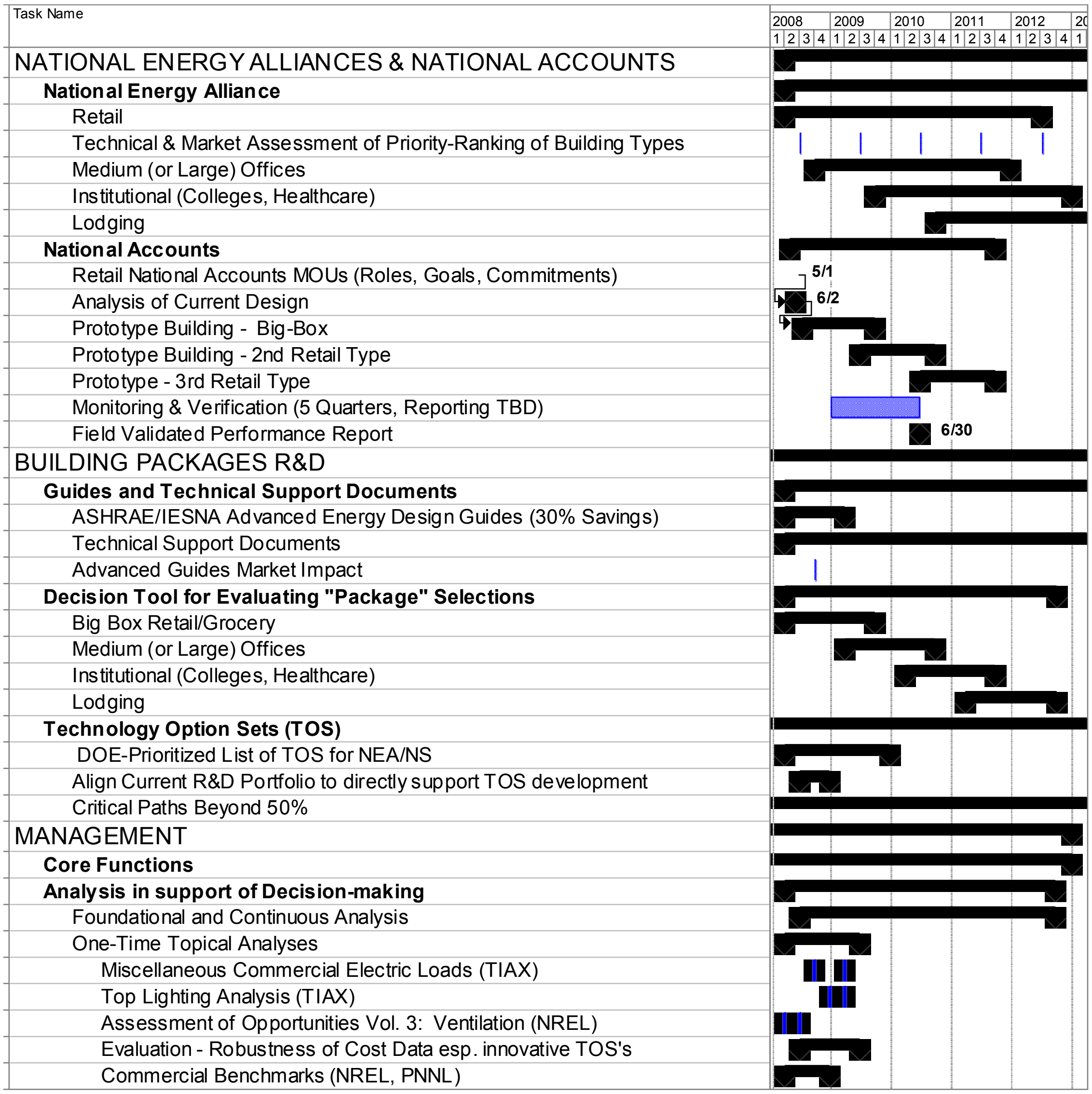
2.2.6 Commercial Integration Milestones and Decision Points

Figure 2-8 identifies Commercial Integration key activities in high performance buildings and integrated systems research. The subprogram will conduct the following assessments to help guide the new program design:

- Technical & Market Assessment of Priority-Ranking of Building Types
- Advanced Energy Design Guides Market Impact
- Tech Pathway Guidance to BT Emerging Tech Sub-Programs on Performance Levels Required for 50% & 70% targets
- Identification of Knowledge Gaps
- One-time topical analysis: MELs, Top Lighting Analysis, Assessment of Opportunities Vol. 3: Ventilation, Evaluation - Robustness of Cost Data (innovative TOS's), and Commercial Benchmarks.

[66] The decisions are: fund the next public release version of the Retail Decision Tool? And, should decision tools for other types by commenced? Decision criteria shall include: determination of whether or not users find the "public release" version useful; determination of the features required to make the next version of greater (or any) value; apparent "market demand" by national accounts for other such tools.

Figure 2-8 Commercial Integration Gantt Chart



2.2.7 Commercial Integration Unaddressed Opportunities

There are several unfunded activities, listed below:

- **Opportunity to launch and manage many energy alliances quickly**. The most important "unaddressed opportunity" will be the slow rate at which national energy alliances can be developed and launched, as well as the degree of technical support provided. Energy alliance development, and national account engagement is proportional to the resources appropriated. Many market sectors will have to remain unaddressed as Commercial Integration will only be able to develop and launch a select number of alliances, staged over time. With greater resources the rate of "launch" can be greatly accelerated and the level of DOE technical support provided to the alliance members will be significantly greater. This, in turn, translates directly into the speed with which DOE can affect buildings' energy performance – especially of new buildings.

- **Plug Loads.** Another important unaddressed opportunity is commercial plug loads. DOE currently has no program in this area – an area whose importance becomes more manifest as higher performance buildings are attempted. This is articulated in recent analysis by NREL.[67]

- **CBECS Sample Size**. EIA's CBECS is a foundational resource for characterizing commercial buildings, but the sample size means that data parsing, by region, type and vintage quickly leads to statistically unreliable estimates of particular data queries. This can seriously hinder BT's understanding of selected market segments. With more resources, BT could enhance the data collection of targeted market segments by increasing the number of survey respondents.

- **Energy Management and Control Strategies**. With the exception of the ongoing work on the BVCTB and the completed work on demand-controlled ventilation, Commercial Integration is doing little in the area of building controls. In several studies over the last few years, the BT role in the area of building sensors and controls has been established as one of developing controls methodologies and strategies that provide optimum building operation but not sensors or equipment.

[67] S. Pless, P. Torcellini, and N. Long. 2007. *Technical Support Document: Development of the Advanced Energy Design Guide for K-12 Schools—30% Energy Savings.* NREL/TP-550-42114. NREL, Golden CO. http://www.nrel.gov/docs/fy07osti/42114.pdf

2.3 Lighting

Table 2-15 Solid-State Lighting Summary

Start date	2001
Target market(s)	Commercial and residential specialty, task and directional lighting applications (e.g., MR16, PAR38) and from 2015-2025, all sectors, general illumination.
Accomplishments to date	• September 2007. Cree, Inc. developed an LED array prototype that delivers 95 lm/W at 350 mA. • September 2007. GE Global Research set a new record for solution-processed white OLED devices, demonstrating a performance greater than 14% peak W/W (overall power conversion efficiency). Further improvements will enable the demonstration of a 45 lm/W illumination-quality OLED that proves near-term technology viability as an incandescent replacement for certain applications. • September 2007. Universal Display Corporation (UDC) fabricated a 6-square-inch OLED panel that produces 100 lumens of light at an efficacy of 31 lm/W and a brightness of 3,000 nits, relatively brighter than todays fluorescent lamps. • June 2007. Eastman Kodak developed a new device architecture for white OLED devices that demonstrates an extraction efficiency of 46%, a tremendous improvement over previous devices. • *September 2006:* CREE Inc. released new EZBright™ power chip for general lighting applications. The new blue power chip delivers up to 370mW at 350mA drive current, and up to 800mW at 1A. • *July 2006*: CREE demonstrated a cool white LED array prototype with luminous efficacy of 79 lm/W, exceeding the DOE FY06 Joule target. CREE's prototype uses an array of several high-power, large-area chips to produce sufficient light for practical application in the general illumination market. • *August 2006*: As a result of the improved light extraction, Universal Display Corporation (UDC) achieved a new record external quantum efficiency of 30 percent for a white OLED device. Operating at 850 nits, this white OLED was able to obtain efficacy values of 30 lm/W with a CRI of 70. • *2006*: Scientists at Pacific Northwest National Laboratory (PNNL) have created a blue OLED device with external quantum efficiency of 11 percent at 800 nits, previously

	exceeding their record blue EQE of 5 percent. This breakthrough will enable an entire new class of improved efficiency OLED devices appropriate for SSL. • *2006*: University of California, Santa Barbara (UCSB), achieved a record brightness of 25,000 nits in a solution fabricated blue-green OLED capable of operation at increased current densities. This achievement is the highest ever reported for this approach at producing a blue emitting device.
Current activities	**LEDs** *Core Technology & Product Development:* 1. Large-area substrates, buffer layers, and wafer research 2. High-efficiency materials 3. Device approaches, structures, and systems 4. Design and development of modeling & diagnostic tools 5. Encapsulants and packaging materials 6. Research into low-cost, high efficiency reactor designs and manufacturing methods 7. Electronics development 8. Implementing strategies for improved light extraction and manipulation **OLEDs** *Core Technology Product Development:* 1. Improved OLED materials 2. Improved contact materials and surface modification techniques 3. Strategies for improved light extraction and manipulation 4. Approaches to OLED structures between the electrodes 5. Cost reduction techniques and tools 6. Develop architectures that improve device robustness increase lifetime and increase efficiency *Lighting Commercialization:* 7. Development of ENERGY STAR SSL Specifications 8. Design competitions for SSL 9. Market transformation, consumer and business awareness, & technology procurement programs 10. Technical information resources – Test Procedures
Future directions	• Continue to drive development of more energy-efficient, white-light SSL sources through research in both inorganic and organic technologies by working both in the core technology and product development arenas. • Initial emphasis on core technology to accelerate development of more robust, energy-efficient SSL devices; later, emphasize

	product development activities, to improve manufacturing capabilities, reduce costs and encourage market penetration • Hold annual meetings with the SSL community to solicit input on the prioritization of the Lighting R&D portfolio
Projected end date(s)	The projected end-date is 2025 when the program achieves 50% reduction in electricity use of SSL luminaries compared to 2005.
Expected technology commercialization dates	**LEDs** *2008:* General illumination commercial product with efficacy of 80 lm/W, an OEM price of \$25/klm (lamp only), and a life of 50,000 hrs with a CRI greater than 80 and a CCT less than 5000°K. *2010:* Cool white device at greater than 140 lm/W and warm white greater than 90 lm/W. 2012: Luminaire at least 120 lm/W emitting ~1000 lumens *2015:* Commercial product available at less then \$2/klm. **OLEDs** *2008:* Niche product with an efficacy of 25 lm/W, an OEM price of \$100/klm (lamp only), and a life of 5,000 hrs. CRI should be greater than 80 and the CCT should be between 3,000-4,000°K. *2010:* Product cost of less than \$70/klm. *2015:* Product greater than 100 lm/W and a life of 40,000 hrs.

DOE initiated its work in solid-state lighting (SSL) research and development in 2000. In this short time frame, DOE researchers have made considerable progress working with partners such as industry leaders, research institutions, universities, trade associations, and national laboratories. The lighting subprogram focuses on Light Emitting Diodes (LED) and Organic Light Emitting Diodes (OLED), measuring performance in terms of color rendering index (CRI), correlated color temperature (CCT) and product lifetime.

For solid-state lighting technologies, another performance target focuses on the energy efficiency rating of the device. The unit of performance commonly used when discussing light sources and systems is lumens of light produced per Watt of energy consumed. The technical term for this metric is 'efficacy' measured in lumens per Watt. Several lighting products, including fluorescent lamps and incandescent reflector lamps, are regulated using an efficacy target.

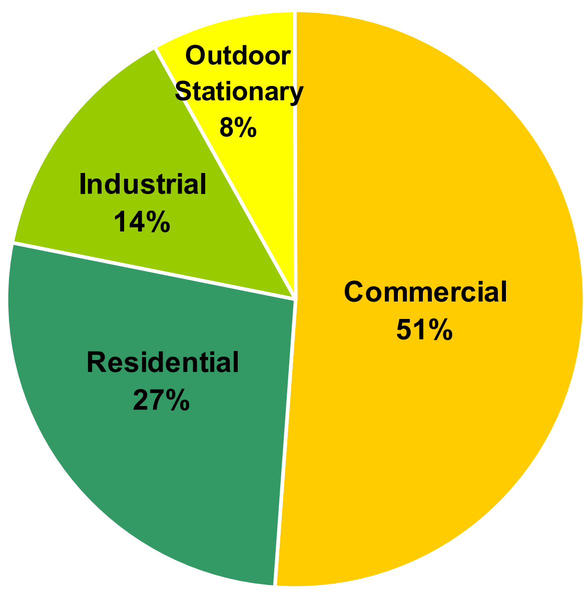
2.3.1 Lighting Support of Program Strategic Goals

Energy consumption for lighting in buildings in the U.S. is approximately 7 quads, or about 18 percent of the total energy consumed by the building sector.[68] Nationally, total

[68] BED

energy use in commercial and residential buildings was approximately 39.7 quads, of which electricity use was approximately 28.6 quads.[69] Thus, in these residential and commercial building sectors, lighting constituted approximately 18 percent of total building energy consumption, or approximately 24 percent of total building electricity use. On a national basis, Figure 2-9 provides a break-down by building sector of the energy consumption for lighting homes, offices and other metered applications around the country. The figure shows that just over 4 quads were consumed in 2001 in the commercial sector, the largest energy user for lighting. As lighting contributes to a building's internal heat generation and subsequent air-conditioning loads at peak times, BT has targeted to develop more efficient lighting technologies specifically in the commercial sector.

Figure 2-9 National Lighting Energy Consumption by Sector[70]



Lighting constitutes approximately 12 percent of residential building energy consumption and 25 percent of commercial building energy consumption. This electricity consumption figure does not include the additional loads due to the heat generated by lighting, which is estimated to be up to 40 percent in a typical "stock" building. Further technology and cost improvements and market acceptance of SSL technologies will

[69] BED
[70] EERE: Lighting Research and Development. http://www.eere.energy.gov/buildings/tech/lighting/

dramatically reduce lighting energy consumption, and thereby the total energy consumption, of residential and commercial buildings by 2025.[71]

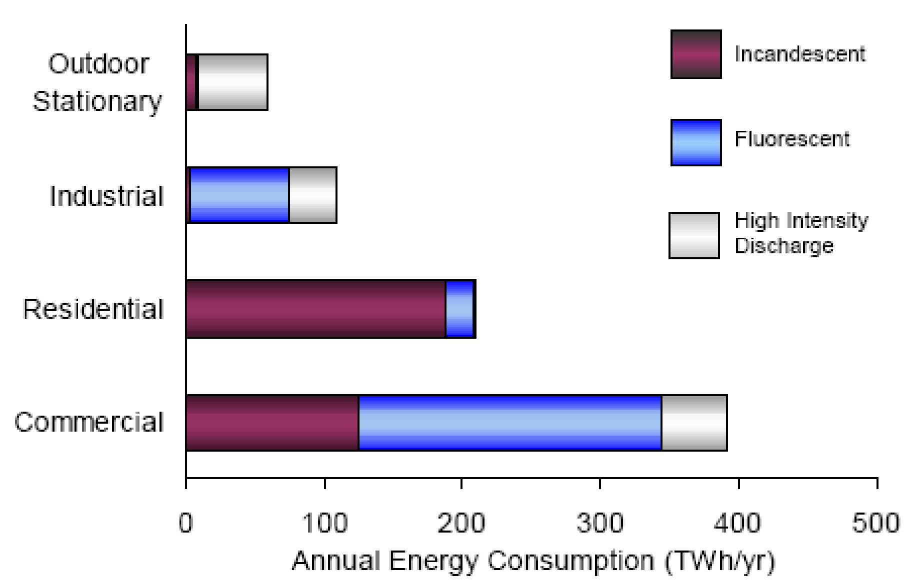
Figure 2-10 illustrates the breakdown by sector of national energy consumption for lighting in units of site electricity consumption (terawatt-hours/year), disaggregated by source type. These units represent the electrical energy consumed on-site for lighting throughout the United States. The figure shows that fluorescent sources in the commercial sector are the single largest lighting energy-consuming segment in the U.S., slightly greater than incandescent lamps in the residential sector. However, across all sectors, incandescent is the leading electricity consumer in the U.S. consuming 321 terawatt-hours per year (TWh/yr) in 2001. Fluorescent lighting is a close second with approximately 313 TWh/yr and HID is third with approximately 130 TWh/yr.[72]

This comparison examines the replacement not of incandescent technologies (although these are in use in 2005), but of more efficient fluorescent sources, which were identified as the largest single user of electricity for lighting in commercial buildings. Linear fluorescent lamps operating in a system (including ballast and fixture losses) can offer efficacies as high as 83 lumens per Watt luminaire efficacy. Compact fluorescent lamps, a derivative of this technology, are less efficient (approximately 60 lumens per Watt source efficacy); however, they still offer a four-fold improvement over incandescent at 14 lumens per Watt.

[71] 2006 Building Energy Data Book, U.S. Department of Energy, Office of Planning, Budget and Analysis, Energy Efficiency and Renewable Energy. Prepared by D&R International, Ltd., September 2006. Hereafter, BED.

[72] U.S. Lighting Market Characterization Volume I: National Lighting Inventory and Energy Consumption Estimate. Prepared by Navigant Consulting, Inc. for the Department of Energy. Washington D.C. September 2002.

Figure 2-10 National Lighting Site Electricity Consumption by Sector & Source[73]



The goal of BT lighting research and development is to increase end-use efficiency in buildings by aggressively researching new and evolving lighting technologies. Working in close collaboration with partners, DOE aims to develop technologies that have the potential to significantly reduce energy consumption for lighting.

2.3.2 Lighting Support of Program Performance Goals

In order to develop technologies with the technical potential to reduce energy consumption by 50 percent over 2005 technologies, SSL will need to increase its efficacy to more than 160 lumens per Watt. Typical fluorescent luminaries today operate at approximately 80 lumens per Watt, and incandescent systems (depending on the fixture) can range from 5 to 25 lumens per Watt. Thus, the strategy of improving the efficacy of SSL will result in considerable life-cycle cost benefit to consumers, once the technology is available and commercialized. A projection of the performance of SSL devices was created in consultation with the NGLIA Technical Committee, a team of solid-state lighting experts, assuming a "reasonable" level of funding by both government and private industry; it anticipates that SSL will exceed 160 lumens per Watt (SSL device). Although the overall Lighting subprogram may be expected to continue until 2025 in order to achieve technologies capable of full market penetration, forecasts in this section only project performance to 2015.

2.3.2.1 Light Emitting Diodes

The following performance goals are *exclusive* of the driver and fixture. Thus, the goals

---

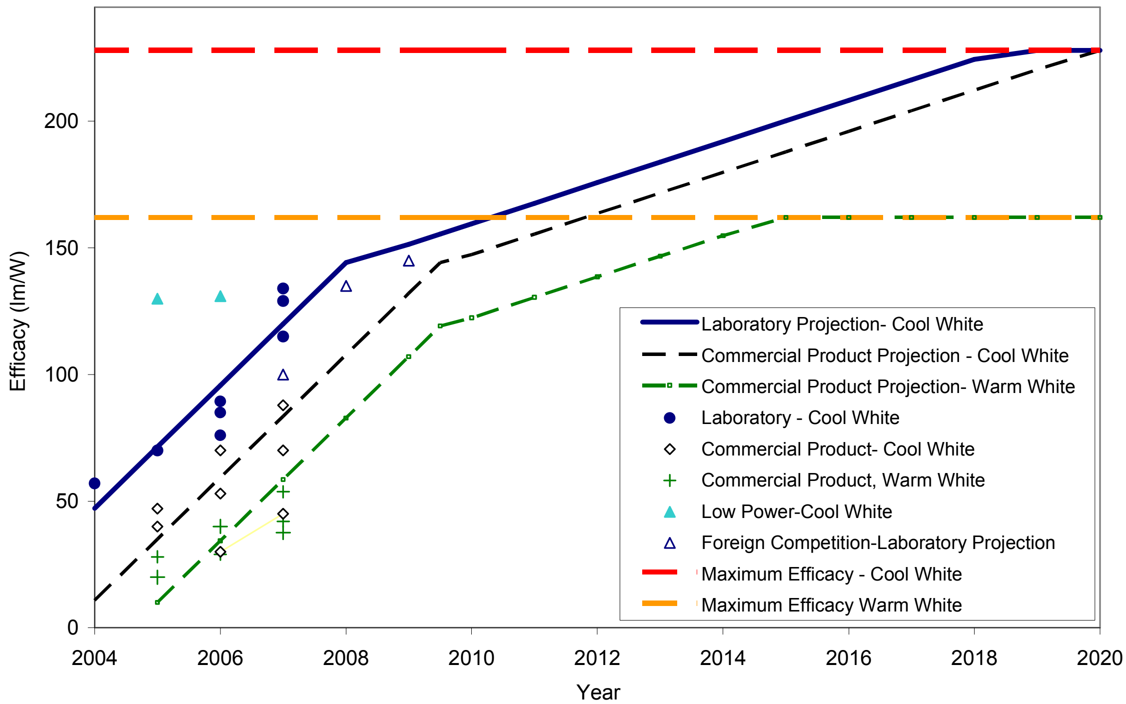
[73] http://www.eere.energy.gov/buildings/tech/lighting/

do not entirely capture the objectives of the Lighting subprogram which relate to *luminaire* efficiency or cost. Reaching these ultimate objectives will take longer than may be inferred from these graphs of device performance, but it is not anticipated that it will be difficult to achieve acceptable driver performance (although there are some challenges). On the other hand, innovative fixtures for LEDs can have a significant impact on overall efficiency, and the challenge in this area is to accommodate aesthetic and marketing considerations while preserving the energy saving advantages.

The price and performance of white LED devices are projected using cool white as a reference point based on currently available commercial LED products. Future improvements will ideally include warmer light at similar efficiencies, but such developments may occur later in the Lighting subprogram, beyond the forecast period. As there is typically a lag of one to two years between laboratory demonstrations and commercialization, two projection estimates are shown, one for laboratory prototype LEDs, and one for commercially available LEDs.

Figure 2-11 shows *device* efficacy improving linearly through 2015 (driver/fixture are excluded). These projections assume a prototype with a "reasonable" lamp life, and the efficacy for laboratory prototypes reaches 186 lm/W in 2015. A number of actual reported results are plotted on the curve as well, although these specific examples may not meet all of the criteria specified

Figure 2-11 White Light LED Device Efficacy Targets, Laboratory and Commercial[74]



Note:
1. Cool white efficacy projections assume CRI=70 → 80, CCT = 4100-6500°K,
2. Warm white efficacy projections assume CRI>85, CCT =2800-3500°K
3. All projections are for high-power diodes with a 350 ma drive current at 25°C, 1mm^2 chip size, device-level specification only (driver/luminaire not included), and reasonable device life.
4. Low power diodes shown have a 20 mA drive current.
5. The maximum efficacy values for warm white (3000K and 90 CRI) and cool white (6500K and 75 CRI) are shown above as asymptotes. The target efficiency assumes a CRI of 90 and a CCT of 4100K and would lie in between these two extremes.

The performance projection is translated into point values in Table 2-16 where cost and lifetime targets are also presented. The cost estimates were developed in consultation with the NGLIA Technical Committee, and represent the average cost of 1-3 watt white-light LED devices driven at 350ma (exclusive of driver or fixture costs). The projected original equipment manufacturer (OEM) lamp price, assuming the purchase of "reasonable volumes" (i.e., several thousand) and good market acceptance, is also shown. The price decreases exponentially from approximately $25/klm in 2006 to $2/klm in 2015. Recent price reduction announcements confirm the trend in the near-term.

[74] NGLIA LED Technical Committee and the Department of Energy, Fall 2007 and Press Releases

The device life, measured to 70 percent, lumen maintenance, has increased steadily over the past few years and appears to be currently at its target of 50,000 hours. An average lamp life of 50,000 hours would allow LED devices to last approximately twice as long as conventional linear fluorescent lighting products, five times longer than compact fluorescent lamps, and fifty times longer than incandescent lamps.

Table 2-16 Summary of LED Device Performance Projections[75]

Metric	Units	2007	2010	2012	2015
Efficacy - Lab	(lm/W)	120	160	176	200
Efficacy – Commercial, Cool White	(lm/W)	84	147	164	188
Efficacy – Commercial, Warm White	(lm/W)	59	122	139	163
OEM Lamp Price- Product	($/klm)	25	10	5	2

Note:
1. Efficacy projections for cool white devices assume CRI=70 → 80 and a CCT = 4100-6500°K, while efficacy projections for warm white devices assume CRI= >85 and a CCT of 2800-3500°K. All efficacy projections assume that devices are measured at 25°C.
2. All devices are assumed to have a 350 mA drive current, 1mm^2 chip size, device-level specification only (driver/fixture not included), and lifetime as stated in table.
3. Price targets assume "reasonable volumes" (several 1000s), CRI=70 → 80, Color temperature = 4100-6500K, and device-level specification only (driver/luminaire not included)
4. Device life is approximately 50,000 hrs, assuming 70% lumen maintenance, "1 Watt device," 350 mA drive current.

Although the subprogram is planned past 2015, it is difficult to make projections further into the future. Additional improvements are anticipated for future years, so a rough estimate of progress towards future higher CRI, lower CCT lamps (still excluding other system components) is also indicated in the figure. These projections will be revised as the Lighting R&D program progresses, and technological breakthroughs are realized.

2.3.2.2 Organic Light Emitting Diodes

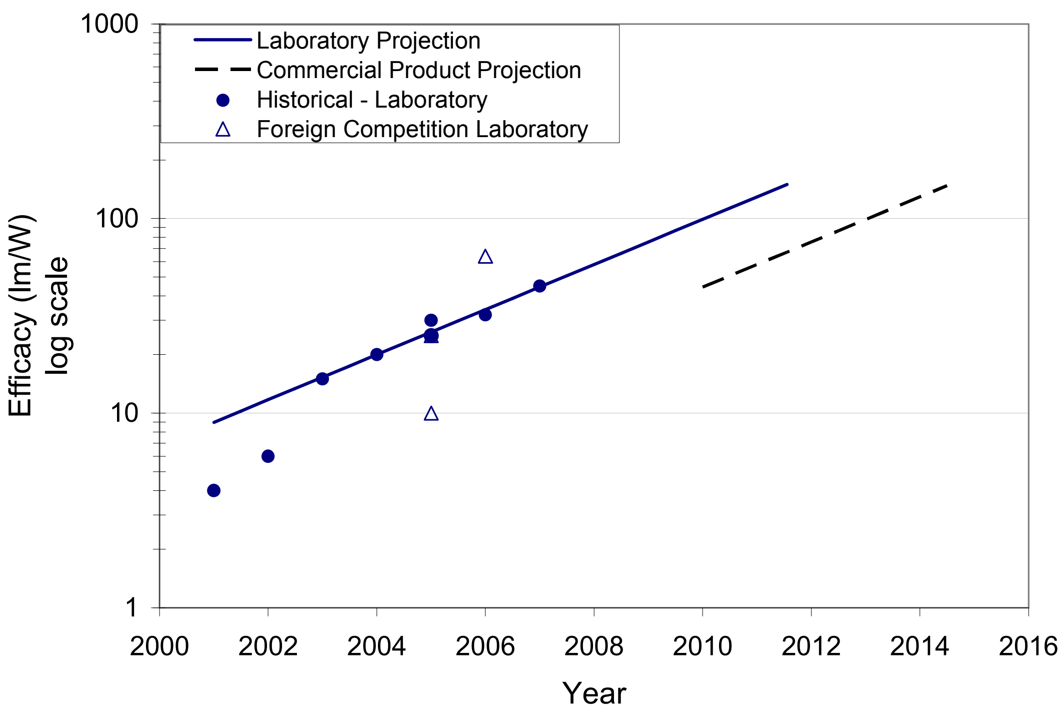
In consultation with the NGLIA Technical Committee for general illumination, BT developed price and performance projections for white light OLED devices operating at a CCT of between 3000-6000 K and a CRI of 80 or higher. Two projection estimates were prepared, one for laboratory prototype OLEDs, and one for (future) commercially available OLEDs.

Figure 2-12 (plotted on a logarithmic scale) shows the efficacy for laboratory prototypes

[75] NGLIA LED Technical Committee, Fall 2007

growing exponentially to exceed 150 lm/W by 2012. As there are not yet any commercial OLED lighting products, the estimated efficacies for commercial products are not meaningful until 2009 and lag approximately three yearse behind current laboratory products. A number of actual reported results are plotted on the curve as well, although these specific examples may not meet all of the specified criteria.

Figure 2-12 White Light OLED Device Efficacy Targets, Laboratory and Commercial (On a logarithmic scale)[76]



Note: Efficacy projections assume CRI > 80, CCT = 2700-4100°K ("near" blackbody curve (Δc_{xy} <0.01), lifetime > 1000 hrs, luminance of 1,000 cd/m^2, total output ≥ 500 lm, and device level specification only (driver/luminaire not included)

Today, the efficacy of OLED devices lags behind LED devices, both in the laboratory and in the market. However, when the projections of commercial LEDs and OLEDs are compared, the efficacy of OLED products is expected to experience exponential improvement, enabling it to approach that of the LED products in the latter part of the current forecast.

Point values from the projection of efficacy improvement of OLEDs are provided in Table 2-17; cost and lifetime targets are also presented. The table displays the projected

[76] Projections: NGLIA OLED Technical Committee, Fall 2007, Laboratory Points: Press Releases

OEM price of commercially available white-light OLED devices (driver and fixture not included) for a luminance of 1,000 cd/m^2. The OEM lamp price decreases exponentially from an estimated $72/klm in 2009 to $10/klm by 2015, assuming reasonable volumes of tens of thousands. The OEM lamp price, measured in $/m^2 is approximately a factor of three greater than OLED device price when measured in $/klm for the assumed luminance.

The lamp life for commercial products is measured to 70 percent lumen maintenance. Although 50% lumen maintenance is industry practice for evaluation of OLED displays, we use 70% lumen maintenance in order to compare lifetimes with other lighting products. The lifetime increases linearly to a value of approximately 40,000 hours in 2015. Lifetime projections below represent the lifetime of the device, not the entire luminaire. Because, the driver may limit the lifetime of the OLED luminaire, improving the lifetime of the driver to that of the OLED device is a goal of the SSL program.

Table 2-17 Summary of OLED Device Performance Projections[77]

Metric	Units	2007	2009	2012	2015
Efficacy - Lab	(lm/W)	44	76	150	150
Efficacy - Commercial	(lm/W)	N/A	34	76	150
OEM Device Price	($/klm)	N/A	72	27	10
OEM Device Price	($/m^2)	N/A	216	80	30
Device Life- Commercial Product	(1000 hours)	N/A	11	25	40

Note: 1. Efficacy projections assume CRI = 80, CCT = 2700-4100°K ("near" blackbody curve (Δc_{xy}<0.01), luminance of 1,000 cd/m^2, total output ≥ 500 lm, and device level specification only (driver/luminaire not included)
2. OEM Price projections assume CRI = 80, luminance of 1,000 cd/m^2, total output ≥ 500 lm, and device level specification only (driver/luminaire not included)
3. Device life projections assume CRI = 80, 70% lumen maintenance, luminance of 1,000 cd/m^2, and total output ≥ 500 lm.

2.3.3 Lighting Market Challenges and Barriers

In recent years, LEDs have entered the lighting market, offering consumers performance and features exceeding those of traditional lighting technologies. While SSL sources are just starting to compete for market share in general illumination applications, recent technical advances have made LEDs cost-effective in many colored-light niche applications. LED technology is capturing these new applications because it offers a

[77] NGLIA OLED Technical Committee, Fall 2007

better quality, cost-effective lighting service compared to less efficient conventional light sources such as incandescent or neon. In addition to energy savings, LEDs offer longer operating life (>50,000 hours), lower operating costs, improved durability, compact size and faster on-time. However, market penetration is limited to specific applications such as traffic signs, holiday lights, commercial signage and others. As LED technology advances–reducing costs and improving efficiency– LEDs will build market share in these and other niche markets.

Table 2-18 Lighting Market (Non-Technical) Barriers

Barrier	Title	Description
A	Market Demand	Only niche markets are currently utilizing SSL technologies, but wider commercial acceptance is necessary for SSL to succeed. LED luminaires are reaching reasonable total lumen output levels although many still perceive LEDs as offering only “dim” light, a significant market barrier.
B	Technical Information and Design Selection Guidance	Buyers need to product purchasing guidance to select products that perform well, and lighting designers need critical new technology application information. Objective, widely available technical information from a credible, respected source is required to help fill information gaps and clear up widespread misunderstanding of the technology, its attributes, and its limitations.
C	Objective Test Results and Industry Standards	Independent performance test results on commercially available products are needed to overcome widespread confusion on actual product performance. Industry standards and test procedures for SSL general illumination products enable basic market infrastructure, which is currently lacking.

2.3.4 Lighting Technical (Non-Market) Challenges/Barriers

There are six technical barriers which the Lighting subprogram is working to address, as shown in Table 2-19.

Table 2-19 Lighting Technical Barriers

Barrier	Title	Description
D	Luminous Efficacy	Although the luminous efficacy of LED luminaires has surpassed that of the incandescent lamps, improvement is still needed to compete with other conventional lighting solutions. While laboratory experiments demonstrate that OLED devices can be competitively efficacious as compared to conventional technologies, no products are yet available.
E	Quantum Efficiency	Quantum efficiency represents the capability of SSL devices to convert electrons into photons The internal quantum efficiency assesses a material's ability to convert electron-hole pairs into photon emissions, and the external quantum efficiency measures the amount of light that leaves the semiconductor device becoming available for collection and use. Increasing both quantum efficiencies is possible through a combination of materials research, photometric modeling and other techniques.
F	Lifetime	The lifetime target for the LED device has apparently been achieved; however, it is unclear whether this same lifetime target has been achieved by the LED luminaire. Potential premature failure due to high temperature operation remains a barrier to general deployment. OLED lifetimes for both devices and luminaires still require improvement.
G	Stability	Stability and control activities address the quality and stability of the white-light emission over time, which requires improvement. Basic material properties and semiconductor physics directly impact photon wavelength, emission bandwidth and ultimately, light color.
H	Packaging and Manufacturing	The first products to enter the market will have to meet high quality standards and appeal to consumers' aesthetic. While OLEDs have been built off of display manufacturing capabilities, there has been little investment by manufacturers in the infrastructure needed to develop commercial OLED lighting products. Lack of process uniformity is an important issue for LEDs and is a barrier to reduced costs as well as a problem for uniform quality of light.

I	Infrastructure	Infrastructure pertains to the installation, maintenance and supporting systems (power conversion) of SSL products. Fixtures and other unique features such as color shifting and dimming controls will require innovation as well as infrastructure development. This research activity also includes health and safety issues, information dissemination and training.
J	Cost Reduction	High first costs of lighting products extend payback periods and reduce the market penetration potential of new technologies. Lowering the cost of highly efficient SSL sources is also necessary to achieve significant energy savings. Cost reduction activities concentrate on materials, methods and techniques to reduce light production costs through the aggressive development of suitable manufacturing and production technologies.

2.3.5 Lighting Approach/Strategies for Overcoming Barriers/Challenges

Currently, the Lighting subprogram focuses both on barriers associated with technical issues as well as market barriers. In order to promote SSL as an efficient lighting product, the Lighting subprogram plans to develop an ENERGY STAR designation for SSL products. Because the ENERGY STAR program has successfully increased the sale of its labeled products by educating consumers of the energy savings associated with that product, it is expected that labeling SSL products as ENERGY STAR will help overcome some of the initial market barriers.

The Lighting subprogram is also engaged in developing product testing and industry standards. Developing testing standards will help provide objective, comparative, performance information about LEDs. This information can then be used to support R&D planning, the ENERGY STAR program, and technology procurement programs that will link SSL manufacturers with high-volume buyers. The testing program will also be used to discourage low quality products, thus preventing buyer dissatisfaction. In March 2006, the Lighting subprogram hosted an LED workshop to promote cooperation among major standards organizations. Helping further coordinate the development of a cohesive set of standards will promote the entry of quality SSL products into the marketplace.

Currently, the subprogram also includes developing design competitions for lighting fixtures and systems using SSL products, coordinating with utility promotions and energy efficiency groups, promoting consumer and buyer awareness programs, and providing information resources for lighting design professionals and students. Taken together, all of these market transformation activities will help accelerate the market adoption of energy-efficient and cost-effective SSL products.

In order to overcome technical barriers, the Lighting subprogram structures its projects into a two-by-two matrix, creating four R&D areas: LED Core Technology, LED Product Development, OLED Core Technology and OLED Product Development. Within each of these areas, there are active, detailed R&D agendas which work towards the larger programmatic objective.

Core Technology

Core Technology research encompasses scientific efforts that focus on comprehensive knowledge or understanding of the subject under study, with possible multiple applications or fields of use in mind. Within Core Technology research areas, scientific principles are demonstrated, technical pathways to solid-state lighting (SSL) applications are identified, and price or performance advantages over previously available science/engineering are evaluated. Tasks in Core Technology fill technology gaps, provide enabling knowledge or data, and represent a significant advancement in the SSL knowledge base. Core Technology research focuses on gaining pre-competitive knowledge for future application to products by other organizations. Therefore, the findings are generally made available to the community at large.

Product Development

Product Development involves using basic and applied research (including Core Technology research) for the development of commercially viable SSL materials, devices, or systems. Activities typically include evaluation of new products through market and fiscal studies, with fully defined price, efficacy, and other performance parameters necessary for success of the proposed product. Laboratory performance testing on prototypes to evaluate product utility, market, legal, health, and safety issues as well as feedback from the owner/operator and technical data gathered from testing are used to improve prototype designs. Product Development encompasses the technical activities of product concept modeling through to the development of test models and field ready prototypes. This area can also include “focused-short-term” applied research, but its relevance to a specific product must be clearly identified.

All Product Development activities are focused on one or more target applications with known cost and performance attributes from which estimates of market share and energy savings potential can be made. Along with the technical aspects of a project, market and fiscal studies are completed to ensure a successful transition from product development to commercialization. To be positioned for success, new products must exhibit cost and/or performance advantages over commercially available technologies. A summary of the strategies used to overcome barriers encountered in reaching specific SSL performance targets are listed in Table 2-20.

Table 2-20 Lighting Strategies for Overcoming Barriers/Challenges

Barrier	Barrier	Strategy
A	Market Demand	Develop design competitions for lighting fixtures and systems using SSL products, coordinate with utility promotions and energy efficiency groups, promote consumer and buyer awareness programs, and utilize Energy Star labeling.
B	Technical Information and Design Selection Guidance	Provide technical information resources on SSL technology issues for consumers, lighting design professionals, and students.
C	Objective Test Results and Industry Standards	Test commercially available SSL products for general illumination. Encourage development of metrics, codes, and standards.
D	Luminous Efficacy	Work to concurrently meet efficacy targets and other performance criteria in a single product.
E	Quantum Efficiency	Produce and extract photons from devices with minimum heat production.
F	Lifetime	Understand degradation & failure mechanisms to extend practical lifetimes of devices to make them as life cycle cost beneficial as possible. Advance scientific understanding of the role of impurities, defects, crystal structure and other factors closely related to materials systems choices.
G	Stability	Improve basic material properties & processes that impact the color & control of the light emitted from the devices.
H	Packaging and Manufacturing	Design devices into practical packages that satisfy marketing and manufacturing goals, UV tolerance and seal out water and oxygen contamination of the products. Focus on SSL device packages that seal out moisture and oxygen, manage heat transfer, and protect optical material from UV degradation.
I	Infrastructure	Examine the marketing, sales, installation and support associated with the introduction of new solid-state light sources and fixtures.
J	Cost Reduction	Reduce the production costs to enable manufacturers to compete with existing, inefficient light sources including fluorescent.

The Lighting subprogram has twenty specific tasks to address the seven barriers (Table 2-21).

Table 2-21 Lighting Research and Development Tasks[78]

Task			Title	Duration*	Barriers
LED	Core Technology	1	High-efficiency semiconductor materials	2008-2018	B, C, D, E, H
		2	Phosphors and conversion materials	2008-2018	B, D, E, H
		3	Encapsulants and packaging materials	2008-2018	A, D,E, F H
		4	Inorganic growth and fabrication processes and manufacturing research.	2008-2013	B, D, E, H
	Product Development	5	Optical coupling and modeling	2008-2013	D, E, F, H
		6	Manufactured materials	2008-2011	D, E, F
		7	LED packages and packaging materials	2008-2016	A, D, E, F, G, H
		8	Electronics development	2008-2016	F, G
		9	Thermal design	2008-2014	F, G
		10	Evaluate luminaire lifetime and performance characteristics	2008-2016	B, F
		11	Power Electronics Development	2008-2016	D, E, F, J
OLED	Core Technology	12	Novel materials and device architectures.	2008-2016	F, G, H
		13	Novel strategies for improved light extraction	2008-2016	D, E, G
		14	Low-cost encapsulation and packaging technology	2008-2011	C, F, H, J
		15	Research on low-cost transparent electrodes	2008-2016	B, H
		16	Investigation (theoretical and experimental) of low-cost fabrication and patterning techniques and tools	2008-2010	H, J
	Product Development	17	Practical implementation of materials and device architectures.	2008-2011	D, E, F, G
		18	Module and process optimization and manufacturing	2008-2015	H, J
		19	OLED encapsulation packaging for lighting applications	2008-2013	C, F, H
		20	Practical application of light extraction technology.	2008-2009	A, D, E, H, J
		21	Low-cost substrates	2008-2016	G, H, J

*Note: Some tasks have been completed for Milestones 1-4, but early work is required in order to meet future projections. See Table 2-22 Table 2-23 for projections.

[78] For a complete list of tasks, see the Solid-State Lighting MYP, March 2008.

A stage-gate system[79], tailored to the SSL subprogram, is applied to each project in the portfolio, and creates a lexicon for discussion, decisions, and planning which ensures a project meets the criteria at each gate before it advances to the next stage. By constructing this type of framework, the Department and its contractors will be properly reviewing the R&D projects and asking the right questions to lead to successful commercialization of energy-saving products. The stage-gate system also offers management an opportunity to terminate poorly performing projects and allocate resources to better projects.

2.3.6 Lighting Milestones and Decision Points

To provide some concrete measures of progress for the overall BT Program, the committee identified several milestones that will mark progress over the next ten years. These milestones are not exclusive of the progress graphs shown earlier. Rather, they are "highlighted" targets that reflect significant gains in performance. Where only one metric is targeted in a milestone description, it is assumed that progress on the others is proceeding, but the task priorities are chosen to emphasize the identified milestone.

2.3.6.1 Light Emitting Diodes

Product milestones for LEDs are listed in Table 2-22. The interim (FY08) LED milestone reflects a goal of producing an LED product with sufficient performance to be a good general illumination product and it could achieve significant market penetration. These goals have been met individually. In fact, some commercial products have achieved device efficacies greater than 100 lm/W. However, all of the milestone targets have not been met concurrently in a single product. For example, a commercial LED, which has an efficacy of 80 lm/W, is currently priced much higher than $25/klm.

FY10 and FY15 milestones represent efficacy or price targets of LEDs devices with a lifetime of 70,000 hrs. Although all milestones in FY08 were not met concurrently, it is expected that the FY10, interim goal of 140 lm/W for a commercial device will be exceeded. Other parameters will also progress, but the task priorities are set by the goal of reaching this particular mark. A new luminaire milestone has also been included in this update: By FY12, DOE expects to see a high efficiency luminaire on the market that has the equivalent lumen output of a 75W incandescent bulb and an efficiency of 126 lm/W. Finally, by FY15, costs should be below $2/klm for LED devices while also meeting other performance goals.

---

[79] Robert Cooper, "Winning at New Products, Accelerating the Process from Idea to Launch." 3rd Edition. 2001.

Table 2-22 LED Product Milestones

Milestone	Year	Milestone Target
Milestone 1	FY08	80 lm/W, < $25/klm, 50,000 hrs device
Milestone 2	FY10	> 140 lm/W cool white device; >90 lm/W warm white device
Milestone 3	FY12	126 lm/W luminaire that emits ~1000 lumens
Milestone 4	FY15	< $2/klm device

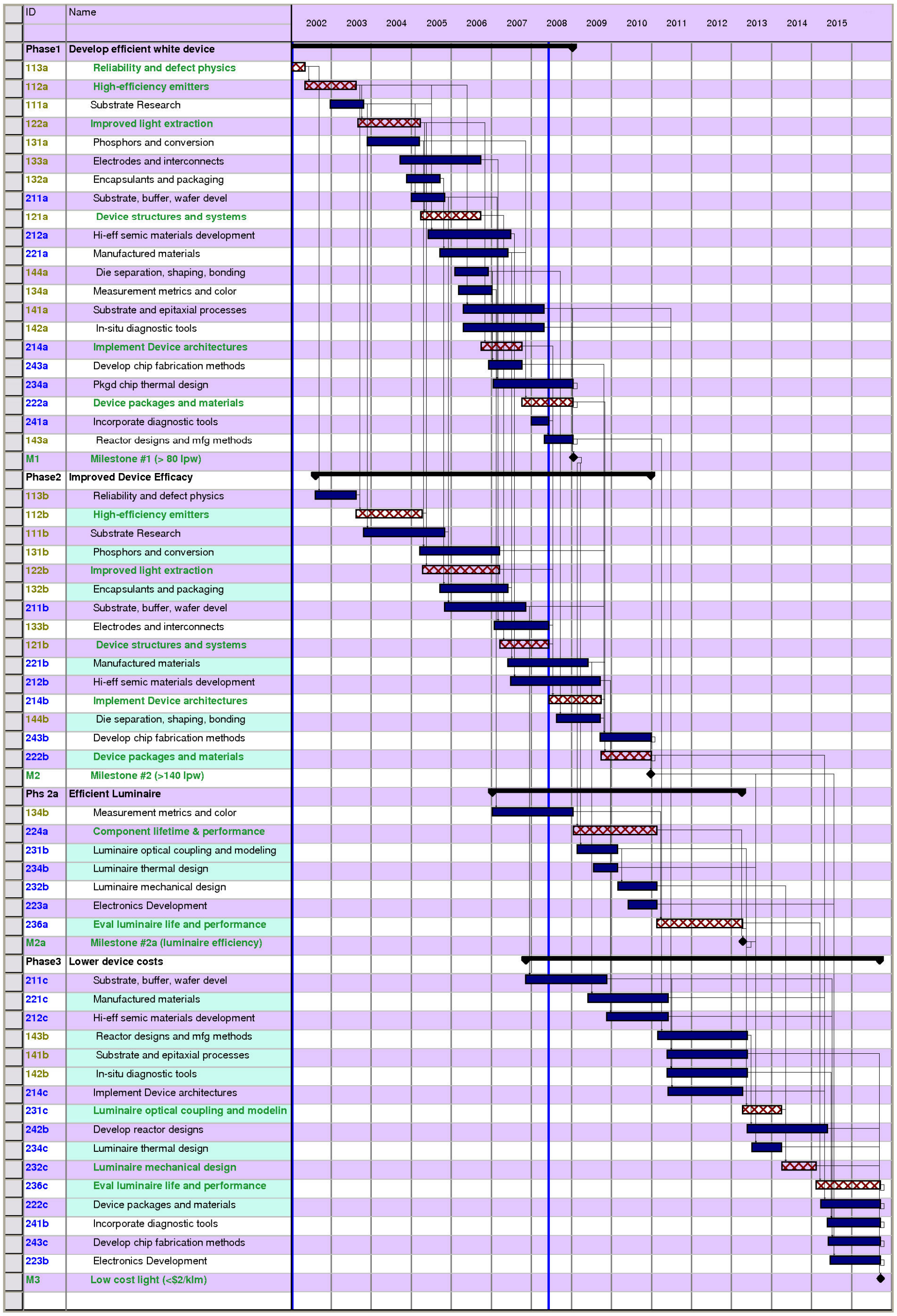
Assumption: CRI > 80, CCT < 5000°K, $T_j = 125^oC$

LED subtasks are shown in Figure 2-13 for four phases of development corresponding to the four milestones. The first phase, essentially complete, is to develop a reasonably efficient white LED device, sufficient to enter the lighting market. Phase 2 is to further improve that efficiency in order to realize the best possible energy savings. This phase should be completed in about two years. Developing a more efficient luminaire is the thrust of Phase 3, expected to last until about 2012. Finally, the fourth phase is to significantly reduce the cost of LED lighting to the point where it is competitive across the board. This phase, currently underway, is expected to continue past 2015.

The bars on the Gantt chart indicate an estimated time period for execution of the task in question, while the connecting lines show the interdependence of tasks. The duration of the task depends to some extent on the amount of resources allocated. As a deeper understanding of each task is developed, duration estimates can be refined and varied according to the applied resources. The letters next to the task numbers (a,b,c) identify phases of the tasks. These phases are not to be confused with the overall program phases (1, 2, 3). Further task phases and program phases will be identified as the program moves past 2015 so that the full potential of solid state lighting can be realized.

Using these estimates of duration and task dependencies, one can identify critical paths to success. Those tasks on the critical path are shown with hashed bars. Tasks identified by the NGLIA/DOE team as high priority have shaded task names. For reasons noted above, the two do not necessarily coincide.

Figure 2-13 Planned Research Tasks – LEDs[80]



80 NGLIA LED Technical Committee, reformatted for SSL MYP.

2.3.6.2 Organic Light Emitting Diodes

As with the LED program, milestones are identified and tasks are linked for OLED development. The OLED milestones have similar character to the LED milestones, but given the early state of OLEDs in lighting, the targets are somewhat more speculative (Table 2-23). They do serve the same purpose, however, which is to focus effort on specific interim goals in order to assure overall progress on the Lighting subprogram.

The FY08 OLED milestone is to produce an OLED niche product with an efficacy of 25 lm/W, an OEM price of $100/klm (device only), and a life of 5,000 hrs. CRI should be greater than 80 and the CCT should be between 3,000-4,000K. A luminance of 1000 cd/m^2 and a lumen output greater than 500 lumens should be assumed as a reference level in order to compare the accomplishments of different researchers. That is *not* to say that lighting products may not be designed at higher luminance or higher light output levels.

Although current laboratory devices have reached efficacies between 25 and 64 lm/W (at reasonable life, luminance, and CCT), there are currently no niche OLED products available in the marketplace for general illumination applications. According to industry experts, major manufacturers will wait for OLED laboratory prototypes to achieve higher efficacies before investing in the manufacturing infrastructure to produce OLEDs for general illumination purposes. Therefore, unless a smaller manufacturer, less averse to risk, develops a niche product, the FY08 milestone will not be met. Milestone 2 targets a commercial price of $70/klm by FY10. At this point the lifetime should be around 5,000 hours. Reaching a marketable price for an OLED lighting product, is seen as one of the critical steps to getting this technology into general use because of their large area. Although the FY08 milestone may be late in coming, cost reduction remains the focus. By FY15 the target is to get a high efficacy, 100 lm/W OLED. Cost and lifetime should show continuous improvement as well.

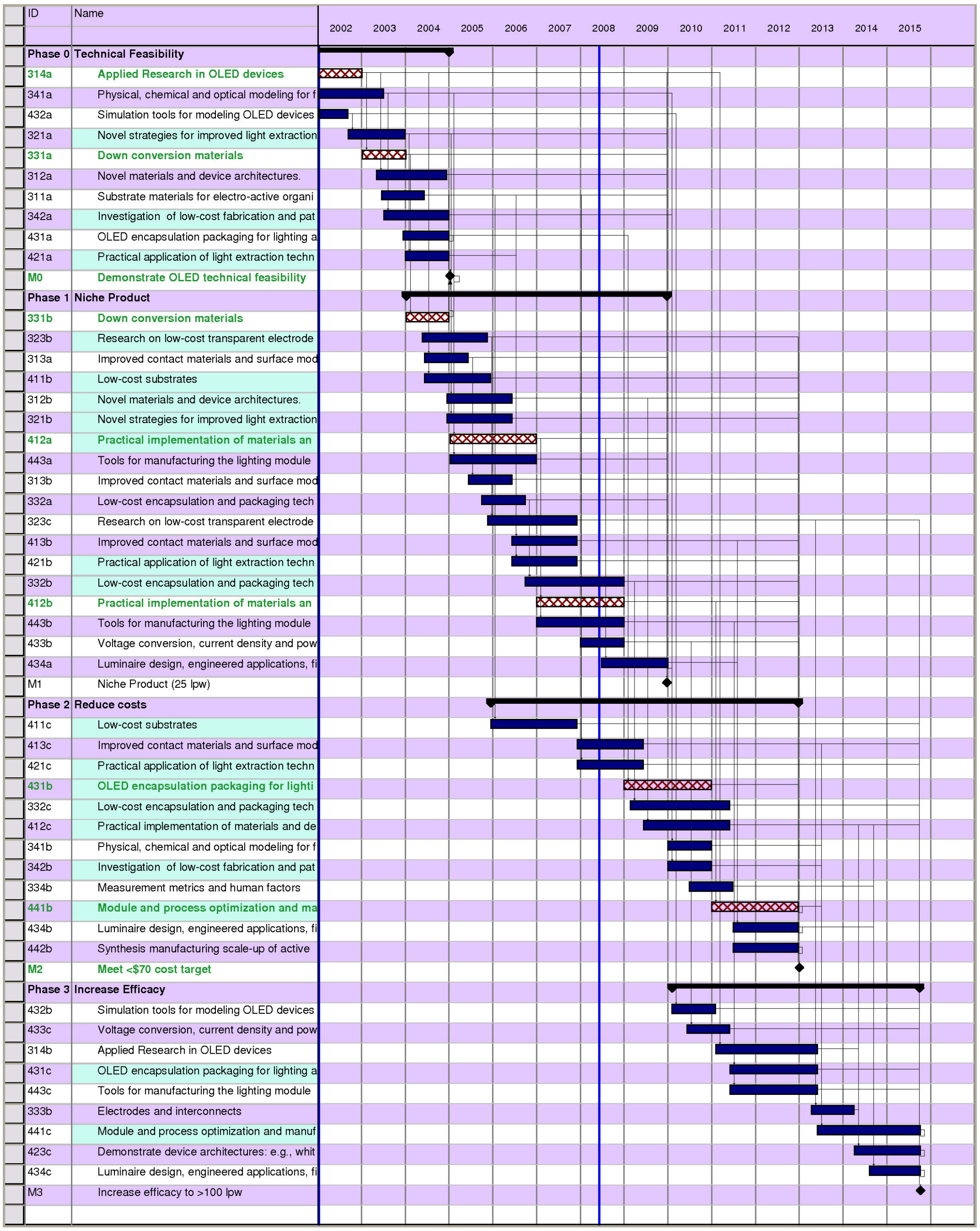
Table 2-23 OLED Product Milestones

Milestone	Year	Milestone Target
Milestone 1	FY08	25 lm/W, < $100/klm, 5,000 hrs
Milestone 2	FY10	<$70/klm
Milestone 3	FY15	>100 lm/W

Assumptions: CRI > 80, CCT < 2700-4100K, luminance = 1,000 cd/m^2, and total output ≥ 500 lumens.

Using the OLED subtask descriptions from Table 2-21, it is possible to associate those requiring significant early progress with the individual milestones. This linkage is graphically shown in the Gantt charts in Figure 2-14.

Figure 2-14 Planned Research Tasks - OLEDs[81]



81 NGLIA OLED Technical Committee

2.3.7 Lighting Unaddressed Opportunities

One area of potential development is to more strongly support improved manufacturing of the products. Though outside the scope of the current program, a development in this area would represent a substantial opportunity for the industry and the country. Several potential benefits of such support are:

- Improved uniformity of processes would improve yields and lower costs.
- Improved control over manufacture would reduce color variation, an impediment to deployment.
- Advanced automation methods could reduce labor content and potentially make domestic production-"made in the USA"- a more attractive option than it is today. Currently most LED chip production has moved to Asia.
- For OLEDs, the manufacturing issue is particularly acute since the needs for displays, the apparent synergistic technology, are actually quite different from what is needed for lighting. This makes the issue of cost reduction a barrier to this technology.

While some manufacturing subtasks are prioritized for core R&D, there is not sufficient funding at this time to support advanced manufacturing development to the extent contemplated above

Technology development of High Intensity Discharge (HID) lighting, has also been identified as an unaddressed opportunity within the Lighting subprogram. This task is an integral step in advancing conventional lighting technology. However, there is currently no funding for this task. Additionally, there is an unfunded initiative in traditional lighting.

2.4 HVAC and Water Heating

Table 2-24 HVAC and Water Heating Summary

Start date	1980s
Target market(s)	Residential and commercial buildings
Accomplishments to date	• Initial development and ongoing improvement/enhancement of the Heat Pump Design Model • Establishment of the total equivalent warming impact as a measure of global warming impacts of heating, refrigeration, and air-conditioning systems • First publication of laboratory measured vapor compression system performance for R-134a, R-32, R-125, and R-143a • Development and commercialization of an aerosol duct sealing technique • Creation of an ASHRAE Standard for estimating efficiencies of thermal distribution systems • Development of a "drop-in" Heat Pump Water Heater (HPWH) • Development and patenting of a low-cost immersed condenser HPWH concept • Development of the Annual Cycle Energy System • Improved diagnostic techniques for duct leakage and other air flows
Current activities	1. Involving manufacturers in refining the IHP, GSHP, and HPWH. 2. Supporting field testing and evaluation of existing equipment in Building America homes to assess their feasibility in zero energy home environments 3. Beginning design, fabrication, and initial proof-of-concept prototype testing of new HVAC system concepts optimized for the ZEH environment 4. Creating conceptual designs of the most attractive integrated water heating appliance concepts, followed by the creation of prototype hardware for testing and evaluation
Future directions	• HVAC systems that meet the needs of a ZEH in various climate zones, including major reductions in energy consumption and peak demand, as well as excellent comfort control • Integrated appliances that combine space conditioning and water heating or capture waste heat for use in water heating

Projected end date(s)	2020
Expected technology commercialization dates	2010 to 2020

The primary focus of Heating, Ventilation, Air Conditioning (HVAC) and Water Heating R&D is to address the critical needs of the ZEH effort. Building America targets dramatic reductions in energy consumption in single-family homes, leading to net-zero energy homes by 2020. Cost-effective, highly efficient space conditioning and water heating systems are critical to reaching this goal. Consequently, the HVAC and Water Heating subprogram will work closely with the Residential Integration subprogram to ensure that R&D is closely aligned with the evolving needs and that those new technologies can be rapidly field-tested in homes and then transitioned to market in cooperation with Building America industry partners.

In addition, over the next several years, the equipment and performance needs of HVAC and water heating systems for commercial ZEBs will become more defined through the efforts of the Commercial Integration subprogram. In subsequent years, the HVAC and Water Heating R&D will work closely with the commercial buildings team to understand their needs, develop solutions, and test the resulting systems. Therefore, while the immediate focus of R&D is on residential ZEH targets, the subprogram anticipates devoting additional resources to commercial ZEB needs in the future.

2.4.1 HVAC and Water Heating Support of Program Strategic Goals

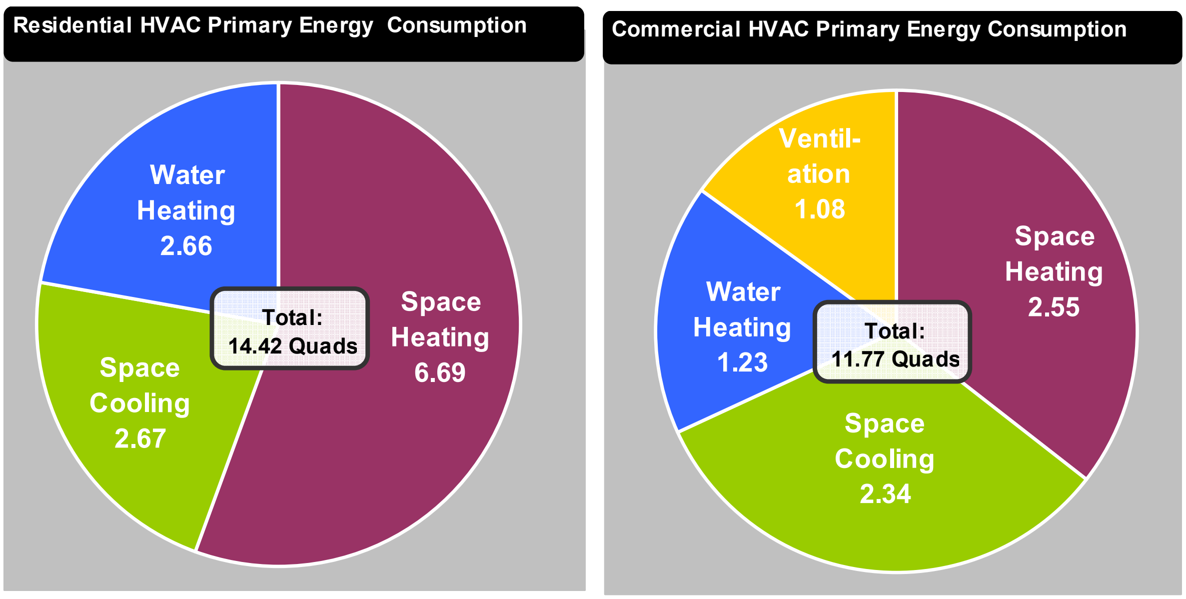
HVAC equipment for residential and commercial buildings consumes approximately 38.6 percent of the total energy used in buildings, a total of 15.34 Quads.[82]. Electric heating and cooling are important contributors to peak electricity demand and water heating also plays a large role in energy expenditures.

In residential buildings, space heating is the dominant component of energy consumption, accounting for 30.7 percent followed by space cooling at 12.3 percent (Figure 2-15).[83] Natural gas-fired furnaces and boilers are the most common heating systems; fuel-oil based systems and hydronic systems each account for less than 16 percent of heating energy consumption.[84] Water heating constitutes the next largest element of primary residential energy consumption after space conditioning, accounting for 12.2 percent of energy consumption.[85]

[82] BED
[83] BED.
[84] Estimated by TIAX, LLC, 2002
[85] BED

In commercial buildings, HVAC is the single largest component of primary energy consumption, accounting for 33.3 percent (14.2 percent for heating, 13.1 percent for cooling, and 6.0 percent for ventilation), while water heating is substantially smaller, at 6.8 percent[86], although it is a significant end use in some building types, such as hotels, hospitals, and restaurants.

Figure 2-15 Residential and Commercial HVAC Energy Consumption in Quads[87]



The HVAC and Water Heating R&D is fully aligned with the strategic goals of the BT program, specifically by developing technologies, products, and solutions that support the ZEB effort. To ensure R&D activities remain aligned with these strategic goals as they evolve, this subprogram will work closely with the Residential and Commercial Integration subprograms through periodic meetings, research collaboration, and participation in their program review meetings.

2.4.2 HVAC and Water Heating Support of Program Performance Goals

Dramatically improving the energy efficiency of HVAC systems and appliances is critical to achieving ZEB performance goals because they constitute a large proportion of the energy consumption in buildings. It is impractical and far too costly to design a ZEB with standard HVAC systems and appliances by attempting to generate all the required energy through on-site renewable energy. As noted in the BT program mission, the approach for a ZEB is to greatly reduce the energy needs through efficiency gains, and

86 BED
87 BED

only then make up the remaining energy needs through on-site renewable generation. Our goal is to develop technologies with the long-term potential to meet this goal with no increase in annual mortgage plus utility costs.

Achieving the ZEH goal will require the development of space cooling and heating equipment that reduces energy consumption by 50 percent relative to the Building America 2004 Benchmark by 2010.[88] Similarly, water heating equipment that reduces energy consumption by 50 to 80 percent relative to the benchmark must also be developed. Substantial improvements in appliance energy efficiency will greatly enhance the viability of the ZEH. While some tradeoffs can be made among the different systems, and the precise requirements differ depending on the climate zone, dramatic improvements in HVAC and water heating energy consumption are essential to ZEH. For design concepts such as the integrated heat pump, which combine space conditioning and water heating, the energy consumption targets will be calculated relative to Building America Benchmark totals for both functions.

Any new high efficiency water heating product must have very modest price premiums over conventional units, while offering substantial energy savings. In order to achieve the goals for ZEH by 2020 and ZEB by 2025, water heating energy consumption from non-renewable sources will need to decrease by approximately 80 percent.[89] Performance targets for HVAC systems, relative to the 2004 Building American baseline, are shown in Table 2-25. The cost target is to achieve the required performance with no increase in mortgage plus utilities costs.

Table 2-25 HVAC and Water Heating Performance Goals

Characteristics	Units	Year	
		2010	2020[90]
Residential Annual HVAC Energy Consumption Reduction versus 2004 Baseline	%	50	-
Residential Annual Water Heating Energy Consumption Reduction versus 2004 Baseline	%	50	80
Commercial Annual HVAC Energy Consumption Reduction versus 2004 Baseline	%	-	80

2.4.3 HVAC and Water Heating Market Challenges and Barriers

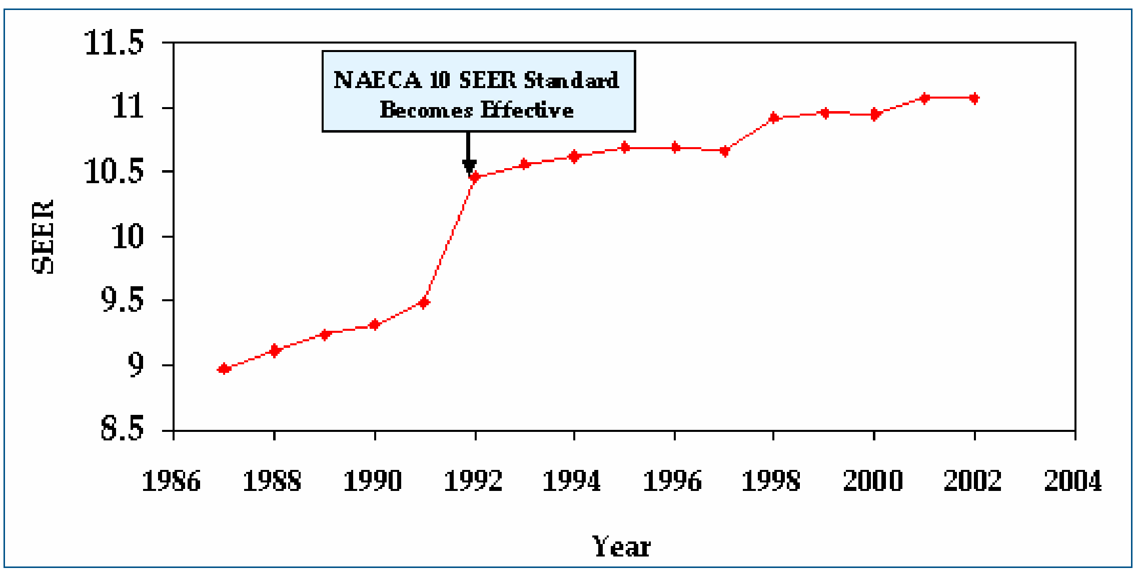
Most high efficiency residential HVAC systems are sold for reasons other than energy savings, though efficiency can be one of several factors. Such systems are typically

[88] ZEH
[89] ZEH
[90] Year 2025 for commercial HVAC Goal

bundled with non-energy features that are attractive to consumers, such a low noise, improved air filtration, or enhanced comfort. In the commercial HVAC sector, improved indoor air quality (IAQ), comfort, and reliability are important non-energy features. However, the majority of space conditioning equipment sold in the U.S. (approximately 70-80 percent in most years) only meets the minimum efficiency standard level mandated by DOE regulations, but does not exceed it. In recent years, the HVAC industry has seen only modest improvements in equipment efficiency, largely driven by the efficiency standards (Figure 2-16). The 13 SEER minimum efficiency standard, which took effect in January 2006, caused another large step increase in equipment efficiency. Premium HVAC systems sold in the U.S. will typically incorporate features that are valued by the customer, such as improved air filtration, reduced noise, and better fit and finish, but have little or no impact on efficiency.

High efficiency HVAC systems are commercially available today, but their market penetration is extremely limited, due primarily to their high initial costs. Such high efficiency systems have other drawbacks as well, including their large size and concerns about humidity control. New product designs and system approaches will be needed to overcome these limitations.

Figure 2-16 Shipment Weighted SEER of Unitary Air Conditioner Shipments[91]



The challenges to selling high efficiency water heating are even greater than for HVAC. Unlike white goods or even HVAC, there are few if any premium features of a water heater (e.g. comfort, aesthetics, image, enhanced functionality) that can be combined with efficiency to up-sell high efficiency products. Furthermore, most replacements are

[91] *ARI Statistical Profile*, Air Conditioning and Refrigeration Institute, October 7, 2004.

emergency sales where immediate availability is essential, and upgrading to more energy-efficient units is not feasible. Finally, the relatively low energy costs of water heating to individual consumers can make it difficult to justify a higher first cost product. Electric heat pump water heaters and condensing gas-fired water heaters offer significant energy savings over conventional products, but have very high price premiums and have therefore achieved a very limited market share. For example, of the 4 to 5 million residential electric water heaters sold annually in the U.S., only a few thousand are heat pump water heaters, whose efficiency can be more than double that of conventional units.[92]

Many aspects of the ZEH technical goal can largely be achieved for some regions of the country, and for some building types, using commercially available technology, but at an unacceptable cost. Reaching the goal with technologies that show promise of becoming affordable is critical. To achieve the economies of scale necessary to produce economical equipment, manufacturers need volumes far greater than the current ZEH market can provide. A viable ZEH strategy must address equipment that can, in the long-term at least, also be part of the broad equipment replacement and new construction market. Therefore, research should address the needs of the ZEH, but should also consider the needs of the large base of existing houses in order to provide a sufficiently large market to warrant the attention of equipment manufacturers.

The market barriers to meeting the HVAC strategic goal and performance goals are described in Table 2-26**Error! Reference source not found.**.

Table 2-26 HVAC and Water Heating Market Challenges and Barriers

Barrier	Title	Description
A	Affordability	The ZEH strategy requires development of much more affordable systems. Many high efficiency HVAC and water heating products and systems are already available in the marketplace, but are far too expensive for widespread adoption. Any new technology or system developed must be cost competitive with today's technologies.
B	Market acceptance	New products need to be easily installed and maintained without necessitating substantial additional training for installers or requiring additional trades' personnel. Current products are very reliable, but HPWHs have suffered from poor reliability, leading to a poor market image. Most water

[92] BED

		heater sales are replacements where immediate availability is essential and "up-selling" is uncommon. Coupled with the commodity nature of the product, this limits the potential for advanced products.

2.4.4 HVAC and Water Heating Technical (Non-Market) Challenges/Barriers

The basic design concept for both vapor-compression HVAC systems and water heaters has changed very little in the past decades. These products look much the same today as they did 20 years ago. Because incremental improvements and minimum efficiency standards (e.g., NAECA, EPACT, ASHRAE 90.1) have captured much of the "low-hanging fruit" available for further efficiency gains, new design approaches are necessary. Therefore, achieving the ZEH goals will require smaller, more efficient.[93] The technical barriers to meeting the HVAC strategic and performance goals are described in Table 2-27.

Table 2-27 HVAC and Water Heating Technical Challenges/Barriers

Barrier	Title	Description
C	Achieving high efficiency in low capacity HVAC systems	Substantial efforts have been made to raise the efficiency of 2-5 ton heat pumps and air conditioners. As system capacity is reduced, certain losses (e.g. clearance volume flow in compressors, high-to-low pressure section leakage in reversing valves) tend to become a larger percentage of total capacity. New developments are needed to achieve high efficiency in small systems.
D	Sustained performance	Systems must be designed to sustain their initial efficiency throughout the life of the equipment or notify users when performance deteriorates so corrective action may be taken. This can be accomplished with fault detection and diagnostic (FDD) systems.

[93] ZEH

E	System efficiency	The benefits of efficient HVAC systems can be realized only if system performance is improved significantly. Therefore, near-zero-loss systems to distribute heating, cooling, and ventilation must be developed which are cost-effective and simple to install. Furthermore, providing comfort conditioning only when and where it is needed to satisfy occupants requires systems that permit efficient zoning and sensors to optimize indoor air quality and humidity while also minimizing energy consumption. Proper air distribution, which can be affected by register design and placement, is also important.
F	Ensuring comfort and indoor environmental quality	Traditional residential HVAC systems do not provide adequate humidity control under certain conditions (e.g. when sensible cooling loads are low) and do not provide sufficient fresh air ventilation which is necessary to ensure IEQ in tight homes.

2.4.5 HVAC and Water Heating Approach/Strategies for Overcoming Challenges and Barriers

Meeting the needs of the ZEH program will require new approaches to generating and distributing heating, cooling, and hot water in order to meet the particular needs of ZEH occupants. Planned activities fall broadly into two categories, one addressing HVAC systems and the other addressing water heating. Some integrated appliance concepts may incorporate both functions in a single product or system. Furthermore, as noted previously, the cost optimal solution may be very different in different climate zones.

The focus of HVAC R&D efforts will be on system energy consumption, rather than simply EER or SEER, which do not capture the impacts of the entire HVAC system. The baseline for comparison will be the Building America 2004 Benchmark. HVAC equipment will also need to be designed specifically to meet ZEH building loads, which will be quite different in magnitude and relative proportions (e.g. cooling, heating, dehumidification and domestic hot water) than those of current homes. Specifically, humidity control in a ZEH can be very challenging using conventional HVAC equipment, and forced mechanical ventilation may be required to ensure acceptable IEQ in these homes, due to their tight envelopes.

Although the energy efficiency of HVAC equipment has increased in recent years, new approaches, including radically new ideas, are required for continued improvements. The dramatic reductions in HVAC energy consumption necessary to support the ZEH goals require a systems-oriented Stage-Gate analysis approach that characterizes each element of energy consumption, identifies alternatives, and determines the most cost-effective combination of options. Therefore, the first task in this effort involved system characterizations, identification of necessary upgrades to analysis tools, and an assessment of cost and performance of alternative solutions. The following technologies are elements of possible solutions identified in cooperation with Residential Integration, but further evaluation may substantially alter these plans:

- Integrated heat pumps which combine heating, cooling, ventilation, humidity control, and water heating
- Reduction of distribution losses, recovery of waste heat, integration of tankless hot water systems, and integration of simple, durable, low cost solar hot water systems.
- Stand-alone, direct expansion dehumidification systems with energy recovery ventilation and possibly hot water pre-heating
- Large surface heat exchangers for radiant floors, walls, or ceilings
- Low leakage thermal loss duct systems
- Low capacity space conditioning systems that may be integrated with night cooling or other evaporative cooling options or use ground contact.
- Combined desiccant/evaporative cooling unit to supply any mix of sensible and latent loads in any climate.

This effort is specifically targeted to achieving demonstration of two design concepts that have the long-term potential to reduce annual HVAC and water heating energy consumption by 50 percent in new residential buildings at neutral cost. The design concepts must also address other critical Building America needs such as humidity control, uniform comfort, and indoor air quality. Several different design approaches will be necessary for optimal performance in different climate zones and building types. If design concepts which combine space conditioning and water heating are proposed, the energy consumption and payback period targets will be calculated relative to Building America Benchmark totals for both functions.

A preliminary business case analysis of the most promising concepts was completed in FY 2006. Future activities will involve prototype development, testing and evaluation of the concepts identified. Besides the integrated heat pump concept, various approaches for high efficiency water heating exist today and have been the subject of considerable R&D in recent years. They include heat pump water heaters and solar water heating; however, both have proven cost-prohibitive despite substantial cost reduction efforts. The HVAC subprogram is not aware of any likely breakthroughs in these technologies that could dramatically reduce their costs, but remain open to the possibility that such breakthroughs may become possible due to advances in new materials, manufacturing technologies, electronics, or technology transfer from other industries or products. The subprogram continues to monitor alternative technologies and remains open to exploring these pathways if dramatic cost reductions seem likely.

The Building America program has recently refined their ZEH analysis using BEOpt, resulting in more stringent targets for cooling efficiency. Residential Integration is targeting 24 SEER systems with substantial dehumidification capabilities, so the HVAC subprogram will explore options for achieving these very challenging goals. The heating performance for this system needs to be better defined.

The HVAC and Water Heating strategies for overcoming barriers and challenges are included in Table 2-28.

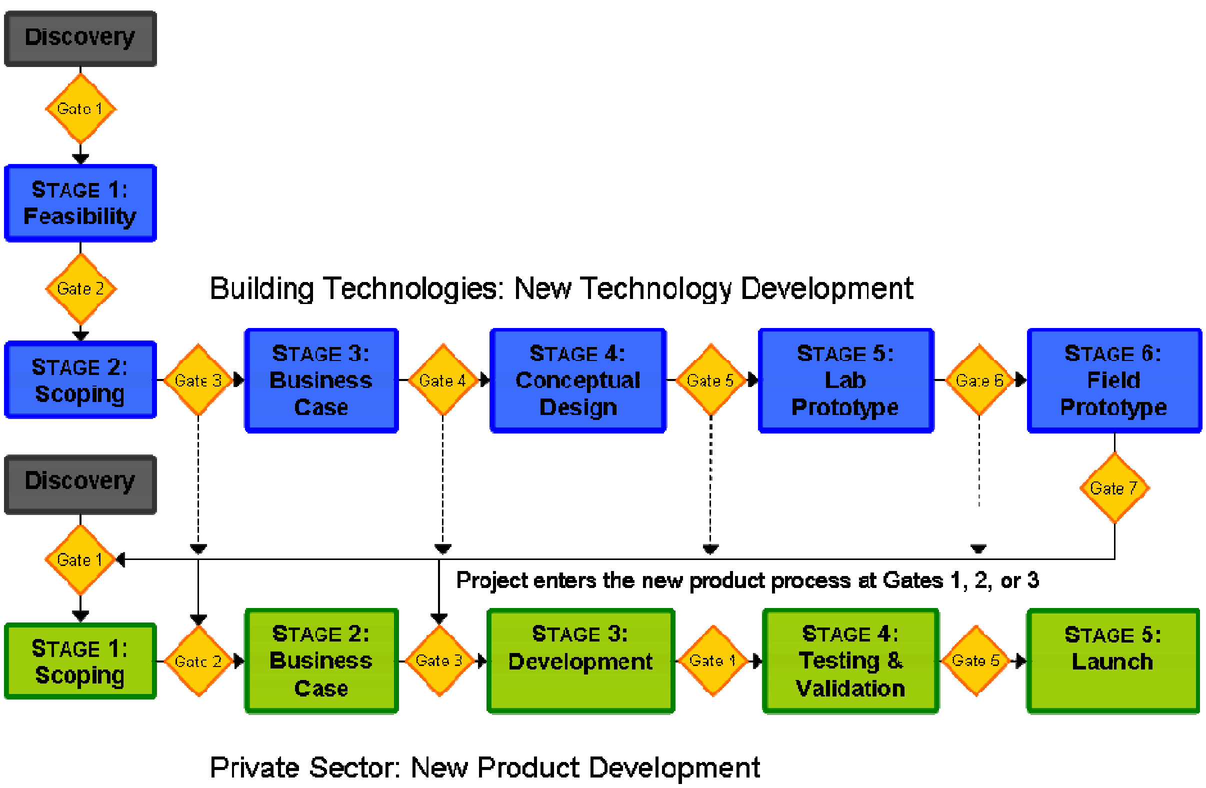
Table 2-28 HVAC and Water Heating Strategies for Overcoming Barriers/Challenges

Barrier	Title	Strategy
A	Affordability	Designs must use simple, off-the-shelf components that are mass-produced, and the concepts may not incorporate other features that raise costs without any energy benefit.
B	Market acceptance	Concepts will maintain design simplicity, use of conventional components, and ease of installation and maintenance. A market study will help address questions related to market acceptance.
C	Achieving high efficiency in low capacity HVAC systems	New design concepts may incorporate point source cooling systems and small capacity, variable speed compressors.
D	Sustained performance	Designs will either include integrated FDD systems or should tolerate typical faults such as modest loss of refrigerant charge without significant performance deterioration.
E	System efficiency	New concepts will target part-load efficiency, reduced energy consumption through smart zone control, and approaches such as waste heat recovery that are not easily captured by the SEER metric but that can reduce energy consumption dramatically. For water heating systems, distribution system losses will also be considered.
F	Ensuring comfort and indoor environmental quality	New HVAC designs will provide integrated dehumidification capable of sufficient latent cooling under all conditions and will also provide low-cost, low-loss mechanical ventilation.

Many different design concepts will be considered, based on stakeholder input and discussions with the Building America team. Because the subprogram cannot predict which solutions will prove most promising, a modified Stage-Gate process is used to reduce risk. The BT adapted Stage-Gate methodology requires certain criteria be met before approval is gained to enter the next stage of the process. [94] The main stages for HVAC and Water Heating include comparisons of possible alternatives, several conceptual designs, and then detailed prototype design, assembly and testing (Figure 2-17). The potential federal role in technology development involves six stages and seven gates, but depending on the nature and status of the concept, some or all of the responsibilities can flow to the private sector for product development beginning as early as Gate 3.

The program starts with ideas that are successively screened by gates 1- 7 to reach feasibility, scoping, business case, conceptual design, lab prototype, and field prototype stage. From the third gate onwards, the program works diligently to encourage appropriate private sector entities to partner with the program at the earliest possible stage, so that technology and product development efforts are complementary rather than duplicative.

Figure 2-17 Stage Gate Process for DOE HVAC & Water Heating R&D Program



The HVAC & Water Heating has developed detailed descriptions for each set of gate deliverables, the criteria for passage, and the outputs, as well as for the typical activity at each funded stage. Criteria include "must-meet" criteria, which are required in order for

---

94 Robert Cooper, "Winning at New Products, Accelerating the Process from Idea to Launch." 3rd Edition. 2001.

the project to pass into the next stage, as well as "should meet" criteria, which are desirable but not mandatory.

The Stage-Gate process structures the tasks and dates for each project (Table 2-29). The designs will first be tested in a Habitat for Humanity house and then ultimately be field tested in Building America homes, which provide an excellent test bed for monitoring real world performance prior to commercialization. It is expected that several different HVAC concepts will be field tested, to address the specific needs of different climate zones.

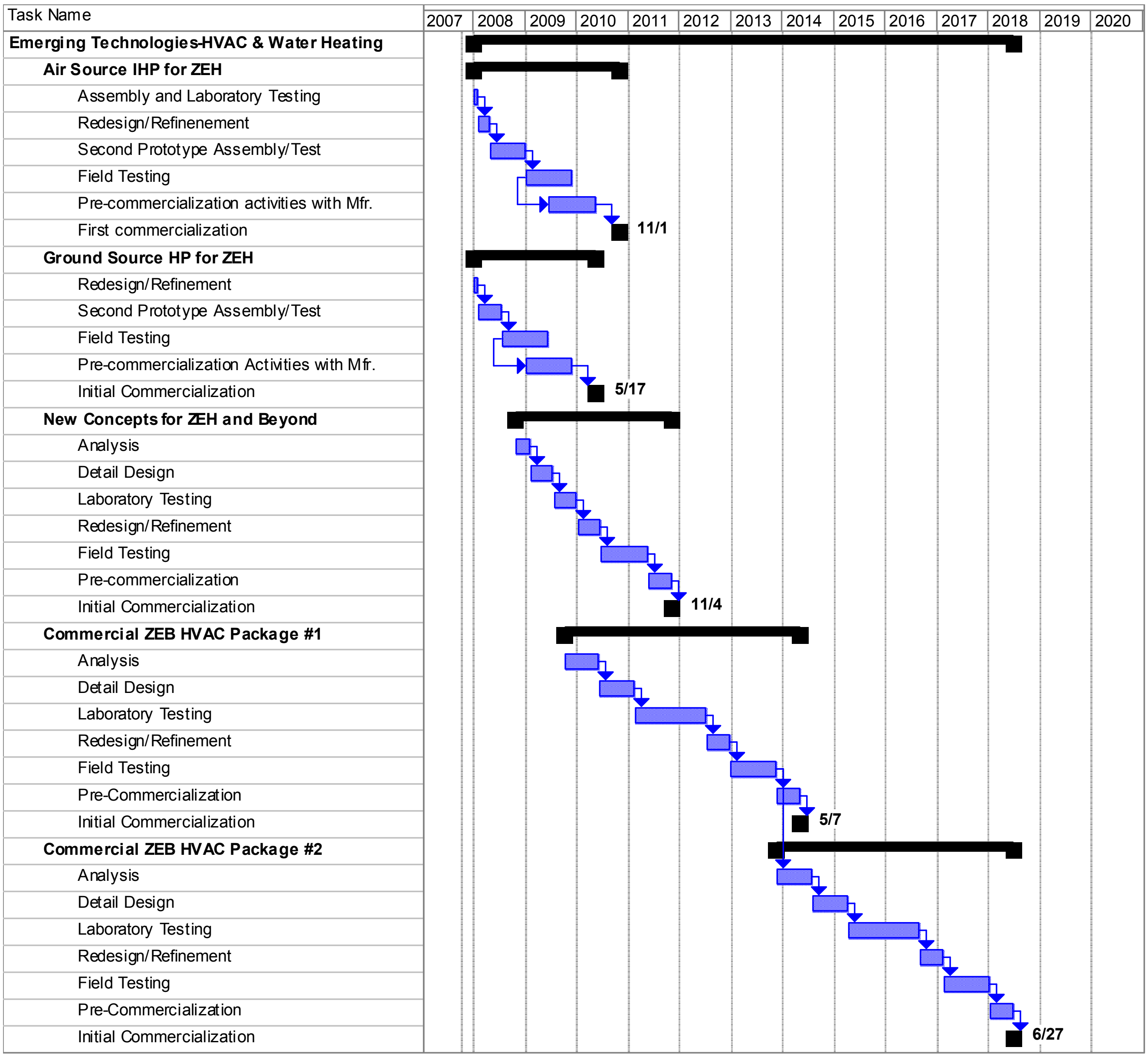
Table 2-29 HVAC and Water Heating Tasks

Task	Title	Duration	Barriers
1	Air Source Integrated Heat Pump for ZEH	2008-2010	A, B, E
2	Ground Source Heat Pump for ZEH	2008-2010	A, B, E
3	High Efficiency Water Heater	2008-2010	A, B
4	New Concepts for ZEH and Beyond	2008-2011	A, B, C, E, F
5	Commerical ZEB HVAC Package #1	2009-2013	A, B, E, F
6	Commercial ZEB HVAC Package #2	2013-2018	A, B, E, F

2.4.6 HVAC and Water Heating Milestones and Decision Points

As shown in the Gantt chart (Figure 2-18), the primary activities for the next several years relate to development and commercialization of the IHP for ZEH. New concepts for ZEH will begin to be analyzed in FY08, leading to detailed design and development of promising concepts in the coming years. The next priority will be to begin development of design concepts to support the commercial ZEB program. The schedule shows two successive efforts related to commercial ZEB concepts, based on the assumptions of roughly level funding in the next few years. If the current budget levels increase substantially, the two commercial ZEB design efforts could occur simultaneously, with additional efforts starting afterwards. An additional sub-activity, addressing needs for low-loss hot water distribution systems, may be added in subsequent years, if appropriate R&D needs are identified through ongoing field studies.

Figure 2-18 HVAC & Water Heating Gantt Chart



2.4.7 HVAC and Water Heating Unaddressed Opportunities

Low-loss domestic hot water distribution system*s*, large surface heat exchangers (radiant floor, wall, or ceiling), low leakage and thermal loss ducting systems, and commercial duct sealing have been identified as an unaddressed opportunity within the HVAC and Water Heating subprogram.

2.5 Envelope

Table 2-30 Envelope Summary

Start date	1980
Target market(s)	New and existing residential and commercial buildings
Accomplishments to date	• Developed and demonstrated energy savings benefits of dark colored metal, clay tile, reflective, and asphalt roofing materials; and wall coatings that are highly reflective • Worked with industry to develop second and third generation of foam insulation materials that are more energy-efficient and less costly • Devised manufacturing methods to dramatically reduce the cost of vacuum insulation materials • Developed methodology and tool to assess potential for moisture related damage and the onset of mold problems in order to guide the development of failure resistant energy-efficient envelope systems • Developed and produced consumer information and software to help homeowners select the proper type and amount of insulation, thereby promoting use of better insulation for building envelopes • Advised the Federal Trade Commission (FTC) on issues associated with their Insulation Labeling Rule • Through active participation in ASTM and ASHRAE, developed, revised, and launched over 100 standards pertaining to insulation materials and building envelopes • Assisted in the development of DOE vapor control recommendations that were submitted to the International Residential Code • Developed and tested a phenolic foam reinforced with cellulose fibers that can be used in Structural Insulated Panels (SIPs)

Current activities	1. Develop the next generation of attic/roof systems through the integration and optimization of cool colors, thermal mass, above sheathing ventilation, advanced lightweight insulation, Phase Change Materials and radiant barriers, including consideration of fundamental new structural components. 2. For Advanced Walls, develop best practices for PCMs. 3. Develop next generation of insulation materials that are lightweight but include thermal inertia for increased energy efficiency and peak load reduction to support ZEBs. These materials include phase change insulation, dynamic membranes, superhydrophobic materials, and insulated structural sheathing. 4. Research energy efficient and durable basement/foundation systems to quantify the effectiveness of sealing crawlspaces versus ventilating them for a large number of crawlspace building envelope and system arrangements. Determine affordable insulation strategies for full and partially insulated basements. 5. Through expert moisture analysis, define parameters for vapor barrier optimization and develop new dynamic membranes to enable the construction of significantly more efficient envelope systems. 6. Conduct Air Barrier Research to determine moisture properties for membrane products. 7. Evaluate thermal performance of metal buildings. Investigate a potential gap in compliance where metal building roof and wall insulation is compressed between the roof or wall skin. Develop a plan and resolution schedule for the possible issuance of a de-rating process within ASTM or ASHRAE. 8. Develop the necessary standards that guarantee building envelope material and system selection is fair and objective so that this work can be carried out by the private sector

Future directions	• Conduct Structural Insulated Panel (SIP) facer development to address environmental sensitivity of existing technology, develop new foam insulation products that have higher R-values, and develop advanced joining techniques that are less installation sensitive • Develop new types of low density insulations that are more opaque to radiative heat transfer and have thermal inertia • Develop roofing products for cooling dominated climates that are consumer accepted and reflect large percentages of solar radiation • Develop new types of wall systems that are inexpensive and insensitive to moisture ingress • Develop new construction techniques that allow the use of the attic space, but allow air distribution systems to be inside the conditioned space • Develop energy-efficient slab and basement foundation systems • Develop tools and standards that allow for the appropriate thermal and hygric design of building envelope systems
Projected end date(s)	*2008:* Improved low density insulation; Exterior insulation systems *2009:* Next generation SIPs: *2010:* Required standards for industry moisture testing: *2015:* Highly-efficient attics
Expected technology commercialization dates	Reflective roofing products: 2007-2009 Improved low density insulation: 2008 Next generation SIPs: 2009

A building's envelope is what divides the working or dwelling space from the outside; it includes roof and attic systems, walls, and foundations. The most common roof and attic system found on single family residential buildings consists of a wooden truss system with blown-in loose-fill fiberglass insulation, though other, newer materials are also used. With current technology the most common wall is wood-framed with a 3.5-in cavity filled with fiberglass batts, which provide R13 or R15. On the other hand, many foundations are un-insulated. Crawlspaces are commonly lined with R11 insulation on the underside of the floor in existing homes but ventilation depends on local building codes.

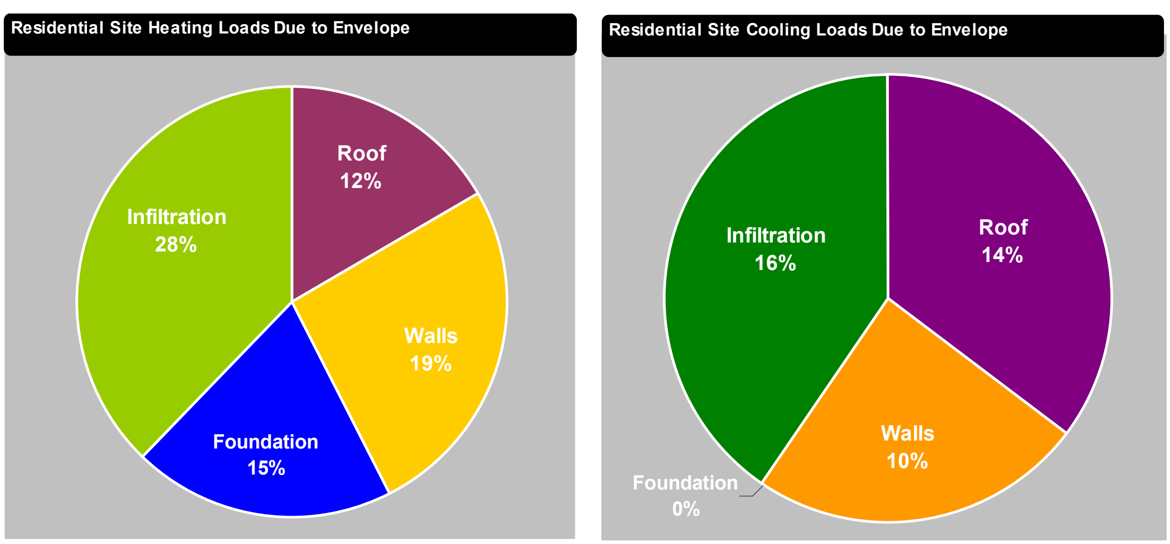
Emerging technology for envelopes focuses on the development of new materials and systems to improve the performance of the building envelope. Technologies developed through BT R&D progress from inception into the marketplace through a technical pathway. Each major Envelope portfolio component progresses from identification of need, allocation of resources, and continuous measurement of results against milestones, with the end objective being deployment into ZEH by Building America.

Commercial buildings have high internal loads due to lighting, miscellaneous electric loads, and other heat sources. A tight envelope increases the heating load, which is counterproductive to ZEB goals. Therefore, the Envelope subprogram focuses on Residential Integration needs.

2.5.1 Envelope Support of Program Strategic Goals

The Building Technology Program's long-range goal of developing ZEB by 2025 will require more cost-effective, durable and efficient building envelopes. To make ZEB affordable, efforts to reduce the energy required for buildings are a necessary complement to efforts aimed at reducing the cost of renewable power. Forty-three percent of the primary energy used in a residence is spent on space heating and cooling (Figure 2-19).[95] Reducing envelope energy consumption will greatly contribute to reaching ZEB since a significant amount of space heating and cooling energy is lost through inefficient envelopes. The importance of the Envelope subprogram has been recognized by the Residential Integration subprogram, as exemplified by the ambitious envelope targets in the Building America list of optimization-critical component needs.[96]

Figure 2-19 Envelope Contribution to Site HVAC Energy Consumption in Quads[97]



The strategic goals have been defined with consideration of their energy saving potential toward the ZEB goal and the research gaps noted in a recent Building America planning

[95] BED
[96] ZEH
[97] BED

meeting.[98] These objectives have been organized to address major building envelope systems, promising new material developments, and enabling technologies.

- Develop the Next Generation of Attic/Roof Systems: By 2015, develop advanced attic and technologies for single-family residences that reduce the space conditioning requirements attributable to attics by 50 percent compared to Building America regional baseline new construction at no additional operating cost and no additional envelope failure risk.
- Develop the Advanced Wall Systems: By 2015, develop advanced wall technologies for single-family residences that achieve R-25+ and 40% solar reflectivity at a small added cost.
- Develop the Next Generation of Envelope Materials: By 2015, develop and demonstrate innovative materials that either: (1) will have effective thermal performance improved by 50 percent relative to functionally-comparable components of the Building America regional baseline new construction; or (2) resolve durability-related problems (moisture, termite, structural, etc.) that may increase envelope failure risk.
- Conduct enabling research that fosters private industry investment in energy-efficient products, examples include air barrier research, performance test protocols, ASHRAE SP 160 Interior Moisture Conditions, etc.
- Develop construction guidelines for optimal foundation performance by 2015.

2.5.2 Envelope Support of Program Performance Goals

The table below lists the performance goals for the Envelope subprogram. All performance measurements are relative to historical baselines that have been set as the Building America regional baseline for new construction. One important constraint included for many components of strategies is that of "no additional operating cost", which is defined here as the sum of the mortgage-amortized installed cost and the annual energy costs savings. Ensuring the durability of the envelope is also an integral aspect of these targets.

[98] *Building America Meetings Series: Quarterly All-Teams Planning Meeting Notes*, November 16-18, 2004, U.S. Department of Energy, Building America Program. Washington, DC.

Table 2-31 Envelope Performance Goals

Characteristics	Units	Calendar Year 2008 Status	Calendar Year 2010 Target
Advanced attic/roof system	R-Value	Conventional R-45	Dynamic annual performance equal to conventional R-45
Color reflectivity (applicable to both walls and roofs)	Solar reflectivity	30%[99]	40%[100]
Advanced wall system	R-Value	Static R-20 in 3.5 in. thick space	Dynamic annual performance equal to conventional R-25[101]
Foundation Systems	Development		Field experiments underway; model development advanced
Phase change energy storage within light-weight building system	Development	Prototype material, laboratory testing, field testing	Commercial PCM-enhanced fiber insulation at no or little extra cost
Thermochromic surfaces for commercial and low-slope residential roofs	Development	Prototype material, field testing, industry demonstrations.	Assessed surface durability; improved prototypes
Improved weather resistive barriers (WRBs)		Define optimal characteristics	Optimized prototype in market

2.5.3 Envelope Market Challenges and Barriers

Building envelope designs and material selections are typically constrained by cost. This is particularly true during new construction when many homes are built using price estimates. Even for retrofit applications, improvements that add cost are very difficult to market unless those costs can be recovered through reduced energy bills.

[99] Durability not yet assured at interim target

[100] With attractive dark appearance, and with long-term durability of both reflective properties and appearance

[101] Subject to no additional operating cost, within the traditional 3.5-inch wall dimension, with acceptable durability characteristics

Table 2-32 Envelope Market Challenges and Barriers

Barrier	Title	Description
A	First cost sensitivities	There is often an economic disconnect between builders and building occupants.[102] Builders are sensitive to first cost and typically receive no benefits from long-term energy performance improvements.
B	Resistance to change	The building industry is fragmented and diverse, with a strong resistance to change.[103, 104] Industry rules-of-thumb often take precedence over technical recommendations based on extensive building envelope research.[105]
C	Local code variability	Local building codes vary greatly, with thousands of code jurisdictions in the U.S. Although there has been great progress in bringing the code bodies together on the national level, local codes for residential construction and, more importantly, code enforcement are less uniform. In many locations, only the electrical system is inspected. In others, outdated codes preclude the application of recent advances in building science.

2.5.4 Envelope Technical (Non-Market) Challenges and Barriers

The building envelope industry is highly fragmented; it is unlikely that an envelope is constructed with products from a single manufacturer. Often, an envelope constructed in the field joins elements that are combined differently in each building, so product integration and performance issues are seldom addressed. Table 2-33 describes the technical challenges and barriers associated with Envelopes.

[102] *High-Performance Commercial Buildings: A Technology Roadmap*, U.S. Department of Energy , Office of Energy Efficiency and Renewable Energy, October 2000.
[103] *Technology Roadmap: Information Technology to Accelerate and Streamline Home Building, Year One Progress Report*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Prepared by Newport Partners, LLC, June 2002.
[104] *High-Performance Commercial Buildings: A Technology Roadmap*, U.S. Department of Energy , Office of Energy Efficiency and Renewable Energy, October 2000.
[105] *Technology Roadmap: Whole House and Building Process Redesign, 2003 Progress Report*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Prepared by Newport Partners, LLC, August 2003.

Table 2-33 Envelope Technical Challenges/Barriers

Barrier	Title	Description
D	Thermal performance versus durability performance	All materials and systems must meet both thermal and durability performance requirements. For example, reflective paint pigments must not only provide the desired radiative properties, but must also be colorfast over long periods of time and must resist wear due to weather exposure.
E	Unknown interactions	Understanding of the physical interactions between building components and systems is incomplete. For example, early efforts to reduce infiltration often led to moisture problems.[106]
F	Material developments	Building industry practices are relatively rigid, so that material developments are necessary to provide certain desirable properties, such as increased heat capacity, within the limitations of typical light frame building practices.
G	Structural support requirements	There are conflicts between structural support requirements and the need to limit heat flow paths between the conditioned space and the external environment.[107]
H	Material property data	Data are unavailable for a number of critical material properties and physical models are unable to accurately predict performance without accurate material property data.
I	Benchmark system data	Benchmark performance data are unavailable for a number of existing systems and for all novel/proposed systems.

2.5.5 Envelope Approach/Strategies for Overcoming Challenges and Barriers

The Envelope subprogram focuses on meeting the building envelope objectives outlined by conducting collaborative R&D with national laboratories, industry partners, standards and professional societies, and universities, including international participation as appropriate.

Develop the Next Generation of Attic and Roofing Systems

The goal for the advanced attic systems project is to make attics constructed by 2010 twice as efficient as Building America's regional benchmarks. The Envelope Performance Goal for the advanced attic/roof system is a dynamic annual performance

[106] *Technology Roadmap: Whole House and Building Process Redesign, 2003 Progress Report*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Prepared by Newport Partners, LLC, August 2003.
[107] *Technology Roadmap: Advanced Panelized Construction, 2003 Progress Report*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Prepared by Newport Partners, LLC, May 2004.

equal to conventional R-45 by 2010. The attic system is defined broadly to include the roof structure as well as the space between the roof and the finished ceiling. Attics were selected because practical solutions for constructing an energy-efficient attic do not exist and that attic and roofing systems represent a significant percentage of the aggregate residential building component loads.[108, 109] Achieving this ambitious goal will require a well-coordinated collection of technical advances, using an effective collaboration of engineering and scientific resources.[110, 111]

The major components of the strategy for attic systems are:

- Integration of PCM, Cool Colors, ASV, Radiant Barrier and Advanced Lightweight Insulations
- Regionally Optimization of Above-Sheathing Ventilation
- Best Practice for Integration of PCM in Roof and Attic Assembly
- Demonstration of Dynamically Active Roof and Attic
- Consolidation of Existing Energy Estimating Tools

Develop the Advanced Wall Systems

Developing a more air tight and energy efficient envelope will significantly facilitate reaching ZEB goals, as exemplified by the ambitious envelope targets in the Building America list of optimization-critical component needs.[112] The Envelope Performance Goal for wall insulation is to meet durability requirements for an R-20 wall by 2010. The goal for the advanced wall systems project is to make these systems constructed by 2010 twice as efficient as Building America's regional benchmarks. These regional benchmarks are based upon the 2003 IECC and vary from a total resistance (including sheathing, framing, and finishes) of R-12 in warm climates to R-26 in cold climates.[113]

A market resistance to increased wall thickness has posed constraints on strategies to improve the energy efficiency of wall systems in many regions. Therefore, advanced materials and systems must deliver significant improvements in energy performance without increasing wall thickness.

---

[108] BED

[109] Anderson, Ren, et all, *Analysis of System Strategies Targeting Near-Term Building America Energy-Performance Goals for New Single-Family Homes*, November 2004, National Renewable Energy Laboratory. Report No. TP-550-36920.

[110] *Building Envelope Technology Roadmap*, U.S. Department of Energy , Office of Energy Efficiency and Renewable Energy, May 2001.

[111] *Technology Roadmap: Energy Efficiency in Existing Homes, Volume Three: Prioritized Action Plan*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Prepared by Newport Partners, LLC, May 2004.

[112] Navigant Consulting, Inc., Zero Energy Homes' Opportunities for Energy Savings: Defining the Technology Pathways Through Optimization Analysis, October 2003

[113] R. Hendron, Building America Research Benchmark Definition, Updated December 15, 2006, NREL/TP-550-40968, January 2007

The major components of the strategy for wall systems are:

- Demonstrate the next generation of exterior insulation finish systems (EIFS)
- Develop a non-organically faced Structural Insulated Panel (SIP)

Develop Advanced Foundations

At this point, work on foundations is limited, but the goal is to have field experiments underway and model development advanced by 2010. Earlier work in this field, especially the results from very long-term exposure tests, will serve as the starting point. Careful experimental design will be used to answer the questions associated with the inter-related aspects of foundation performance, recognizing that the thermal performance may not be the most important. As the other envelope thermal loads are reduced as the program progresses, the thermal losses and gains through the foundation become more important.

Develop the Next Generation of Envelope Materials

The program strategy is to create the opportunity for envelopes to contribute to ZEB by advancing a portfolio of new insulation and membrane materials, including the exterior finishes, having residential and commercial application. Currently goals for envelope materials focus on field testing, durability assessment, and prototyping for market introduction. The needs for new envelope materials have been expressed in a number of roadmaps.[114, 115, 116]

The major components of the strategy for envelope materials are:

- Develop Improved weather resistive barriers (WRBs)
- Develop Phase change energy storage within light-weight building system
- Determine the feasibility and energy saving potential for dynamic roofing surfaces such as thermochromic materials

Durability issues, lack of technical data, and insufficient standards are key barriers that are preventing more energy-efficient building envelopes from becoming routine practice. Moisture is responsible for the largest percentage of building envelope failures, leading to losses in energy efficiency, structural failures, and poor indoor environmental quality.

Enabling Technology

---

114 *Building Envelope Technology Roadmap*, U.S. Department of Energy , Office of Energy Efficiency and Renewable Energy, May 2001.

115 *Technology Roadmap: Advanced Panelized Construction, 2003 Progress Report*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Prepared by Newport Partners, LLC, May 2004.

116 *Technology Roadmap: Energy Efficiency in Existing Homes, Volume Three: Prioritized Action Plan*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Prepared by Newport Partners, LLC, May 2004.

All of the tasks included in this plan address previously listed building envelope issues; enabling technology tasks focus on broader challenges that are applicable to all of the envelope components. These challenges include moisture issues, standards organizations expertise and leadership, and leveraging resources. The major enabling technology strategies that address these broad barriers are:

- Apply world class scientific and engineering analysis to solve moisture issues through analysis and material properties studies identified by Building America and others[117, 118]
- Provide impartial expertise and/or leadership to standards organizations, such as ASTM, ASHRAE, CRRC, and IEA and government agencies
- Leverage public resources with industry collaborations through User Centers with unique experimental facilities[119]

Table 2-34 Envelope Strategies for Overcoming Barriers/Challenges

Barrier	Title	Strategy
A	First cost sensitivities	First, work to reduce the cost of advanced envelope technology and then improve communication with the general public to raise their awareness and increase their demand for better buildings. Finally, promote the incorporation of improved technology into standards that require industry use.
B	Resistance to change	Work to incorporate the advanced technology into codes and standards to compel industry acceptance. Continue with education programs to expand the knowledge-base among building industry members.
C	Local code variability	Continue to work with standards organizations that local code officials rely upon. Expand communication with the general public to raise their awareness and increase their demand for better buildings. Make supporting information available to other elements of the BT program that interact directly with code officials.
D	Thermal performance	Continue cooperative product development programs

117 *Technology Roadmap: Whole House and Building Process Redesign, 2003 Progress Report*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Prepared by Newport Partners, LLC, August 2003.
118 *Building America Meetings Series: Quarterly All-Teams Planning Meeting Notes*, November 16-18, 2004, U.S. Department of Energy, Building America Program. Washington, DC.
119 *Technology Roadmap: Advanced Panelized Construction, 2003 Progress Report*, U.S. Department of Housing and Urban Development, Office of Policy Development and Research. Prepared by Newport Partners, LLC, May 2004.

	versus durability performance	and ambitious testing programs that include both age-acceleration and field-exposure elements in conjunction with laboratory thermal performance testing programs. Use work with standards organizations to accelerate adoption of new energy-conserving products and systems.
E	Unknown interactions	Expand modeling capabilities, with important benchmarks extracted from both field tests and large laboratory experiments.
F	Material developments	Work with building envelope component manufacturers to identify possible modifications that improve energy performance with minimal changes to application mechanics.
G	Structural support requirements	Use modeling capabilities to explore the thermal performance of proposed new building configurations.
H	Material property data	Continue to make the sophisticated measurements necessary to expand the data library. Also, develop new measurement techniques as appropriate.
I	Benchmark system data	Collaborate with industry, using unique experimental facilities to make needed measurements.

Using the strategies described, the Envelope subprogram will focus on the following tasks over the next five years (Table 2-35).

Table 2-35 Envelope Tasks

Task	Title	Duration	Barriers
Task 1. Advanced roof systems and construction methods			
1-1	Integration of PCM, Cool Colors, ASV, Radiant Barrier and Advanced Lightweight Insulations	2008-2015	A, C, D, F
1-2	Regionally Optimize Above-Sheathing Ventilation	2008-2015	B, C, D
1-3	Best Practice for Integration of PCM in Roof and Attic Assembly	2008-2015	A, B, F
1-4	Demonstration of Dynamically Active Roof and Attic	2008-2015	E, F
1-5	Consolidation of Existing Energy Estimating Tools	2008-2015	I
Task 2. Advanced Wall Systems			
2-1	Whole-House Demonstration of Advanced Wall System	2008-2011	A, B, D
2-2	Improved Wall Panels	2008-2011	D, E, F
Task 3. Advanced Foundations		2009-2015	D
Task 4. Envelope Materials		2008-2015	F, H
Task 5. Enabling Technologies			
5-1	Moisture Analysis	2008-2020	H, I

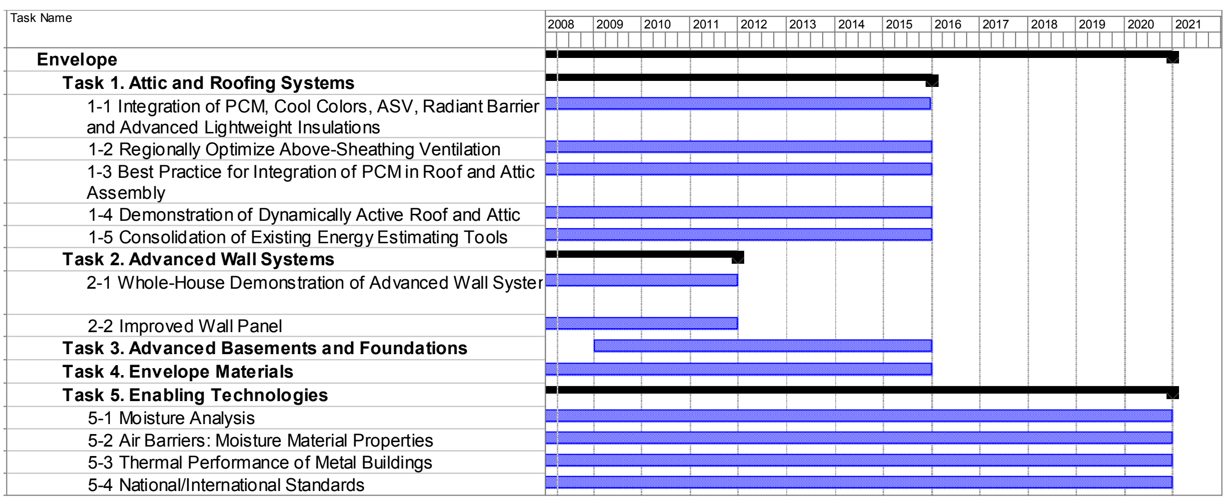
Task	Title	Duration	Barriers
5-2	Air Barriers: Moisture Material Properties	2008-2020	H
5-3	Thermal Performance of Metal Buildings	2008-2020	B, D, E
5-4	National/International Standards	2008-2020	A, B, C, H

Technology development is managed using the Stage-Gate methodology adopted by BT in FY 2005. The Envelope subprogram follows the five gate process and then hands-off developed components to Building America where the envelope technologies are installed in homes.

2.5.6 Envelope Milestones and Decision Points

The Envelope subprogram follows the schedule shown in Figure 2-20. Key technologies for Residential Integration are completed by 2015 to incorporate into Building America research homes.

Figure 2-20 Envelope Gantt Chart



2.5.7 Envelope Unaddressed Opportunities

Additional technology pathways are required to meet the performance targets and overcome barriers within the Envelope subprogram; several tasks have been identified as unaddressed opportunities. Foundations research has only been conducted on a limited basis and as other areas of the envelope are improved, the fraction of energy that is lost through the foundation will become a much larger portion of the total energy consumption. Foundations are generally poorly insulated and there are several opportunities for improvement. Roofs are a high priority within the core funded program; however, virtually all of the research is focused on the next generation of technology for residential homes. While there is Materials research in the core program, there are a multitude of other materials research topics that should be investigated. Lastly, while the Residential program concentrates on the integration of technological solutions with our Building America Team partners, there are sophisticated integration issues that can only be addressed within a high technology laboratory setting. Once these issues have been resolved and optimized on a laboratory basis, then they can be validated in a field setting with the Building America Teams. The tasks listed below are not currently funded.

- Roofing Membranes and Underlayments
- Moisture Buffering Investigation
- Thermally Enhanced Insulation Performance Using Nano-Scale Infrared Opacifiers
- Building Envelopes Residential Test Facilities to remove barriers to collaboration
- Air Pressure Dynamics Testing Facility
- Integrated Building Envelopes

2.6 Windows

Table 2-36 Windows Summary

Start date	1980
Target market(s)	New and existing residential and commercial buildings
Accomplishments to date/Past Activities	• Supported the SAGE and LBNL collaborative design and build of the first highly insulating, switchably glazed window unit. • Completed the New York Times building project, the largest fully daylighted space in the US. • Instrumental in the development of low-e windows that resulted in \$8 billion dollars in net benefits to homeowners.[120] • Demonstrated technical feasibility of thin-film dynamic windows, and supported industry efforts to achieve market-ready first generation products (R&D 100 Award). Measured energy savings with first generation products. • Developed innovative methods for plasma-assisted sputtering to improve manufacturability of energy-efficient coated glazings (R&D 100 Award) • Highly-insulating windows – first field demonstration of window products that outperform insulated walls in cold climates • Enabling technology research for efficient products - suite of software tools in widespread use throughout the industry leading to rapid innovation and product development cycle, reducing the time it takes industry to develop a new product • Partnered with industry in development of the National Fenestration Rating Council (NFRC) window energy rating system, now used to rate over 100,000 products in U.S. and referenced by the ENERGY STAR Window program and most state and federal standards • Daylighting – demonstrated measured lighting energy savings of 40 to 70 percent in daylighting applications; and encouraged industry adoption of techniques with new handbooks, tools and initial web site to provide design guidance • Advanced façade systems – demonstrated integration concepts and control strategies for dynamic, high performance systems that reduce heating, cooling and lighting using a unique, highly instrumented façade test facility

[120] *Energy Research at DOE: Was it Worth It? Energy Efficiency and Fossil Energy Research 1978 – 2000*, 2001, National Academies Press. Hereafter, NAP.

Current activities	1. Dynamic windows – first generation smart windows introduced to market, coating improvements aimed to reduce market prices, initial field test results define issues and potentials, and technical progress in second generation alternative designs 2. Highly-insulating windows – progress in aerogel development, new concepts for high-R windows using gas fills and low-e coatings resulted in demonstration prototype, and thermally improved frames for commercial buildings under development 3. Enabling technology research for efficient products – development of WINDOW6 and supporting THERM6, optics modules, and adding complex glazings and shadings to the tool suite 4. Daylighting and advanced façade systems – enhancement of the Commercial web site, development of first COMFEN software tool prototype, and field measurements of integrated daylight dimming and motorized shades.
Future directions	*Dynamic windows:* Reduced manufacturing costs and improved switching range and durability for first generation coatings as well as new second generation coatings that intrinsically provide better performance at lower costs. Extensive field testing in partnership with industry to develop new operational control strategies that optimize energy performance and comfort for different building types and climates *Highly-insulating windows:* Improved aerogel and vacuum glazings at lower costs; multi-layer glazing, low-e and gas-filled windows reaching R-10 glass values; and improved sash and frame insulating values. Integrate high-R technology with dynamic technology to achieve net-zero window performance. *Enabling technology research for efficient products:* Complete modeling capabilities for complex glazings and shadings within the WINDOW suite, and examine other applications for software and other functionality that should be added to serve industry's development of advanced products and for understanding advanced fenestration impacts on whole building energy use and peak *Daylighting and advanced façade systems:* Explore and develop new high performance optical materials for daylight control; and continue façade integration studies (e.g. with major building owners), with the goal of stimulating market pull to provide cost-effective hardware and systems solutions to optimize energy performance and comfort. Complete a suite of tools for specifiers, consultants, architects, engineers and owners for

	engineering and optimizing high performance façades.
Projected end date(s)	2020
Expected technology commercialization dates	Dynamic windows: 2008 – 2015 Highly-insulating windows: 2008 – 2015 Enabling technology research for efficient products: 2008 – 2020 Daylighting and advanced façade systems: 2008 – 2020

The term "windows" is used generically here for a wide range of fenestration systems: combinations of glazing, sash, frames, shading elements, and other energy control features. These windows can be inserted into vertical walls or become the entire façade; they can be used in sloped glazing applications; and they are used as skylights and other forms of roof glazings. Custom units are applied to light wells, light pipes and other daylighting redirection technologies.

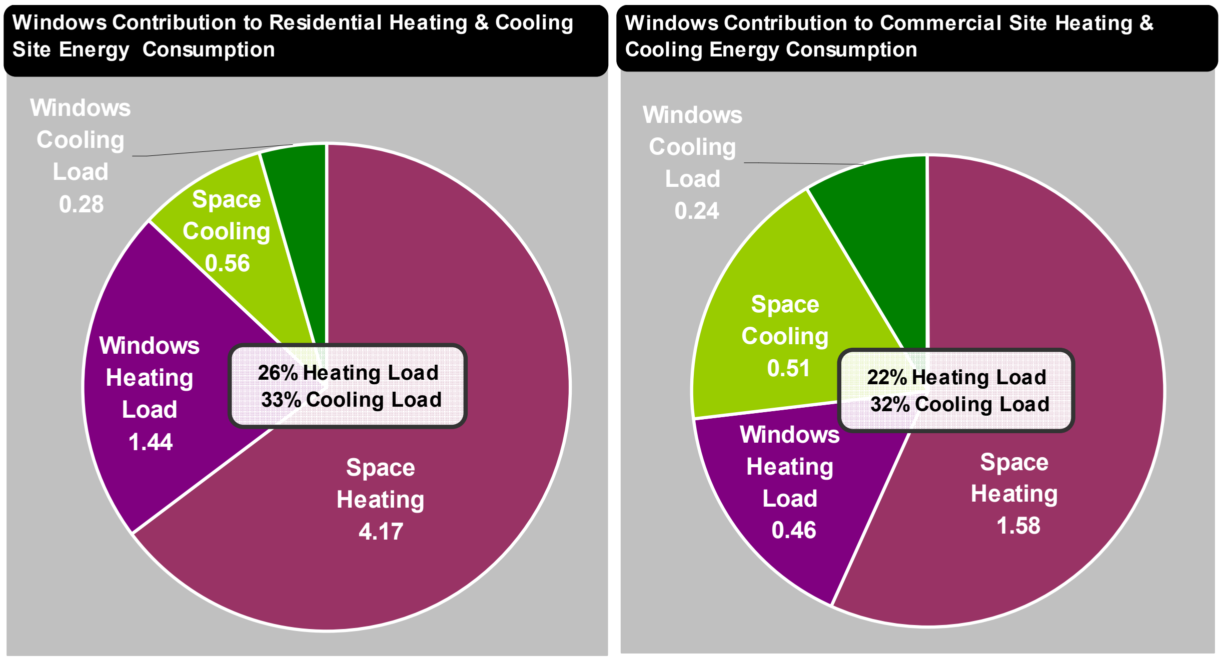
Windows are applicable in all building types in all parts of the country. About 60 percent of window sales are to the residential sector and 40 percent to commercial, and approximately half of all windows sold are in new construction and half are installed in existing buildings. Therefore, windows for new and existing residential and commercial buildings are included in the R&D subprogram.[121]

2.6.1 Windows Support of Program Strategic Goals

Windows typically contribute about 30 percent of overall building heating and cooling loads with an annual impact of about 4.4 quads (Figure 2-21)[122] and there is the potential to reduce lighting impact by 1 quad through daylighting. The energy and demand impacts of windows are complex as they do not intrinsically consume energy resources. A non-optimal window can add to a heating or cooling load, and the building requires additional energy to maintain comfort. On the other hand, a window can provide heat to a home in winter by letting light– and thus heat– pass through the building envelope without consuming energy in the process. A window can also comfortably light a room throughout most of the day without requiring electricity. Since windows are not directly connected to metered and purchased energy flows, their impacts on building energy use are via other building systems, such as space conditioning and lighting. These linkages are sometimes complex and the net quad impacts of these systems in buildings must typically be calculated rather than metered.

[121] *Characterization of the Non-Residential Fenestration Market*, Lawrence Berkeley National Laboratories and Northwest Energy Efficiency Alliance. Prepared by Eley Associates, November 2002. Report No. 02-106.
[122] BED

Figure 2-21 Residential and Commercial Energy Loads Attributed to Windows in Quads[123]



The potential role of windows as a *net energy gainer*[124] is a unique role for windows relative to most other building systems that simply consume energy. Furthermore, building owners do not need to be convinced to add windows to their buildings because they include windows for other reasons such as view, natural light, and aesthetics. Finding the best performing windows for specific applications is often challenging because building owners need to know which window technologies, sizes and applications are ideal for their building type, orientation, and climate. Unlike many building elements, the optimal window, from an energy performance perspective, is highly dependent on climate, orientation, and building use characteristics.

Windows have the technical potential to supply useful energy services to a building by providing solar heat gain in the winter and daylight year round, thus contributing to the BT ZEB goals. The overall BT approach is to first convert windows from their current role as significant thermal losses to the point where they are energy neutral (where useful gains equal reduced losses), and then move to a higher level of performance where they contribute to a net energy surplus. The thermal and daylighting benefits provided by high performance windows offset other building energy uses, and the surplus energy contributes to the BT goal of ZEB. In order to provide net benefits windows must be significantly improved in terms of their current impacts on heating, cooling and lighting.

[123] BED
[124] Windows do not directly produce energy as PV or wind power would; however, when optimized they have the potential to eliminate the need for lighting energy while reducing heating and cooling loads.

Furthermore, in order to meet the demanding ZEB performance goals they must change their role from that of a static element to a dynamic element since performance requirements change by hour, season, and weather conditions. The details of windows' optimization strategy may vary with building type and location, but the general approach is to greatly reduce, thermal losses in winter, capturing solar gain captured when available (subject to comfort requirements, e.g. no overheating). In summer, sunlight must be carefully controlled (and typically excluded), subject to the need for view and daylight. Daylight is desired in almost all seasons and conditions, but it must be balanced with comfort constraints. Finally, these demanding energy performance goals must be met in the context of technology that addresses many other practical concerns (e.g. safety, affordability, appearance, view, durability, and maintenance). The challenge is to create a window system whose function, and therefore properties, will change dramatically throughout the year; thus, leading us in the direction of "smart, dynamic" systems, a key BT R&D priority.

2.6.2 Windows Support of Program Performance Goals

Windows supports BT performance goals by introducing advanced windows technologies and practices for both residential and commercial buildings. These activities enable Residential Integration to achieve a 70 percent reduction in energy consumption by 2020 and Commercial Buildings to develop technology packages that reduce consumption by 50 percent by 2015 and 70 percent by 2025. Table 2-37 lists the performance measurement targets for the Windows subprogram that work towards BT performance goals. All performance measurements are relative to the historical baseline set as new construction in 2003.

Table 2-37 Windows Performance Goals

Characteristics	Units	Calendar Year			
		2007 Target	2010 Target	2015 Target	2020 Target
Dynamic Solar Control	Price/SF	$50	$20	$8	$5
	Size (Sq. Ft.)	16	20-25	25+	25+
	Visual Transmittance	60 to 4%	65 to 3%	65 to 2%	65 to 2%
	Solar Heat Gain Coefficient	0.50 to 0.10	0.53 to 0.09	0.53 to 0.09	0.53 to 0.09
	Durability* (ASTM Tests)	High	High	High	High
Enabling Technology Research for Efficient Products	Tool Capability for Residential (R), Commercial (C) and New Technology (N)	R – Fully C – Partial N – No	R – Fully C – Fully N – Partial	Assess need for industry support	Assess need for industry support
Highly Insulated Windows	U-Value	0.20-0.25	0.17	0.10	0.10
	Incremental Cost $/ft^2	5	5	4	3

Daylight Redirecting	Percent Lighting Energy savings	50	50	60	60
	Perimeter Zone Depth (Feet)	15	20	20	30
	Incremental Cost $/ft^2 – Glass	8	8	6	6
*Represents component durability, system reliability will be addressed in future years, < 20K cycles – Low; 20K – 50K Cycles – Medium; > 50K Cycles – High					

Given the target windows improvements above, and the impact of windows on energy use in the nation's building stock, the Windows R&D subprogram has four objectives. They are listed below with a rationale for how the performance requirements above are translated into these objectives.

Dynamic Windows
Develop optical switching coatings that provide dynamic control of sunlight over a wide-range (center glass: Visible Transmittance VTc: 0.65 - 0.02; SHGCc: 0.5 - 0.1) while meeting market requirements for cost, size, durability, and appearance. The dynamic windows should be integrated into building control systems to provide energy and comfort improvements in all buildings in all climates.[125]

Enabling Technology Research for Efficient Products
Develop the tools, test facilities and data resources needed to accurately predict component, product, and systems thermal, optical, daylighting, and energy performance under a full range of operating conditions. Support industry product rating efforts to facilitate deployment of efficient technologies. Ensure that tool capabilities are updated, so they remain a relevant and integral part of industry's R&D process.[126]

Highly-insulating Windows
Reduce heat loss rates of windows and skylights from current market values (ENERGY STAR) of 0.35 to 0.1 Btu/^{o}F-hr-ft^2 using technology solutions that meet market needs for

[125] The range of control is needed to provide the equivalent of a clear window in the clear state and a highly-reflective window that can modulate bright sun to comfortable levels. The range of control can be provided functionally in two ways: intrinsically in the glass system, or as an "add-on" shade, blind, or similar element that modifies the window properties. These "mechanical" devices inevitably have operating mechanisms that require replacement periodically. Thus, the ultimate objective for the industry is to provide the control function within the glass system.

[126] Windows are unlike almost any other building system in that a single set of windows will never provide optimal performance in all building types and climates. State of the art measurement and simulation tools are essential to guide public and private sector R&D investments in new technology, to guide architects and engineers in their integrated design of complete building systems, and provide feedback on how actual field performance compares to predictions. These tools and resources provide enormous leverage since they are made available to the entire industry, and have been shown to be accurate and unbiased.

cost, optical clarity, weight, durability, manufacturability, and other key features. Provide solutions with high solar heat gain for use in northern climates. The overall objective includes not only improvements in center of glass, but in edge and frame conditions also.[127]

Daylighting and Advanced Façade Systems
Develop daylighting technologies that displace 50-90 percent of annual electric lighting needs in perimeter zones, and extend perimeter zones to increase building-wide savings. Develop integrated façade solutions that achieve net 60-80 percent energy and demand savings compared to façades that meet ASHRAE requirements for typical climates.[128]

2.6.3 Windows Market Challenges and Barriers

Window designs and material selections are typically constrained by cost, performance, appearance and additional non-energy factors. The relative importance of these parameters varies between new versus retrofit, residential and non-residential, and owner-occupied versus leased space. Windows are a very visible element in most homes, unlike insulation or HVAC equipment which are typically hidden from view. However, evaluating window performance is complex; since windows do not directly consume energy, their impacts on home or business energy bills are often misunderstood. Many benefits of advanced windows show up as systems benefits (i.e. reduced HVAC sizes and duct runs, greater flexibility in space use, and increased comfort). Thus energy reductions and financial benefits are not directly attributable to windows, which make marketing high-performance windows challenging. These benefits have many secondary financial benefits and will influence decision-making and adoption of new technology, but there must be educated demand from builders and users (Table 2-38).

[127] An end use breakdown of window energy impacts shows that heating energy is currently the largest end use. The most direct way to reduce heating energy is to reduce thermal losses as addressed in this objective. The reduction in U-value must be balanced by providing a suitably high solar heat gain coefficient in winter to capture sunlight.

[128] The single largest energy use in most commercial buildings is lighting and the use of daylighting technologies in smart façades to capture daylighting benefits addresses this need. To offset electric lighting energy, three requirements must be met: daylight must be admitted and distributed as needed, overall intensity must be controlled to provide glare control and prevent overheating or adverse cooling impacts, and electric lighting must be controlled, e.g. dimmed, to save energy and reduce demand. Success thus requires a degree of integration that is not currently available in U.S. markets.

Table 2-38 Windows Market Challenges and Barriers

Barrier	Title	Description
A	High first cost for innovative products	New technologies that can increase the energy efficiency of windows can lead to higher first cost for innovative window products.
B	Lack of educated demand	There is a lack of "educated demand" for innovative products – builders and end users can be unaware of the significant benefits that are afforded by energy-efficient window products.

2.6.4 Windows Technical (Non-Market) Challenges/Barriers

The fundamental technical challenge is to produce technologies that are so efficient that they can convert the window from a net energy drain to energy neutral, and then to a net energy gainer. In order to reach these goals, windows need better static properties (e.g. much lower U-value). In addition, windows need dynamic performance properties to balance tradeoffs in winter versus summer, glare versus view, and daylight versus solar gains to decrease space conditioning loads while promoting comfort. The Windows subprogram needs to capture the benefits of daylighting in all buildings and all climates, but primarily in commercial buildings where the lighting bills are higher.

Windows will increasingly become dynamic and "smart" with sensors and active control elements. These units must be integrated with other smart building elements (e.g. dimmable lighting) and into the overall building control system. Currently, the industry is not well positioned to aggressively pursue these kinds of partnerships.

Finally, the window technologies and systems listed here are not inherently self-optimizing and self-assembling; architects, engineers, homebuilders and homeowners need data and tools to guide decision-making and optimization. Since windows are intended to last 20 to 50 years,[129] access to sufficient information is critical during the design and building process because windows are only changed at a greater cost later.

The barriers to commercially available innovative window technologies were identified in the Windows Technology Roadmap, published in 1999 (Table 2-39).

[129] Historically windows have lasted over 100 years because they were single pane. Since double pane windows have greater failure modes, the window industry is experiencing a paradigm shift.

Table 2-39 Windows Technical Challenges/Barriers

Barrier	Title	Description
C	Technical risks inhibit investments	There are technical risks associated with industry's investment in new technology.
D	Inability to predict performance	Industry may be unable to adequately predict the performance benefits from new technology.
E	Inadequate or inconsistent building codes	Building codes are dissimilar from state to state and across regions. They can also be poorly enforced, and inconsistent with national and international guidelines and codes.
F	Lack of integration tools	Industry lacks integration tools that are necessary to achieve system integration.
G	Durability issues	Industry lacks assurance that durability issues have been adequately addressed for advanced technologies.

2.6.5 Windows Approach/Strategies for Overcoming Challenges and Barriers

All of the barriers represent areas where the federal government can provide support to change the energy marketplace; the ideal BT role varies in different project areas. In the case of high-risk technical R&D, government support in the form of cost shared R&D reduces the risk for companies to develop innovative technology. In many cases, the company with the new idea has neither the market experience nor the capital to set up manufacturing and distribution. BT might play a partnering role to expose small innovative firms to market leaders with the capability of commercializing the window once the R&D is successfully completed. Once a technology development project moves beyond specific technical milestones, the activity may exit the Windows subprogram as manufacturers take a lead role in development and commercialization.

In other cases, technology R&D may be successfully concluded, but the functional impacts of the technology are not well understood or accepted by potential purchasers. In this case, field testing or other third-party testing provides accurate unbiased data on technology performance. Measurement and evaluation protocols are often not available for new technologies and BT support can provide accurate unbiased approaches. In a similar way, designers must have the analysis tools to assess performance of design options when new materials and systems are being used. Designers are risk-averse, and will not risk their professional reputation to try technologies for the first time if they cannot confidently predict performance. The product manufacturers often do not have the capability or resources to produce the evaluation tools and specifications, and even if they did, designers would unlikely to put full faith in the information due to perceived producer biases in favor of their own products.

In terms of technology development, there is profit motivation for a company to complete the R&D and get the technology to market so that it can begin to earn money. In other non-technology areas such as providing accurate information and tools, BT may need to play a longer-term role if there is no suitable business for industry to take over the BT role and if the lack of such activity would significantly reduce energy savings impacts. In such a case, Windows strategy may eventually involve developing a mechanism for those in industry who benefit from the service to pay for it, as done in 2006 with the International Glazing Database. Finally, BT is not the only public sector partner with an interest in more efficient energy use and demand control. State energy agencies, non-profits, and utilities all have an interest in sustaining public goods activities such as those supported by BT. An explicit strategy in this subprogram is to partner whenever possible with other parties for co-support of R&D. The electrochromic field test program is an example where the California Energy Commission (CEC) has matched BT's funding for a three-year field test program.

The fenestration marketplace serves a variety of distribution pathways, price points and architectural styles. Early adopters (and therefore potential partners) may be large existing manufacturers (e.g. Andersen windows led the market with Low-E products) or a smaller niche player catering to a specialty market (Southwall offered highly-insulating glazings in the 1990s). Each has different needs and interests to facilitate market impacts. BT can facilitate product innovation and development by methods other than direct support of product development. Through leveraging the purchasing power of owners when incremental innovation is needed, BT can provide cost-shared support of a demonstration with a major building owner. The owner's willingness to sign large procurement contracts induces manufacturers to invest in R&D to develop new product lines for large projects, and the products become available to everyone.

However, the building industry traditionally has been slow to innovate, and slow to adopt demonstrated technology into the marketplace. The commercialization of low-E and other innovations has been studied to better understand the drivers of successful innovation leading to large-scale market impacts. Based on this work, the subprogram leverages several market trends to overcome obstacles in the marketplace.

Windows serve numerous non-energy needs (e.g. view, acoustics, appearance), and are valued by most building owners. Coupling energy functions with other desired occupant benefits is a strategy for maximizing market impacts of efficient products. Low-E market penetration was accelerated by the marketing arguments for improved comfort and ultraviolet-fading resistance.

Utilizing the strategies listed in Table 2-40, the subprogram addresses market and technical barriers. In addition, crosscutting support within BT subprograms could facilitate industry progress towards high-end, high-performance windows.

Table 2-40 Windows Strategies for Overcoming Barriers and Challenges

Barrier	Title	Strategy
A	Lack of educated demand	Develop tools to inform consumers, and recruit partners to maintain tools in the future. Work with voluntary program sponsors (i.e. CEE, LEED, NAHB, etc) to promote advanced windows
B	High first cost for innovative products	Fundamental research on dynamic and highly-insulating windows is directly related to cost reduction
C	Technical risks inhibit investments	In association with fundamental technology development, conduct case studies and field studies with partners
D	Inability to predict performance	In association with the National Fenestration Rating Council, work to ensure all products (dynamic and highly-insulating) are properly rated
E	Inadequate or inconsistent building codes	Provide fundamental tools regarding energy performance of windows so that other government and non-government organizations can promote improved codes
F	Lack of integration tools	Develop control and system performance algorithms to optimize dynamic and advanced façade systems for energy savings and peak demand reduction, while addressing comfort, glare and occupant acceptance
G	Durability issues	Assist industry with the establishment of universal certification for today's and the next generation of fenestration products. Develop fundamental test protocols to predict durability.

Development of cost-effective, highly-efficient glazing and fenestration systems for all building types and all parts of the country will require a portfolio of projects that address the key barriers through the strategies outlined above. The general approach for the subprogram can be considered as three key elements:

1. R&D on dynamic windows, highly insulating windows, daylighting and advanced façades.

2. Lab and field testing to quantify and demonstrate the benefits of new technologies for industry
3. Development of improved analytical tools and software to enhance the ability of industry to assess, adopt, and commercialize new technologies; thereby, reducing industry risk

The subprogram R&D will focus on breakthrough, high-risk technologies that are likely to product large energy savings if successful and technologies that have the potential to be readily adopted by industry. Windows will also address technology areas in which industry under invests – e.g. there is no profit motive to engaging in the R&D, or there are no established market mechanisms to support the efforts.

Below are key task areas of research conducted in the Windows subprogram.

Dynamic Windows

- **Reflective hydride dynamic windows**: The presence or absence of sunlight is effectively the single largest natural energy flow in a building. Therefore, switchable coatings for glass or plastic that would enable dynamic control of this energy flow are sought by the Windows subprogram.BT research will continue to develop the second generation of materials, chemical engineering applications, and advanced manufacturing processes that can offer substantial reductions in cost for dynamic windows while maintaining a high level of reliability and durability with a broad range of optical properties. The key FY 2009 goal will be to further improve durability and scale the prototypes up to larger sizes. The second generation of dynamic windows is targeted to enter the market in the 2010 to 2015 timeframe with substantially lower prices.

Highly-insulating Windows

- **Develop high-R frame designs and advanced materials solutions**. When high-R glazing systems are used in typical residential window frames, about half of the heat loss through the entire window is through the frame. Improving the heat transfer of a frame system is difficult because frames must perform so many functions: in addition to being structural components, they must be weather resistant, operational, and durable. BT will develop advanced materials with innovative thermal properties which can be used to reduce heat loss in all building types. FY08 efforts will develop strategies for design and construction of high-performance frames for residential applications. Topics examined will include: how low-conductivity materials are used, the potentials of insulating voids, the use of thermal breaks in selected areas, suppression of radiation and convection within voids, interactions of spacers, impacts of hardware, and product design for function.

- **Develop low-cost, high-R value insulating glazing units.** The best performing windows in the U.S. market today have U-values in the range of 0.15-0.35. Many of these windows achieve these performance levels using multiple glass panes and gas-filled air spaces. These designs tend to be heavy and costly, and have not achieved significant market share. The cost and market acceptance of these prototypes are critical design features for consideration. Technical progress must be matched with other research activity that integrates the new glazings into full frame and façade systems. The optimal tradeoffs for heat loss and solar heat gain must be considered for each climate. Developing new high performance glazing variants using proven, available components allows industry to better utilize their existing manufacturing infrastructure and keep costs low.

Enabling Technology Research for Efficient Products

- **Develop tools to assist manufacturers in designing more efficient products.** In the past, product innovation was slowed by the time and costs required to design and build a prototype, to test the prototype and assess its performance problems, to return to the shop to re-engineer the prototype, and then to begin the process over until desired results are obtained. Powerful new computer tools have been developed that enable manufacturers to quickly and cheaply design and prototype new "virtual products." The same toolkit has been adapted for use to determine rating and labeling properties. Tools include software packages for heat transfer and solar gain through glazing, heat transfer through framing, and the associated databases that are required to operate the tools. The tools need to be carefully validated by BT with state-of-the-art measurement in appropriate thermal test facilities. The capabilities of these tools need to be extended so that they stay current with (and preferably stay ahead of) materials R&D efforts. The lack of such tools will slow industry investment in innovative technology if the properties and benefits cannot be objectively quantified.
- **Provide technical assistance for BT mandatory and voluntary programs.** BT leverages its work by partnering formally and informally with other organizations that promote energy efficiency such as utilities and state and local agencies. BT partners with these groups to ensure that its information is made available to those activities to encourage widespread adoption of the energy-efficient windows. One of the largest beneficiaries of the Windows R&D activity is the ENERGY STAR Windows program which is based in part on simulation results from BT tools.

Daylighting and Advanced Façade Systems

- **Develop daylighting technologies.** Develop and assess performance of new daylighting technologies that increase savings in perimeter spaces and permit deeper penetration of daylight, allowing extension of the effective zone of daylighting savings. Compared to 20 or even 50 years ago, there are few products today on the market that employ significantly different optical performance to obtain better daylight management (this contrasts with thermal management where there have been major advances). Optical technologies continue to evolve quickly in other fields and some represent a potential use in buildings. Scan emerging optical technologies, assess the subset that make sense for use in buildings, and develop these into viable daylighting products. Several high performance systems are in the marketplace for roof lighting applications (e.g. light pipes), so the near-term emphasis is on optical systems for vertical façades.

- **Façade system integration and optimization.** Façade systems use more than glazing and framing. The best systems today employ some form of dynamic shading and link to dimmable lighting controls. Develop control algorithms, new sensor technology, shading controllers, etc. and demonstrate overall performance of the complete system in test facilities and in the field. Develop commissioning and operation strategies to ensure that projected savings are realized. Undertake collaborative work with the International Energy Agency (IEA) and other international partners as a vehicle for exploring more options at lower cost and gaining access to additional product and performance data.
- **Field testing of façade systems.** Façade systems are complex entities whose overall operation is often more that the sum of the parts. Many aspects of performance can best be assessed by direct observation and extensive testing in a completed building. Accurate data for calibrating simulation models can best be obtained in highly instrumented controllable facilities where comparative and absolute measurements can be made under controlled conditions. BT funded the construction of a unique three room test facility which has been designed to accommodate a range of glazing, window and façade systems. To date the facility has been used extensively for electrochromics testing but it is now being reconfigured to study dynamic motorized façade shading and daylighting systems.
- **Develop information resources for system designs.** Develop a series of decision support materials to assist designers and building owners to select appropriate daylighting and façade systems. This includes a tiered set of tools to address the differing needs of different users, such as a book, a website and a variety of other information resources including daylighting modeling tools, a custom annual energy model specifically for fenestration performance assessment at the whole building level, as well as addressing non-energy impacts, such as glare, that are critical to decision-making. Develop measurement tools and protocols to assess qualitative and quantative aspects of daylighting performance in buildings.

Table 2-41 provides an overview of BT’s currently planned or funded core tasks that support Windows’ strategies.

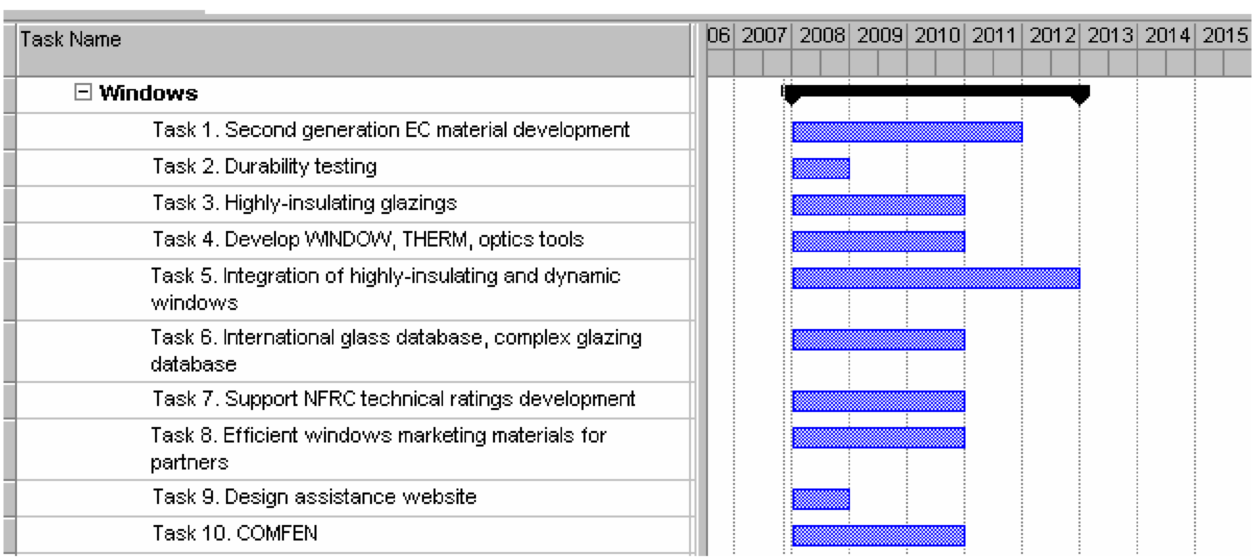
Table 2-41 Windows Tasks

Task	Title	Duration	Barriers
1	Second generation EC material development	2008-2011	B, D
2	Durability testing	2008-2009	G

3	Highly-insulating glazings	2008-2010	B, D
4	Develop WINDOW, THERM, optics tools	2008-2010	A
5	Integration of highly-insulating and dynamic windows	2008-2012	DB, D
6	International glass database, complex glazing database	2008-2010	C
7	Support NFRC technical ratings development	2008-2010	C, E
8	Efficient windows marketing materials for partners	2008-2010	A
9	Design assistance website	2008-2009	A
10	COMFEN	2008-2010	A

2.6.6 Windows Milestones and Decision Points

Figure 2-22 Windows Gantt Chart



2.6.7 Windows Unaddressed Opportunities

The Windows subprogram has identified several tasks as unaddressed opportunities. These tasks are recognized as integral steps to addressing the barriers and meeting performance targets. However, there is currently either inadequate or no funding for these opportunities listed below:

- New Integrated Window Systems for Airflow Control and Natural Ventilation
- Smart Glazings and Coatings

- Field Demonstration of Net-Zero-Energy Fenestration Solutions
- Software Tools for Zero-Energy Façade and Building Design
- Green Design and Sustainable Fenestration Products
- Laboratory Tests for Emerging Products
- International collaboration

2.7 Analysis Tools

Table 2-42 Analysis Tools Summary

Start date	1977
Target market(s)	Architects, engineers, energy consultants, researchers, standards developers, building owners
Accomplishments to date/Past Activities	• EnergyPlus, Award for Excellence in Technology Transfer, 2004, Technology Transfer and Intellectual Property Office, Lawrence Berkeley National Laboratory • EnergyPlus, R&D 100 Award, 2003 • EnergyPlus, Award for Excellence in Technology Transfer, 2002, Federal Laboratory Consortium • EnergyPlus, IT Quality Award for Technical Excellence, 2002, U.S. Department of Energy Chief Information Officer Annual Awards • DOE-2, Energy 100 Award[130]
Current activities	Development, validation and testing of increasingly more capable versions of energy simulation program, EnergyPlus
Future directions	• Add capability to model absorption chillers that use exhaust heat from distributed generation sources as the energy source for the chiller desorber component • Include radiant heat transfer between attic surfaces, including radiant barriers, and duct surfaces because of the large temperature differences and large exposed areas that occur in attic zones • Model piping pressure drops to better account for pump energy. • Add a cooltower model (similar that used at Zion National Park Visitor Center) • Add model for wind turbine power generation at the building scale • Window modeling upgrades to match or use the capabilities of Window 6 and its successors
Projected end date(s)	2020
Expected technology commercialization dates	Commercialization of EnergyPlus began in 2001 with release of first version (1.0), continuing with two releases per year

[130] *Department of Energy Honors Most Notable Scientific and Technological Accomplishments*, U.S. Department of Energy, Office of Science, January 8, 2001.

Architects, engineers, and other building designers have always "envisioned" buildings before beginning construction. In the 20th century this process began with pencil sketches and inked drawings. These 2-D representations were sometimes supplemented with 3-D scale models to better understand spatial relationships and appearance. The engineering side of construction was supported by an elaborate infrastructure of tables and manuals that documented workable solutions derived from analytical calculations, cumulative empirical data, and the rules of thumb widely used in the construction industry. With built-in safety factors and incremental advances based on new findings, these approaches were adequate to support the slowly evolving buildings sector through most of the last century.

The sudden interest in building energy efficiency in the 1970s changed the information management needs of designers. The subsequent availability of cheap desktop computing and its software infrastructure continue to revolutionize virtually all aspects of design and construction. However, in most cases computers are relegated to doing conventional tasks, albeit more quickly and accurately. But there are also emerging opportunities where computers and simulation tools can provide novel analysis of complex interactions between systems and new performance insights that are revolutionizing building design and operation. Computers are certainly useful tools to sum the overall heat loss of a building quickly and more accurately than by hand. But powerful new simulation tools—which in a few minutes can calculate the behavior of building control systems and the resultant impact on energy use, peak demand, equipment sizing and occupant comfort—provide performance insights that have been previously unattainable. It is precisely these insights that are needed if the building community is to break away from a "business as usual" approach to energy use in buildings and effective design high performance and zero energy buildings.

Building energy performance, particularly in ZEB, is the result of interactions among many elements including climate (outdoor temperature, humidity, solar radiation and illumination), envelope heat and moisture transfer, internal heat gains, lighting power, HVAC equipment, controls, thermal and visual comfort, and energy cost—and these complex interactions cannot be understood and quantified without simulation tools. For example, the effect of daylighting dimming controls on the electric lights with daylighting has several effects: lighting electricity use goes down as does the heat gain from lights. Lower heat from lights reduces cooling use (amount depends on cooling equipment efficiency), but in the winter it can significantly increase the heating energy. Thus, the annual impact of daylighting on energy use requires detailed calculations that consider these interactions. The simulation tool must include control sensors, strategies, and systems; building performance in operation; and integrated airflow analysis to account for the complex interactions within a building. In a series of field evaluation case study reports, the National Renewable Energy Laboratory found that simulation tools were one of the essential elements for tuning the building design as well as the operating building performance.

BT software tools are the benchmark against which other tools are tested, with BT tools dating to the 1970s. BT produced a series of increasingly more sophisticated energy analysis tools, collectively named DOE-2, which finished in 1997. The initial program, DOE-2.1E, is currently the underlying calculation engine[131] for more than 20 tools and the basis for building energy standards development and research throughout the world. In The National Academy of Sciences in their review of the value of energy research at DOE, found:

> The development of this computer program [DOE-2.1E] also stimulated the promulgation of performance-based standards that provided designers with multiple ways to meet particular efficiency targets. The committee concludes that DOE-2 was influential in the development of both California's Title 24 and the American Society of Heating, Refrigerating and Air-Conditioning Engineers standards that have guided the development of building standards throughout the United States (and indeed the world). Compliance with these standards has resulted in significant energy, environmental, and security benefits.[132]

The Energy Policy Act of 2005 included tax deductions for commercial buildings, which creates both opportunities and challenges for the Analysis Tools subprogram. DOE developed processes for certifying energy analysis tools as qualified for use in calculating the commercial building tax deduction. The tax deduction has also increased demand for more capable building simulation software. Also, the California Energy Commission decided in late 2005 to move from DOE-2.1E to EnergyPlus for development and compliance with the Title 24 Standards (mandatory California building energy standards) partially for the 2008 standards and completely for the 2011 standards.

The goal of the Analysis Tools Sub-program is to ensure robust and accurate tools exist and are used to easily evaluate the design and operating performance of low energy buildings and to support research and development, and eventual design and operation of zero energy commercial buildings. The key features driving R&D in the Analytical Tools plan are:

- *Simplicity* - For all but the simplest buildings, architects and engineers require tools that permit rapid analysis of multiple design choices to assess their costs and performance levels.
- *Controllability* - Facility managers need greatly improved controls and energy information tools if they are to operate buildings efficiently under a wide range of typical conditions (occupancy, weather, and energy cost); dynamic conditions

[131] BT develops an unbiased, reliably tested 'engine' for calculating building energy flows. This engine is then used by the private and public sectors in the underlying calculation engine for a wide variety of tools and user interfaces.
[132] NAP

(e.g., real-time pricing and demand limiting); and finally under more stressful conditions (unusually high energy prices, weather extremes).
- *Flexibility* - Product developers, researchers, educators and others need a tool with capabilities that surpass the limitations of today's widely used tools. Examples of these are given later in this plan.
- *Interoperability* - Architectural and engineering firms will not react well to a flood of new tools, each of which describes the building and its parts in a unique way. A superior approach is to organize all tools around a shared, open building data model that allows each tool to transfer information seamlessly to others.
- *Marketability* - Industries with large energy costs and highly concentrated and capitalized firms typically use energy simulation tools. However, the buildings industry often lacks sufficient incentives to promote widespread use, so the public sector must take a leading role in developing analysis tools.

2.7.1 Analysis Tools Support of Program Strategic Goals

One of BT strategic goals is to develop the technologies and strategies that will allow zero energy commercial buildings to be constructed by 2025. Reaching this goal requires both improving the performance of individual building components (e.g. windows, appliances, heating and cooling equipment, lighting) and a revolutionary approach to building design and operation. Together, it should be possible to achieve up to 70 percent reductions in energy use with a careful integration of onsite or purchased renewable energy supplies. Similar technologies and design approaches can also be applied to improve the performance of existing buildings.

These high levels of energy efficiency and effective systems integration will not be achieved by basic technology substitutions or by expecting designers to simply meet tighter standards or apply prescriptive approaches to design. Achieving efficiency goals requires new capabilities such as a powerful simulation tool that supports evaluation of new ZEB demand-reduction and energy-supply technologies, as well as support for various decision points throughout the life cycle of building design and operation.

The Analysis Tools subprogram is working with other BT subprograms to transition their simulation program needs to EnergyPlus. To support BT activities that work towards ZEB, the Analysis Tools subprogram is extending the functionality of EnergyPlus, training the BT subprogram staff and lab researchers, and assisting with the transition to new methodologies. EnergyPlus is also being positioned by BT as the primary software tool for planning and analysis for codes and standards development. The focus continues on developing increasingly more robust versions of EnergyPlus that can be used to design net-zero energy and high performance buildings.

The primary technical goal of the Analysis Tools subprogram is to establish BT software tools as the primary calculation engine for evaluating the design and operating energy performance of integrated low and net-zero energy buildings, the BT strategic goal.

2.7.2 Analysis Tools Support of Program Performance Goals

The performance goals for Analysis Tools are shown in Table 2-43, and through meeting these goals, the subprogram will enable BT to meet its performance goals for energy reductions by evaluating buildings energy use.

Table 2-43 Analysis Tools Performance Goals

Characteristics	Units	Calendar Year	
		2010 Target	2015 Target
Extend Capabilities of Energy Analysis Tools:			
Support development, analysis and compliance with building energy standards (ASHRAE 90,1, 189.1, California Title 24)	Percent of technologies covered	80	100
Support BT RD&D (elements that currently employ building simulation tools that use EnergyPlus for research and analysis)	Number of BT elements	8	11
Coverage of state-of-the-art building energy efficiency and renewable energy and other ZEB technologies that analysis tools can evaluate[133]	Percent	75	90
Validate Energy Analysis Tools:			
Methods of test coverage of whole building analysis tools[134]	Methods Covered	4	6
Deploy Analysis Tools:			
Interoperability with other building design tools[135]	Percent	50	75
Design firms trained and provided continuing assistance on the use of EnergyPlus	Number	9	20
Extend EnergyPlus to other broader based engineering design tools	Number	2	2

The first strategic goal for Analysis Tools is to establish the software tools as the primary calculation engine of choice for evaluating the design and operating energy performance of integrated low and net-zero energy buildings. This objective will be measured by the percent coverage of state-of-the-art building energy efficiency, renewable energy and energy supply technologies that EnergyPlus can evaluate as compared to other similar software including DOE-2 and BLAST. In this case, the objective is considered met when EnergyPlus can evaluate 90 percent (by 2010) of the state-of-the-art technologies under development (by 2010) or planned (by 2015) by BT R&D.

---

[133] Including advanced and near-market technologies and systems, building integrated PV, on-site Combined Heat and Power (CHP)/Distributed Energy Resources (DER), controls strategies, predictive/optimization control systems, and multizone airflow and pollution transport

[134] See Table 2 for current status of validation methods of test

[135] Includes CAD geometry, CAD HVAC, CAD lighting and electrical, HVAC design, cost estimating, and project management. Current status is full interoperability with CAD geometry (the most difficult issue for interoperability) and the capability for interoperability with CAD HVAC, but there is no other tool yet able to share data.

The second aspect of the strategic goal is to establish EnergyPlus as the primary software tool for BT program research, planning and analysis. This objective is measured by the ability of EnergyPlus to address technical aspects of the BT subprogram, for instance, integrated building controls. Additionally, success is measured by the number of subprograms that rely upon building simulation tools that in turn use EnergyPlus. In both cases, the objective is met when 90 percent of the subprograms can use and are using EnergyPlus by 2010. By utilizing a common tool as well as analysis benchmarks, BT research and standards development will be more consistent and effective.

The second Analysis Tools goal is to work with designers of high volume, high visibility, and large buildings to demonstrate the value of building simulation. This effort initially focused on the leading firms, which now use DOE-2 for building energy simulation, and now aims to move them towards EnergyPlus through training workshops (three each year for three years with continued support). This objective will be measured by how many of these firms successfully transition to EnergyPlus; if two-thirds of these firms are using EnergyPlus regularly by 2008 the objective is met. Secondly, continuous testing and validation (using industry standards) as new capabilities are added will demonstrate that EnergyPlus can accurately simulate actual building performance and energy savings.

Each of the performance goals includes measurable progress that includes how well EnergyPlus approaches state-of-the-art technologies for net-zero and low-energy buildings and how many other BT subprograms have transitioned from alternative tools to EnergyPlus.

2.7.3 Analysis Tools Market Challenges and Barriers

Market challenges are the predominant barriers to simulation tool adoption (Table 2-44). Use of powerful tools to accurately simulate and emulate all aspects of product life-cycle performance is not a new concept: the aerospace, automobile and industrial process industries have developed such tools and routinely and successfully use them. These industries are typified by large energy costs, and highly concentrated and capitalized firms. However, in the buildings industry there is often little incentive to use energy simulation tools—the cost of energy is usually a secondary consideration in most building design. This gives private investors little motivation to make significant investments in building energy tool development. Thus if the large but diffuse energy savings in buildings are to be captured, it is up to the public sector to lead the development effort and to support deployment at least until the value of the tools is well established.

Table 2-44 Analysis Tools Market Challenges and Barriers

Barrier	Title	Description
A	Unrecognized value	The building industry does not realize the bottom-line value of simulation analysis, and has not adopted it as part of regular practice. An analysis tool, regardless of functionality, cannot provide benefit if no one uses it
B	Lack of interoperability	On today's design projects, most designers routinely use CAD and cost-estimating tools. But they often do not use energy simulation tools, in part because of the time and cost of data input and output, all constrained by limited design fees. The interoperability paradigm is necessary so energy simulators can quickly begin energy analysis using building design and geometry data imported directly from CAD tools.
C	Ease of use	An easy to use simulation tool is an important aspect of market acceptance. The private sector has already developed two major interfaces for EnergyPlus, but the pace is slow and an impediment to full adoption and use in the market.

2.7.4 Analysis Tools Technical (Non-Market) Challenges/Barriers

Much of the underlying technical research required to establish models of technologies, systems, and controls for new simulation capabilities is performed elsewhere – either by other BT subprograms or external research organizations, universities, and sponsoring organizations. For example, BT is not developing an easy-to-use interface for EnergyPlus because development is expensive and time consuming. One interface typically cannot serve all user needs so the private sector is better suited to develop interfaces that serve specific needs. Therefore, the technical challenges for the Analysis Tools subprogram focus on balancing accuracy of energy estimation techniques with usability and speed of calculation, and are not considered to be significant barriers

2.7.5 Analysis Tools Approach/Strategies for Overcoming Challenges and Barriers

The Analysis Tools subprogram will revolutionize the ways buildings are designed and operated. The Analysis Tools subprogram has identified a plan, relying on four strategic elements, to achieve the subprogram's goal and overcome challenges and barriers.

- *Extend Capabilities*: support standards development, incorporate advanced technologies, and enable zero-energy buildings evaluation through design and operation.

- *Validate Tools*: use a well-established internal process for in-house products and robust, widely adopted test methods for all building simulation tools.
- *Deploy*: target key owners and design firms through training and establish the value of energy simulation, provide seamless interoperation of buildings design tools and energy simulations, and extend capabilities to building operation.
- *Exit*: develop the institutions, protocols, and mechanisms to sustain this effort without DOE's direct and continued involvement.

The strategies for overcoming the barriers and challenges identified above are shown in Table 2-45. Much of the development activities for Analysis Tools will focus on demonstrating the value of building simulation. By working with interface developers, market leaders, and other key groups, Analysis Tools will work to overcome the interoperability and easy of use barriers, demonstrating the value of simulation tools.

Table 2-45 Analysis Tools Strategies for Overcoming Barriers/Challenges

Barrier	Title	Strategy
A	Unrecognized value	Extend the capabilities of energy analysis tools, and validate energy analysis tools. Demonstrating and deploying the right simulation tools to key design firms is a critical activity because it encourages utilization. These tools must prove accurate in their simulation of actual building operation.
B	Lack of interoperability	Deploy analysis tools. This vision of "interoperability" has been discussed for many years but is just now reaching commercial viability worldwide under the direction of the International Alliance for Interoperability (IAI).
C	Ease of use	Deploy analysis tools

EnergyPlus and its related tools, databases and documentation are an accessible portal, filter and archive for critical knowledge generated from BT research. The Analysis Tools activities within BT must be intimately linked to and supported by the other R&D and standards development activities to realize these benefits. As BT-developed technologies become market ready, the Analysis Tools subprogram will be ready with new modules which can easily allow others to simulate the benefits in an integrated, whole building design or retrofit. From the perspective of the building industry, a suite of tools which continuously embodies the best of BT R&D will effectively attract and maintain private sector interest in and involvement with EERE programs, making the tools a powerful deployment vehicle for BT.

Linking Analysis Tools with other R&D subprograms, BT management decided to adopt EnergyPlus throughout BT subprograms in 2005. This multi-year transition began in 2006 by focusing on Building America and training building simulation experts from key laboratories that were not yet using EnergyPlus. The transition requires a plan for each subprogram which identifies required capabilities that must be added to EnergyPlus and changes to the analytical infrastructure.

These strategies are implemented through the tasks shown in Table 2-46, which are described in more detail below. [136]

Table 2-46 Analysis Tools Tasks

Task	Title	Duration	Barriers
Extend Capabilities			
1	Support standards development, analysis, and compliance of ASHRAE 90.1 and California Title 24	2008-2015	A, B
2	Support BT R&D Elements	2008-2015	
3	Support evaluation, design, and operation of net-zero energy buildings	2008-2015	A, B
Validate Energy Analysis Tools			
4	Validate EnergyPlus	2008-2015	A, B
5	Develop "Methods of Test"	2008-2015	A, B
Deploy Analysis Tools			
6	Target key owners and design firms	2008-2015	C
7	Seamless extension of EnergyPlus and other tools	2008-2015	A, B
8	Tool-based services for operation	2008-2015	A, B
Exit Strategy			
9	Establish consortia	2008-2015	A, C

Incorporate Current Technologies, Systems and Controls into EnergyPlus. Energy standards, such as ASHRAE 90.1, ASHRAE 90.2 and California Title 24, were developed with whole building simulation tools and future improvements to these standards cannot be developed without analysis tools. New and currently available technologies cannot be considered in a standard unless the tool used to produce the standard can model that technology. Add currently available energy efficiency technologies that will allow EnergyPlus to be used for development of future standards

[136] The Analysis Tools Multi-year Plan (November 2003) provided an initial list of capabilities and features which are needed to successfully model ZEB. In FY 2004, we completed an initial identification and prioritization of future ZEB features. In January 2005, the Residential Integration team held a workshop with the Building America teams on issues and needs for simulation tools. As the transition to EnergyPlus occurs in other BT subprograms, their issues and needs will be added to the prioritized features for future releases. These needs have been added to the prioritized list of features for future releases.

and compliance with current energy standards. Certification of EnergyPlus for Title 24 2008 ACM, Scheduled Completion: FY 2008.

Develop Versions of EnergyPlus to Support Development and Evaluation of Low- and Zero-Energy Buildings. Based on prioritization completed in FY 2004, develop increasingly more ZEB-simulation capable versions of EnergyPlus. The prioritization will be reviewed and updated on an annual basis as new technologies reach the market, in consultation with leading design firms, and based on research progress in energy efficiency, renewable energy and energy supply technologies.

- EnergyPlus for 40 percent ZEB. Add prioritized features which allow EnergyPlus to be used in development and evaluation of 40 percent ZEB including simulating complex building control strategies and predictive-model control. Scheduled Completion: FY 2008.
- EnergyPlus for 60 percent ZEB. Add prioritized features which allow EnergyPlus to be used in development and evaluation of 60 percent ZEB including energy supply and control systems technologies. Scheduled Completion: FY 2009.
- EnergyPlus for 80 percent ZEB. Complete prioritized features which allow development and evaluation of 80 percent ZEB including multizone airflow, further controls technologies and strategies, as well as emerging energy supply technologies. Scheduled Completion: FY 2011.

Testing and Validation. Working with international and national industry groups, extend standard methods of test to cover the full matrix of validation methods for building simulation tools. Continue testing and validation of new features as they are added to EnergyPlus. Testing for each EnergyPlus Release, FY 2008-FY 2011. Complete IEA SHC Task 34, December 2007. Addenda and periodic updates to ANSI/ASHRAE Standard 140 in FY 2008 and FY 2010.

Push Analysis Tools into the Marketplace. Work with and train two to four leading-edge engineering/architecture design firms to employ EnergyPlus as part of their everyday design practice. Work with major HVAC manufacturers to adopt EnergyPlus as the calculation engine for their programs. Identify and support the analysis tools required for BT R&D and standards development efforts. Support efforts of national and international industry organizations that promote the use of analysis tools through training and conferences. Working through international interoperability standards, enable seamless and robust multi-directional data flow/exchange from CAD to EnergyPlus to cost estimating to facilities management and building operations. Support International and National simulation conferences, FY 2008-FY 2011.

The Stage-Gate process is used to manage Analysis Tools, ensuring the right projects are being funded, and the projects are working towards goals. Table 2-47 outlines the stages and gate criteria for Energy Plus.

Table 2-47 Energy Plus Stage-Gate Management

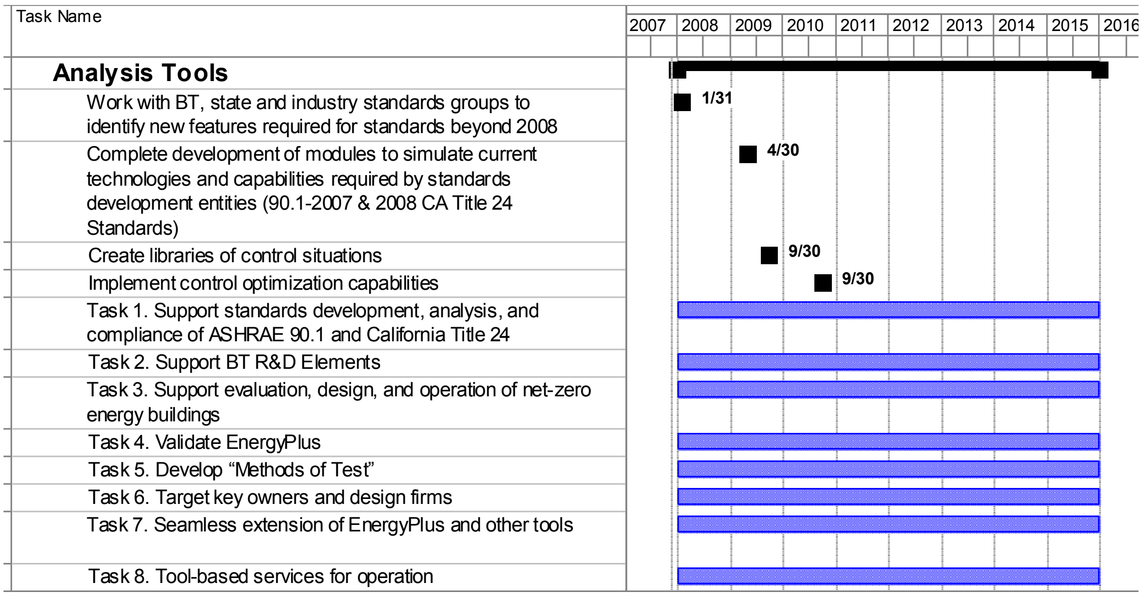
Stage	Title	Activities	Criteria	Key Deliverables
0	Ideation	Update list of potential enhancements with input from: • Development team • EnergyPlus users • BT R&D staff • Surveys of outside groups such as code developers and interface developers	• None at this Stage	List of desired features and enhancements
1 & 2	Analysis and Prioritization	• Prioritize list of potential features and enhancements • Prioritization team: BT TDMs, development team leads	Must Meet Criteria • Meet MYP goals and EnergyPlus and BT objectives? • Funding to cover anticipated cost? • Algorithm model and validation data exist? Should Meet Criteria • Significant energy impact? • Increase in market attractiveness of EnergyPlus?	Prioritized list of new features for next FY AOP
3	Advanced Development	• Analyze and document the data requirements and data flow • Develop initial design (flow chart) of module/feature	Must Meet Criteria • Models, data, and "hooks" identified? • Input/output definitions created? • Module prototype developed? • Example input files and output tables and report variables created? Should Meet Criteria • Input/output and engineering documentation developed?	Design specifications for module or enhancement
4	Engineering Development	• Develop and test code	Must Meet Criteria • Prototype tested/ debugged/retested? • Passed formal full set of the Standard Method of Test?	Prototype module

Stage	Title	Activities	Criteria	Key Deliverables
5	Product Demonstrati on	• Develop documentation • Continue code testing in beta version of EnergyPlus	Must Meet Criteria • Documentation developed? • Validity tests completed and available? • Version test/debug complete? • All other significant bugs fixed? Should Meet Criteria • User support offered? • All other identified bugs fixed? • Deployment activities underway?	Final code and documentation, ongoing support
6	Commercial-ization	• Licensing to interface developers • Support developers (interface and new modules) • Development of supporting tools	Must Meet • Licensed and distributed in other tools (interfaces) • Widespread use throughout BT for research and codes Should Meet • Growth in EnergyPlus licenses and downloads	EnergyPlus integrated in other tools: interfaces, other analytical tools, and code development/ compliance

2.7.6 Analysis Tools Milestones and Decision Points

The following milestones in the Gantt chart (Figure 2-23) cover the Analysis Tools activities, milestones and decision points in FY 2008 and beyond.

Figure 2-23 Analysis Tools Gantt Chart



2.7.7 Analysis Tools Unaddressed Opportunities

Several tasks within the Analysis Tools subprogram have been identified as unaddressed opportunities. The tasks listed below are outlined for overcoming barriers and meeting milestones of the subprogram; however, they are not currently funded:

- Work with leading-edge architecture and engineering firms to encourage their use of EnergyPlus
- Work with key HVAC manufacturers to encourage their adoption of EnergyPlus
- Work with the International Alliance for Interoperability to ensure that building energy is integral to the interoperability standards
- Provide technical assistance to user interface developers with operational issues of EnergyPlus

3.0 Equipment Standards and Analysis

Building Technologies' Equipment Standards and Analysis activities address our continuing legislative requirements to improve the minimum efficiency for buildings by implementing energy efficiency standards for appliances and building equipment.

National standards provide manufacturers with a single set of requirements rather than an array of potentially conflicting State and local regulations. By eliminating the most inefficient technologies, Equipment Standards and Analysis activities complement the other BT strategies which develop and promote advanced, highly efficient technologies and practices.

3.1 Appliance and Building Equipment Standards

Congress legislated initial federal energy efficiency standards and established schedules for DOE to review and revise these standards. For some products, Congress has directed DOE to set standards in the absence of initial standards or to determine if such action is necessary. Standards benefit consumers by requiring that appliance manufacturers reduce the energy and water use of their products – and thus the costs to operate them. BT's subprogram carries out activities in three areas: test procedures, mandatory energy conservation standards, and labeling,

- *Test Procedures:* DOE outlines the test procedures that manufacturers must use to certify that their appliances meet the standards. The test procedures measure the energy efficiency and energy use, providing an estimate of the annual operating cost of each appliance. Test procedures are typically maintained by industry associations and incorporated by reference into the rules set by DOE.
- *Mandatory Energy Conservation Standards:* DOE establishes federal standards to keep consistent, national energy efficiency requirements for selected appliances and equipment. By law, DOE must upgrade standards to the maximum level of energy efficiency that is technically feasible and economically justified. DOE strives to establish standards that maximize consumer benefits and minimize negative impacts on manufacturers and other stakeholders.
- *Labeling:* The Federal Trade Commission (FTC) is required to prescribe labeling rules for residential appliances. DOE and FTC share responsibility for labeling commercial equipment.

Recent requirements (associated with section 141 of the Energy Policy Act of 2005 (EPACT 2005), Pub. L. 109-58), which pertain to the Department of Energy's failure to comply with deadlines for new or amended energy conservation standards, led to DOE outlining its approach to appliance and equipment standards to Congress. The report covers the MYP associated with appliance and equipment standards, providing background on the subprogram. Specifically, it:

- Presents a history of appliance and equipment standards and the Process Rule adopted in 1996 that gives the reader a full understanding of the historical context and statutory requirements for the subprogram.
- Summarizes all rulemaking activities and requirements under existing statutes, including EPACT 2005.
- Provides a detailed description of DOE's rulemaking processes and the statutory requirements for conducting rulemakings.
- Describes the reasons for the delays in completing rulemakings, including the unintended consequences of the Process Rule that introduced delays into rulemaking activities.

- Presents DOE's plan for addressing the problems and issues identified, and explains several productivity enhancements that will be used to significantly increase the creation of energy conservation standards.

- Presents and explains the multi-year schedule the Department will follow as it addresses the backlog and implements the requirements of EPACT 2005.

The entire report can be downloaded at: http://www.eere.energy.gov/buildings/appliance_standards/pdfs/congressional_report_013106.pdf.

In addition, section 141 of EPACT 2005 requires semi-annual implementation reports. The most recent semi-annual implementation report (August 2007) can be downloaded at: http://www.eere.energy.gov/buildings/appliance_standards/pdfs/congressional_report_0807.pdf

4.0 Technology Validation and Market Introduction

Consumers lack reliable information about underutilized technologies already on the market. Many barriers thwart the adoption of advanced technology, including a hesitancy to accept unproven new technologies, lowest first-cost procurement policies, tax disincentives, and a lack of credibility about professed benefits. To overcome these barriers, BT's Technology Validation and Market Introduction (TVMI) activities, including ENERGY STAR®, work with partners to speed the adoption of energy efficiency and renewable technologies in the marketplace.

Partners are central to bridging the gap between research and widespread utilization. Some of the major stakeholders in this endeavor are State governments, local entities, utilities, retailers, and manufacturers. They have established infrastructures, networks, and delivery mechanisms to reach the ultimate consumers, and their relationships with consumers give them credibility. BT exchanges information with its stakeholders to ensure the feedback critical to the development of successful next-generation research and regulation.

4.1 ENERGY STAR

ENERGY STAR® uses government and industry partnerships to promote adoption of energy-efficient building products and appliances through voluntary labeling. By improving energy efficiency in buildings, ENERGY STAR serves several important policy objectives, including saving energy and money, preventing air pollution, and enhancing energy security.

BT's ENERGY STAR activities include developing technical requirements and qualifications for new ENERGY STAR product categories, raising the bar on existing criteria when market penetration goals are reached, working with stakeholders to promote the manufacture and purchase of ENERGY STAR qualified products, and other deployment activities, such as communications, promotions, and campaigns.

During the past twelve years, BT has established technical compliance criteria for achieving the ENERGY STAR label on the following products:

- Clothes Washers
- Dishwashers
- Refrigerators
- Room Air Conditioners
- Freezers
- Windows, Doors and Skylights
- Compact Fluorescent Lights
- Solid State Lighting Luminaires
- Domestic How Water Heaters

Secretary Bodman greeting the 2006 ENERGY STAR Windows Partner of the Year.

The process for labeling an ENERGY STAR product involves the steps in Figure 4-1.

Figure 4-1 ENERGY STAR Labeling Process

Step 1: Establish criteria
Working with stakeholder groups, including manufacturers, retailers, energy efficiency program sponsors and interested non-governmental organizations, BT provides technical analysis to ensure ENERGY STAR criteria are established in a manner that highlights cost-effective products available to consumers through a variety of distribution channels. The program criteria are set in such a way as to not rely on a single manufacturer's proprietary technology and to ensure the establishment of ENERGY STAR criteria does not compromise product functionality.

↓

Step 2: Develop "distribution mechanisms" for qualified products
A key part of ENERGY STAR success lies in its ability to work with a network of partners to highlight the benefits of efficient products. This includes manufacturers, national and local retailers, and local energy efficiency program sponsors, who provide financial incentives and consumer education materials. ENERGY STAR works to ensure each key stakeholder's activities are coordinated to the highest degree possible.

↓

Step 3: Conduct Consumer Education
ENERGY STAR provides technical and educational tools and outreach campaigns to help highlight the benefits of these products to consumers. These include cost calculators, brochures, product facts, media outreach, events, etc.

4.1.1 ENERGY STAR Support of Program Strategic Goals

ENERGY STAR is a driver of technology. The overall objective of the ENERGY STAR subprogram is to accelerate the commercialization and increase the market share of energy-efficient products and services in residential and commercial marketplaces to help American consumers realize over 0.14 quads and $2.6 billion energy savings by 2014.[137] Full commercialization of these technologies is essential to helping BT realize its goal of achieving cost-effective net-zero energy homes by 2020 and buildings by 2025.

4.1.2 ENERGY STAR Support of Program Performance Goals

The ENERGY STAR subprogram supports BT performance goals of increasing the market penetration of windows to 72 percent by 2013 and maintaining the market penetration of appliances at around 30 percent. The key specific targets that work towards BT performance goals are included in Table 4-1.

[137] *ENERGY STAR Program Review*, November 28, 2007.

Table 4-1 ENERGY STAR Performance Goals[138]

Strategy/Activity		Targets							
		2003(1)	2007	2008	2009	2010	2011	2012	2013
Increasing Market Penetration	Appliances	30%	27%	29%	31%	28%	30%	32%	34%
	CFLs	2%	10%	12%	14%	16%	18%	20%	22%
	Windows	40%	57%	60%	62%	65%	67%	70%	72%
Enhancing Existing Products with New Criteria		–	Clothes Washers and Dishwashers	–	–	Room Air Conditioner and Refrigerators	–	–	–
Accelerating the Introduction of Advanced Products into ENERGY STAR		–	–	–	Solid State Lighting	Heat Pump Water Heaters, PV Systems, Small Wind	–	–	–

Note: (1) 2003 is the baseline.

4.1.3 ENERGY STAR Market Challenges and Barriers

The ENERGY STAR subprogram faces a variety of market barriers that require the program to constantly update its criteria and strategies. One of the most inherent barriers is as the market penetration of the ENERGY STAR products increases or as federal standards establish a new baseline by which products are measured, the energy and financial savings from some compliant products become increasingly irrelevant to consumers. An example is the ENERGY STAR-qualified refrigerator, which currently saves an average consumer less than $10 per year. The ENERGY STAR subprogram will have to continually update the criteria for its products to ensure savings.

Another barrier and one of the biggest risks to the ENERGY STAR subprogram is losing the ability to leverage the resources of the network. As the past decade has demonstrated, huge market shifts have occurred when this network has coordinated its efforts on promoting specific technologies. ENERGY STAR will have to change its technologies and approach to reflect the needs of the partners as the network changes. For example, many utilities and local energy planners are presently concentrating on controlling the growth of peak electric and gas demand. ENERGY STAR-labeled technologies can help address this need by using less energy and reducing demand, and by shifting the use since these loads are not usually time dependent. ENERGY STAR will have to adjust its approach by addressing peak demand reduction in addition to energy savings.

A third barrier is identifying the projects that will reach the most consumers and have the greatest influence. With limited resources, the ENERGY STAR subprogram needs to focus

[138] *ENERGY STAR Program Review*, November 28, 2007.

its efforts in the areas that can provide the greatest results and increase the market penetration of its products. Therefore, the subprogram will need to identify strategic marketing initiatives that reach and influence the most consumers.

A fourth barrier is the lack of consumer awareness of the benefits of efficient technologies and services. Often, consumers do not know what technologies and options exist, and/or do not fully understand the energy and non-energy benefits of the technologies or services, or are overwhelmed by the technical detail usually provided in explaining the technology or service. The ENERGY STAR subprogram will have to educate consumers to understand the benefits of its labeled products.

The market barriers that the ENERGY STAR subprogram will address over the next five years are summarized in Table 4-2 below.

Table 4-2 ENERGY STAR Market Challenges and Barriers

Barrier	Title	Description
A	Need to enhance existing or introduce new criteria	When market penetration goals are reached or as federal standards establish a new baseline by which products are measured, the bar of existing criteria needs to be raised.
B	Leveraging the network	The biggest risk to the realization of ENERGY STAR's goals is losing the ability to leverage the energies and resources of the network.
C	Reaching the consumers	A barrier is identifying the most efficient projects that reach the most consumers for the least cost.
D	Lack of consumer education	Consumers are unaware of the benefits of efficient technologies and services.

4.1.4 ENERGY STAR Technical (Non-Market) Challenges and Barriers

The ENERGY STAR subprogram also faces some technical barriers. New technologies are continually being developed and introduced to the market, which poses another barrier to the ENERGY STAR subprogram. These new technologies need to be evaluated and labeled if ENERGY STAR determines that labeling is appropriate.

Another challenge is tapping the energy savings potential of existing homes. Many energy savings opportunities come from system, rather than product optimization. For example, most of the efficiency gains in existing homes from central air conditioning products come from proper installation and improvement of air handling systems, not from increasing equipment efficiency levels.

The technical barriers that the ENERGY STAR subprogram will address over the next five years are summarized in Table 4-3 below.

Table 4-3 ENERGY STAR Technical Challenges/Barriers

Barrier	Title	Description
E	New technologies introduced to market	New technologies are continually being developed that need to be evaluated and labeled if determined appropriate.
F	Realizing systems energy savings in existing homes	Existing homes have untapped potential energy savings and many opportunities lie in systems solutions.

4.1.5 ENERGY STAR Approach/Strategies for Overcoming Challenges and Barriers

ENERGY STAR has planned a six strategy approach over the next five years for addressing the challenges mentioned above and achieving its goal of accelerating the commercialization and increasing the market share of energy-efficient products in residential and commercial buildings. These strategies also support the BT goal of Zero Energy Homes by 2020 and Zero Energy Buildings by 2025.

The six strategies are summarized in Table 4-4 below and then described in more detail.

Table 4-4 ENERGY STAR Strategies for Overcoming Barriers/Challenges

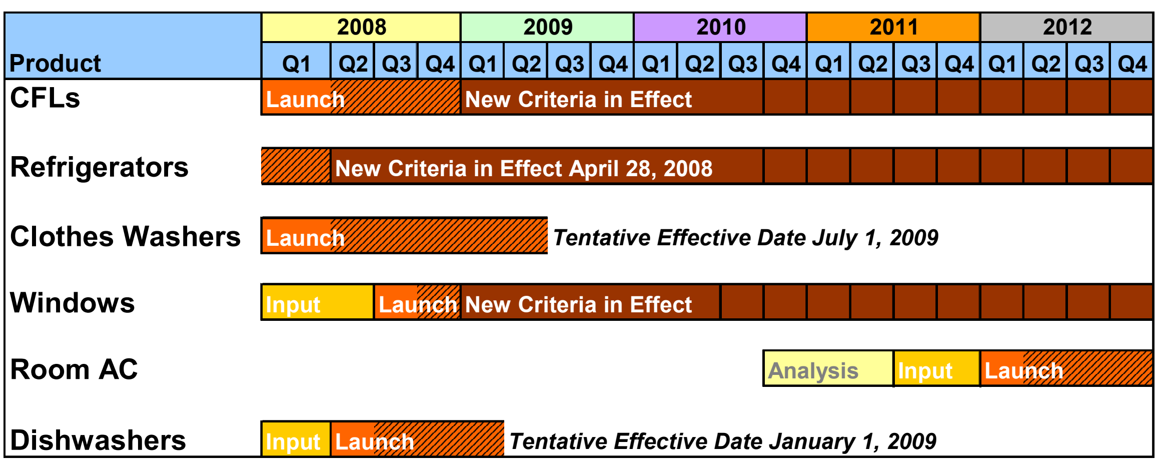
Barrier	Title	Strategy and Description
A	Need to enhance existing or introduce new criteria	**1. Criteria Revisions** ENERGY STAR will adjust criteria for current products as market share grows.
B	Leveraging the network	**2. Partner Support and Relationship Building** ENERGY STAR will encourage partners to promote qualified products; share costs and resources.
C	Reaching the consumers	**3. Strategic Marketing Initiatives** ENERGY STAR will implement strategy projects that produce big results with consumers for relatively small dollars.
D	Lack of consumer education	**4. Outreach Efforts** ENERGY STAR will generate excitement and bolster sales through visible outreach efforts.

Barrier	Title	Strategy and Description
E	New technologies introduced to market	**5. Advanced Technology Program Design** ENERGY STAR will expand the product portfolio to include advanced technologies.
F	Realizing systems energy savings in existing homes	**6. Home Performance with ENERGY STAR** ENERGY STAR will partner with other Federal agencies to develop a whole-house approach to efficiency in existing homes.

Strategy 1: Criteria Revisions

The core strategy of the ENERGY STAR subprogram is to continue to revise the criteria of labeled products when the market share has increased or Federal standards have raised the baseline. The process of setting criteria includes analysis, gathering stakeholder input, and launching the criteria. The frequency of criteria revisions is a function of the product, how quickly manufacturers can change their production processes, the incremental savings and costs for each product, and the level of support for the products in the efficiency program sponsor community. Six existing products are scheduled for criteria revisions over the next five years as shown in Figure 4-2.

Figure 4-2 ENERGY STAR Criteria Revision Schedule for Existing Products



Strategy 2: Partner Support and Relationship Building

The partner network is one of the greatest assets to the ENERGY STAR subprogram. BT will continue to build and leverage this network by enhancing existing relationships and building new ones to increase visibility. ENERGY STAR will continue to strengthen and increase collaboration with manufacturers, retailers, and energy efficiency partnerships

(EEPs) through the Application Centers. Then, as additional products are launched the subprogram will build new relationships with partners in these technology areas.

The ENERGY STAR subprogram will also work to strengthen its partnership with the Environmental Protection Agency (EPA). The benefits include more effective deployment of EERE building technologies, positioning of DOE as a full partner in planning and campaigns, and enabling better support of efforts in home and commercial building performance, and streamlining ENERGY STAR qualification of products for which DOE has already verified energy performance. Additionally, the subprogram will cooperate with Housing and Urban Development (HUD) to raise the visibility of DOE in the ENERGY STAR program, and improve partnerships in ways that mutually benefit DOE, EPA, and HUD strategic objectives and missions.

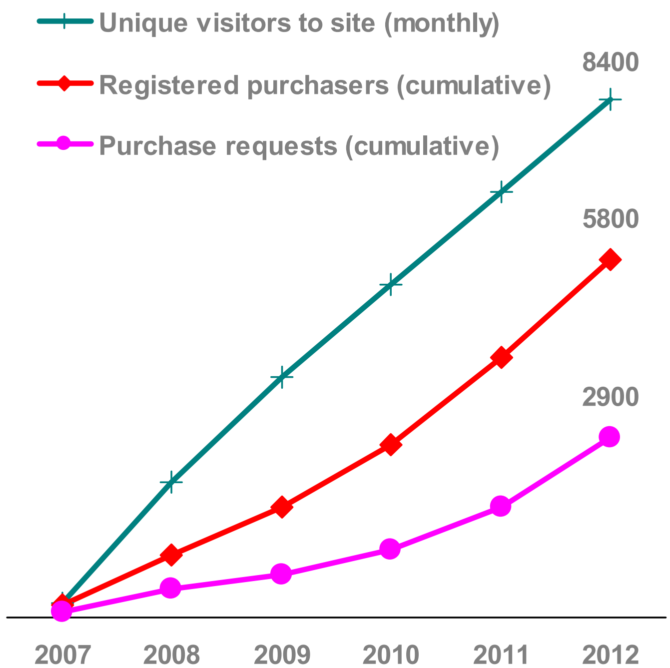
Strategy 3: Strategic Marketing Initiatives

In order to influence the most consumers and make the most impact, the ENERGY STAR subprogram is enacting two strategic marketing initiatives: the Realtor Initiative and the Bulk Purchasing program.

The goal of the realtor initiative is to leverage realtors to help spur energy efficiency improvements in existing homes at the time of sale. In the short-term, the subprogram will provide energy efficiency courses for realtors, Multiple Listing Service (MLS) and best practices by realtors, and sign a Memorandum of Understanding with the National Association of Realtors (NAR). Over the long-term, the initiative will include state-by-state inclusion of energy course for associations, 25% MLS inclusion, partnering with Residential Energy Services Network (RESNET), American Council for and Energy-Efficient Economy (ACEEE), Home Performance with Energy Star and others, and housing related groups/programs.

The goal of the bulk purchasing program is to increase sales of ENERGY STAR products in institutional markets. The current strategy is to leverage trade associations and other groups to promote ENERGY STAR quantity quotes to institutional purchasers. In addition, the bulk purchasing program will outreach to military housing, partner with the Clinton Climate Initiative and the U.S. Conference of Mayors, and add more products to Quantity Quotes Online Tool. Figure 4-3 outlines the Quantity Quotes multi-year goals for purchasers and purchase requests.

Figure 4-3 ENERGY STAR Quantity Quotes



Strategy 4: Outreach Efforts

The goal of the outreach efforts is to educate consumers, increase awareness, and drive product sales. Outreach will include campaigns, which conduct seasonal or short-term efforts that promote specific "calls to action." The specific campaigns are Change a Light, Change the World (CFLs), Refrigerator Recycling, and the Military Challenge. ENERGY STAR will partner with Oscar de la Hoya and NASCAR.

Strategy 5: Advanced Technology Program Design

New technologies typically flow from a conceptual stage of development to full adoption in the commercial arena via a series of linked activities. These specific activities in the innovation process are idea generation and selection, R&D, pre-commercial demonstration and promotion, and adoption into commercial arena. Poor linkage between these activities results in decreased delivery of technologies and value to the commercial arena. One of the key determinants for successful product development and deployment includes "institutions for collaboration" that effectively link upstream R&D with commercial deployment.[139] Without strong linkages, new products will not be transferred effectively to the marketplace; the full value from the R&D investment will not be captured. In a colloquium of leading

[139] Porter, Michael and Scott Stern. *National Innovative Capacity, The Global Competitiveness Report 2001-2002*, 2001, New York: Oxford University Press.

innovation practitioners, 50 major companies exchanged knowledge and best practices regarding innovation and identified linking R&D activities to commercialization as one of the major historic barriers affecting innovation success.[140] Therefore, to capture the full potential of the value created by investments in upstream R&D, it is necessary to invest especially in the linkages between upstream R&D and the commercialization market.[141] ENERGY STAR, through its commercial partners and networks, is ideally positioned to assist in the commercialization of new products.

To assist, BT will examine ways of using the ENERGY STAR network of manufacturers, retailers, and energy efficiency program sponsors to accelerate the commercialization of products to incorporate into the ENERGY STAR subprogram and properly promote and incentivize. BT rolled out a new program for SSL luminaries in 2007, soon to be followed by a program for advanced residential water heaters. BT will also begin work on developing ENERGY STAR criteria for residential-scale renewable products, such as rooftop photovoltaic systems and small wind turbines.

Strategy 6: Home Performance with ENERGY STAR

If ENERGY STAR is to fully contribute to BT's goals of achieving cost-effective ZEH retrofits by 2020, in addition to supporting the implementation of Home Performance with ENERGY STAR (HPwES) locally-sponsored programs and direct-to-contractor pilots, we need to work closely with the R&D activities to assist in developing consumer-oriented "pathways" to whole home improvements that include whole-house home performance assessments and improvements including: envelope sealing and insulation, HVAC upgrades and system optimization, lighting upgrades, renewable energy technologies, and whole home energy management systems. This work will be undertaken in conjunction with Home Performance with ENERGY STAR, as well as with the HUD's Partnership for Advancing Technology in Housing (PATH).[142]

This collaborative group will promote the whole-house approach to assessing a home's energy performance and appropriate efficiency improvements, technical specifications, quality assurance protocols, and in addition, will work to encourage widespread market adoption of these elements. BT's role in this process will be defined in consultation with its collaborators, but includes the following activities:

- Working with EPA and HUD to promote both the elements and overall framework of a whole home approach, drawing on DOE's technical resources as appropriate;
- Developing standards and field guides for home performance contracting in association with industry associations such as the Building Performance Institute (BPI) and RESNET;

---

[140] *Priority Issues in Technology and Innovation Management,* Arthur D. Little, 2002.
[141] *Emerging Technologies Whitepaper*, California Energy Commission, February 2005.
[142] *Joint Initiative to Improve the Energy Efficiency of Existing Homes*, *DRAFT Document*, December 8, 2004.

- Recruiting and supporting local sponsors, providing technical assistance and marketing materials;
- Working closely with national manufacturers and retailers to facilitate their entry into the home performance contracting market via the direct-to-contractor pilots;
- Focusing on quality assurance and contractor training to ensure that consumers are achieving real savings;
- Cultivate consistent messaging to consumers on the value of home performance contracting; and
- Collaborate with EPA ENERGY STAR staff to leverage the ongoing work with the residential market and present a common message from the Federal government on home performance contracting.

Within each of these elements, critical activities will need to be executed:

- *Supporting standard and field guide development for home performance contracting.* DOE, EPA and HUD have contributed to the development of the national certification and accreditation programs for home performance contractors with BPI and RESNET. In addition, DOE is contributing to the development of ANSI-approved standards for BPI, which is a multi-year multi-standard and certification effort.
- *Conducting Consumer Outreach.* One of the biggest barriers to achieving whole home performance is consumers do not understand the benefits of systems improvements nor what such improvements entail. They also require quality assurance as these whole-house retrofits typically have a high initial cost. Under this task, DOE will work with EPA, and HUD to determine effective strategies for conveying benefits to consumers, and then coordinate with stakeholders who develop outreach materials and technical tools. This activity ensures contractors have the right sales tools necessary to sell these services to consumers. DOE also helps develop the web site content, marketing materials, program development materials, and outreach to local sponsors at RESNET and regional Affordable Comfort Institute (ACI) conferences. DOE has targeted the remodeling community, providing educational sessions at the International Builders Show and the Remodelers Show. In addition, DOE has targeted Realtors and real estate agents as a highly effective target-market to educate about the monetary and non-monetary benefits of home performance improvements as a means to educate home sellers and home buyers about the benefits.
- *Workforce Development.* Another significant barrier to improving home performance in existing homes is the lack of a trained workforce to assess homes and install improvements. Under this task, DOE, in conjunction with EPA and HUD, will develop a workforce development summit, from which a roadmap using existing training and curriculum can be explored to increase the number of home performance contractors nationally using a variety of media. Stakeholders include existing DOE partners such as the National Association of Universities and Land Grant Colleges

(NASULGC) the USDA Extension Service, Hudson Valley Community College, and other community colleges and training institutions currently offering training in home performance assessment and installations.

- *Institutionalize the Market Infrastructure for Whole Home Services.* If successful, these home performance services must be profitable and practical for contractors, remodelers, homeowners, realtors and retailers who are becoming increasingly interested in efficiency gains. In addition, the benefits must be rigorous enough for inclusion in public benefit programs at the state and local level. Under this task, DOE recruits local program sponsors, non-profits, and utilities who will implement the program. Additionally, DOE is establishing relationships with manufacturers, retailers, and national contractor networks to pilot an direct-to-contractor pilot in several metropolitan areas.

ENERGY STAR has identified the following tasks over the next five years to carry out the strategies for overcoming barriers (Table 4-5).

Table 4-5 ENERGY STAR Tasks

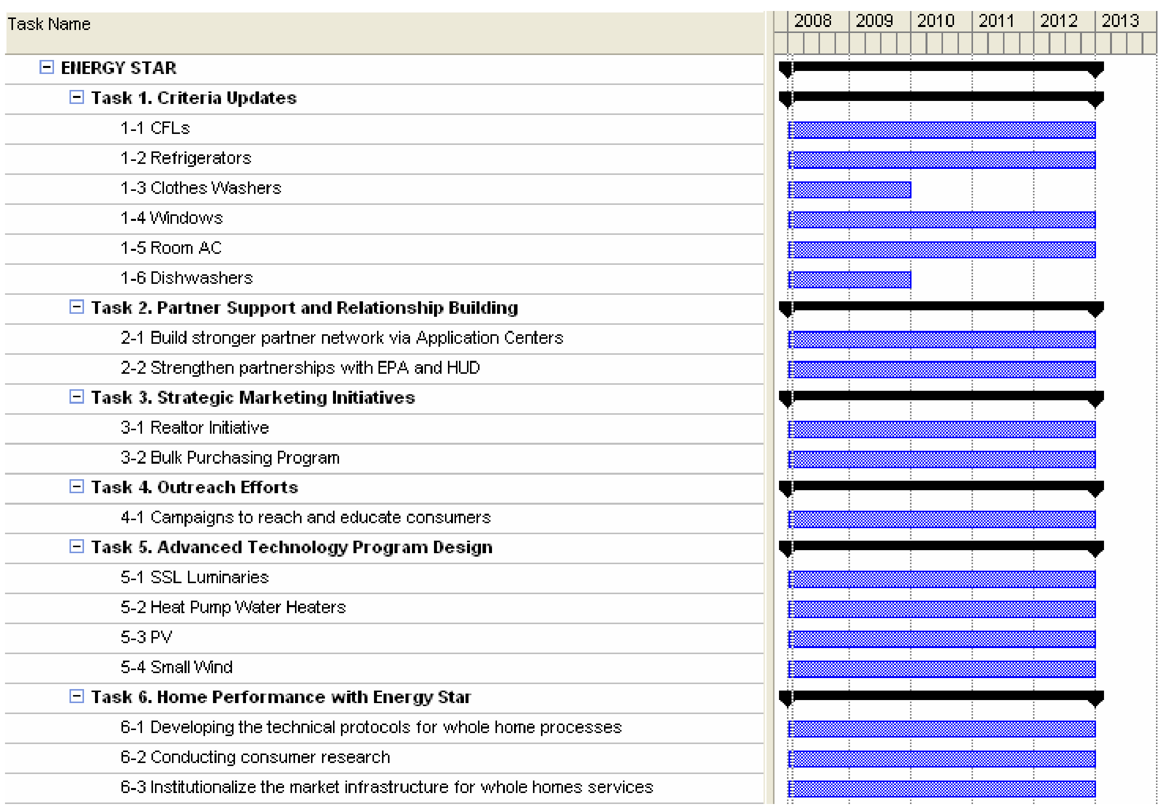
Task	Title	Duration	Barriers
1	Criteria Updates	2008-2012	A
1-1	CFLs	2008-2012	A
1-2	Refrigerators	2008-2012	A
1-3	Clothes Washers	2008-2009	A
1-4	Windows	2008-2012	A
1-5	Room AC	2011-2012	A
1-6	Dishwashers	2008-2009	A
2	Partner Support and Relationship Building	2008-2012	B
2-1	Build stronger partner network via Application Centers	2008-2012	B
2-2	Strengthen partnerships with EPA and HUD	2008-2012	B
3	Strategic Marketing Initiatives	2008-2012	C
3-1	Realtor Initiative	2008-2012	C
3-2	Bulk Purchasing Program	2008-2012	C
4	Outreach Efforts	2008-2012	D
4-1	Campaigns to reach and educate consumers	2008-2012	D
5	Advanced Technology Program Design	2008-2012	E
5-1	SSL Luminaries	2008-2012	E
5-2	Heat Pump Water Heaters	2008-2012	E
5-3	PV	2008-2012	E

5-4	Small Wind	2008-2012	E
6	Home Performance with Energy Star	2008-2012	F
6-1	Developing the technical protocols for whole home processes	2008-2012	F
6-2	Conducting consumer outreach	2008-2012	F
6-3	Institutionalize the market infrastructure for whole home services	2008-2012	F

4.1.6 ENERGY STAR Milestones and Decision Points

The major milestones for ENERGY STAR are displayed in Figure 4-4.

Figure 4-4 ENERGY STAR Gantt Chart



4.2 Building Energy Codes

Building energy codes define the minimum requirements for new construction, including additions and alterations to existing buildings. Building energy codes set minimum requirements for building thermal envelope performance, building mechanical system performance[143], and building lighting and power system performance (commercial buildings only). Commercial building energy codes also set building mechanical equipment requirements that are the starting point for BT's equipment standards rulemakings.

Table 4-6 is derived from the Building Energy Data Book to show what portion of building energy usage is impacted by building energy codes. End uses covered by codes are listed with the site and primary energy impacts.

Table 4-6 Residential and Commercial Energy Usage Subject to Building Energy Codes[144]

Sector	**Residential Quads(1)**		**Commercial Quads(2)**	
End Use	**Site**	**Primary**	**Site**	**Primary**
Space Heating	5.61	6.69	2.04	2.55
Water Heating	1.75	2.66	0.84	1.23
Space Cooling	0.84	2.67	0.75	2.34
Lighting	Not covered	Not covered	1.44	4.57
Ventilation	Not split out	Not split out	0.34	1.08
Refrigeration	Not covered	Not covered	Not covered	Not covered
Wet Clean	Not covered	Not covered	Not covered	Not covered
Electronics	Not covered	Not covered	Not covered	Not covered
Cooking	Not covered	Not covered	Not covered	Not covered
Computers	Not covered	Not covered	Not covered	Not covered
Other	Assumed zero	Assumed zero	Not covered	Not covered
Adjustment to SEDS	Not covered	Not covered	Not covered	Not covered
Total Covered	8.19	12.02	5.41	11.77
Total Sector	11.63	21.78	8.49	17.91
Percent Covered	70%	55%	64%	66%

Notes: 1) Residential end uses taken from 2007 BED Table 1.2.3; 2) Commercial end uses taken from 2007 BED Table 1.3.3

While the end-use table indicates that a considerable fraction of both residential and commercial sector energy use is subject to building energy codes, it bears repeating that this coverage is shared with appliance standards, and also that this coverage is for new construction in new and existing buildings. Separating the impact of building energy codes from appliance standards is not easy, and no attempt to do so is made here.

143 The efficiency of many classes of HVAC equipment, especially equipment generally used in residences, is preemptively regulated by manufacturing standards resulting from the National Appliance Energy Conservation Act of 1987 (NAECA) and is therefore outside the scope of building energy codes.

144 BED

4.2.1 Building Energy Codes Support of Program Strategic Goals

The Building Energy Codes subprogram seeks to identify new cost-effective technologies or new ways to determine cost-effectiveness in their efforts to improve codes. For example, BT is currently evaluating if a cost credit for downsizing HVAC equipment as a result of improved building envelopes could be used to help cost-justify those improved envelopes. This is a simple application of integrated design principles commonly used in individual building designs, but applying that same principle to the generic building designs considered in building energy codes is challenging.

The strategic goals of the Building Energy Codes subprogram are to:

1. Drive the development of voluntary sector building energy codes to achieve 30 percent energy savings in new commercial construction by 2010 relative to American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 90.1-2004 and 30 percent energy savings in new residential construction by 2009 relative to International Code Council's (ICC) International Energy Conservation Code (IECC) 2006.

2. Continually update the Federal sector building energy codes to achieve energy savings in new Federal construction of approximately 30 percent beyond corresponding voluntary sector building energy codes during the 2008 to 2025 period.

These Building Energy Codes goals align with BT strategic goals as they support the implementation of energy-efficient buildings– affecting both new and existing buildings.

4.2.2 Building Energy Codes Support of Program Performance Goals

The BT performance goal for Building Energy Codes is as follows:

The Building Energy Codes activities will support the development and implementation of energy-efficient building codes, which increase the construction of more energy efficient buildings.

Building Energy Codes support BT performance goals through working towards more efficient building codes. Targets for the various building sectors are shown in Table 4-7.

Table 4-7 BT Improvement Goals for Building Energy Codes[145]

Sector	Goal
Voluntary Residential	30% energy savings by 2009 relative to IECC 2006
Federal Residential	Equivalent to ENERGY STAR
Voluntary Commercial	30% energy savings by 2010 relative to ASHRAE 90.1-2004

[145] Expressed in code change cycles rather than annual metrics

Federal Commercial	Voluntary sector code plus all cost-effective measures (based on Federal sector economics; targeted at 30% above voluntary sector)

The ability of codes to influence building energy usage depends on the ability of codes to continuously improve. In the codes world, code improvement is typically tied to cost-effectiveness. Improvement in codes tends to occur in one of three ways:

1. The costs of new technologies are reduced sufficiently that they can be considered for inclusion as mandates in codes.
2. Code developers become cleverer in how they determine cost-effectiveness.
3. Economic parameters change enough to make existing technologies appear more attractive.

4.2.3 Building Energy Codes Market Challenges and Barriers

The primary risks and barriers in both DOE's larger codes efforts and in BT's specific building energy codes efforts tend to be more political or economical than technical. The basic premise in the development of all building energy codes is that whatever is required by the code or standard should be so obviously beneficial to the building owner or building occupants that there is little opposition to the requirement (except, possibly, for entrenched special interests). This is the basis for the consensus processes that various code-writing organizations tend to follow.

Thus, the Building Energy Codes subprogram faces none of the technical risk associated with the development of new building technologies or new construction techniques. If those new technologies or techniques are developed and shown to be cost-effective, then they may eventually be incorporated into building energy codes. But as a general rule, building energy codes are developed to be technology neutral by the code development organizations, such as ASHRAE and ICC. Neither of these organizations is interested in "pushing" specific technologies for fear of stifling innovation and in their own self-interest as they try to avoid being accused of favoritism or market manipulation by competitors in the marketplace. Because BT is only one of many players in the processes controlled by ASHRAE and ICC, BT is essentially constrained to remain technology-neutral as well.

Table 4-8 Building Energy Codes Market Challenges and Barriers

Barrier	Title	Description
A	Opposition to regulation	The single largest barrier faced by the Building Energy Codes subprogram is opposition to regulation and especially opposition to increased stringency of regulation on a particular component, system, or

		building.
B	Low tolerance for code complexity	Code users (builders, contractors, and code officials) resist adoption because of code complexity.

This opposition is commonly expressed in terms of economics, but opposition also takes the form of detailed questioning of assumptions, baseline conditions, methodologies, etc. The bottom line is that it makes sense to many participants in the buildings community to oppose at least some aspects of building energy codes and so opposition is spirited. The role of the Building Energy Codes subprogram in all this is to provide thorough, balanced, and well-documented analysis that will lead to the incorporation of cost-effective improvements to building energy codes. This is really where the bulk of the effort in this subprogram takes place.

The second barrier, low tolerance for code complexity, results from two problems: 1) a lack of technical sophistication (more a residential issue than commercial) and 2) a perception that efforts spent on energy code compliance have no or low returns in terms of recouped costs, increased marketability, or reduced liability. For these reasons, a large portion of BT's effort is devoted to making the codes simpler and easier to understand and use, with the goals of overcoming resistance to "some complex code" and making the lack of technical sophistication less an issue.

4.2.4 Building Energy Codes Technical (Non-Market) Challenges and Barriers

The largest technical barriers that BT's Building Energy Codes subprogram faces are described in Table 4-9.

Table 4-9 Building Energy Codes Technical Challenges/Barriers

Barrier	Title	Description
C	Lack of hard data	Lack of hard data on current construction practice (primarily a commercial issue), making it hard to determine if codes are too stringent or not stringent enough
D	Lack of detailed construction cost data	Lack of detailed construction cost data (worse for commercial than residential, but an issue for both, especially for "non-standard" constructions), making it hard to develop cost justification for new requirements in building energy codes
E	Lack of current code compliance data	Lack of current code compliance data, making it hard to identify code requirements that might be too complex or simply unworkable

The intended use of this data is primarily to counteract arguments that proposed code changes are too expensive, too stringent, or unworkable, but also to help identify new areas for code change proposals. With the continued scaling back of DOE's Commercial Buildings Energy Consumption Survey (CBECS) and the ending of commercial building permit data collection in the mid-1990s, data on growth of the commercial building sector on a state-by-state basis and knowledge of what those buildings look like has been increasingly hard to gather. All of this type of data is necessary in efforts to demonstrate that proposed changes to codes are both cost-effective and enforceable nationally, and in states that might consider adopting the codes. BT has made some efforts to collect current construction practice data (via the New Commercial Construction Characteristics (NC3) dataset effort), but use of building energy codes funding for this type of effort is problematic at best.

4.2.5 Building Energy Codes Approach/Strategies for Overcoming Challenges and Barriers

The two biggest barriers to building energy codes are often associated with resistance to code adoption within states and local jurisdictions, and low tolerance for code complexity on the part of code users (builders, contractors, and code officials). BT's efforts in developing support software were almost entirely focused on making the code easier to use and making it easier for code officials to enforce. BT's recent efforts in rewriting the residential portion of the ICC IECC were also focused largely on simplification and elimination of ambiguities.

There are a large number of tasks associated with the voluntary commercial, voluntary residential, Federal commercial, Federal residential, and manufactured housing aspects of BT's Building Energy Codes subprogram. Rather than repeat the contents of the individual project management plans for the commercial and residential subprograms of DOE's overall codes efforts, a general summary of the tasks associated with these efforts will be provided. Specific details and funding levels will vary from year to year for each task.

Federal Sector Activities
Both the residential and commercial subprograms contain tasks supporting the ongoing development of Federal sector standards, as mandated by the Energy Policy Act of 1992. These tasks are focused on development of new Federal building rules. Deployment and training associated with these rules has historically been the responsibility of BT's Federal Energy Management Program (FEMP), rather than Weatherization and Intergovernmental Program (WIP).

Formal Determination Activities
Both the residential and commercial subprograms contain tasks to perform the analysis leading up to DOE's formal determination of energy savings for new versions of the ICC IECC (residential) and ASHRAE Standard 90.1 (commercial), as mandated by the Energy Policy Act of 1992.

Support for EPACT-Designated Voluntary Sector Code Development
Both the residential and commercial subprograms contain tasks to support the development of EPACT-mandated voluntary sector standards (the ICC IECC for residential and ASHRAE Standard 90.1 for commercial). Commercial tasks may have multiple subtasks for support of the various subcommittees charged with developing these building energy codes or for addressing various aspects of these building energy codes (envelope, mechanical systems, lighting, etc). The primary tasks for residential codes tend to focus on the building envelope and mechanical systems, and the whole building tradeoff approach utilized in the IECC. During the course of working with these various subcommittees, the Building Energy Codes subprogram does come into contact with other code development participants who can and will supply the current practice, cost, and compliance data that can help address the barriers listed above.

Support for Alternative Voluntary Sector Code Development
Both the residential and commercial subprograms contain tasks to support the development of alternative voluntary sector codes that are commonly adopted or considered for adoption by the states or have the potential to be incorporated into the IECC. In the residential sector, the "alternative" building energy codes are the ICC IRC and ASHRAE Standard 90.2. In the commercial sector, the "alternative" code is the IECC, which is actually the most commonly adopted set of commercial requirements. These tasks are not explicitly mandated by EPACT, but do fall in the area of supporting state adoption of codes (another DOE mandate in EPACT) because many states do adopt the IECC and IRC.

Support for "Above Code" or "Beyond Code" Efforts
Both the residential and commercial subprograms contain tasks to support various above code or beyond code activities that may provide insights into future code enhancements. In the residential sector, the main above code efforts that this subprogram interacts with are BT's Building America and the RESNET, which maintains the most commonly used specification for Home Energy Rating Systems (HERS). In addition to mining these better-than-code programs for potential new code provisions, these activities also assist the programs in eliminating code barriers to the use of new and innovative materials, equipment, and construction techniques.

In the commercial sector, the three main above/beyond code interactions include:

- ASHRAE's Special Project 102 Advanced Energy Design Guide: Small Office Buildings;
- The New Buildings Institute's (NBI) Benchmark; and
- The U.S. Green Buildings Council's Leadership in Energy and Environmental Design (LEED) program.

ASHRAE's Advanced Energy Design Guide series is intended to complement ASHRAE Standard 90.1 by providing energy savings of 30 percent above Standard 90.1 for small office buildings. ASHRAE will be developing 30 percent above code guides for additional building types that do not usually receive intensive design attention (small retail and roadside motels are on the list), and ASHRAE is also planning to take on guides that will achieve 50 percent and 70 percent savings above code.

NBI's Benchmark covers many common commercial building types and was originally targeted at 30 percent savings as well. Benchmark did achieve this level of savings for some, but not all building types. Benchmark is currently being used as the design guidance basis for EPA's ENERGY STAR by Design program. BT's role in the above code programs can be summarized as follows:

- Participation and leadership of development (ASHRAE SP 102)
- Promotion of above code material through code compliance software and online resource center (ASHRAE SP 102, NBI Benchmark, Building America)
- Use of above code material as basis of "codes of the future" (ASHRAE SP 102, NBI Benchmark, Building America)
- Participation in reformat of ASHRAE Standard 90.1 Energy Cost Budget Method to assist in LEED usage

Working with groups on above and beyond code issues is another venue to obtain the current practice, cost, and code compliance data mentioned in barriers above. The general strategies to overcoming challenges and barriers are addressed in Table 4-10.

Table 4-10 Building Energy Codes Strategies for Overcoming Barriers/Challenges

Barrier	Title	Strategy
A, B	Opposition to regulation, Low tolerance for code complexity	The Building Energy Codes subprogram focuses on making simpler, easier to understand, and more usable. Additional activities are focused on voluntary codes.
C, D, E	Lack of hard data, detailed construction cost data, and current code compliance data	Working with these various subcommittees, while drafting codes, the subprogram requests current practice, cost, and compliance data from other participants.

4.2.6 Building Energy Codes Milestones and Decision Points

The milestones of the Building Energy Codes subprogram are listed below for the residential, commercial, and Federal sectors. The use of milestones instead of targets is indicative of the fact that the Building Energy Codes subprogram participates in code and standard development processes that are owned and controlled by other organizations. The building energy codes listed here will be published on the dates mentioned with or without DOE participation. DOE's role is to support the development of these building energy codes and achieve the desired energy savings outcomes (described below). The tasks associated with the Building Energy Codes milestones are listed in Table 4-11.

Residential Sector

- By 2008, have published in the *Federal Register* a determination that the 2006 IECC will increase the energy efficiency of residential buildings, initiating a requirement that the states and territories certify by 2009 to DOE that they have determined whether they should update their residential codes to meet or exceed the 2006 edition of the IECC.
- By 2008, have upgraded the technical assistance core tools and materials to assist states to upgrade their codes to the 2006 IECC.
- By 2010, have supported the upgrade of the 2009 IECC to include improved envelope and mechanical requirements for residential buildings.

Commercial Sector

- By 2008, have supported the upgrading of Standard 90.1-2007, *Energy-efficient Design of Buildings Except Low-Rise Residential Buildings,* to include:
    - Additional lighting control requirements, including occupancy sensors;
    - Improved building envelope requirements because of integrated design considerations;
    - Cool roof requirements; and
    - Improved mechanical system requirements related to demand control ventilation, energy recovery, and variable-speed drive pumps.
- By 2008, have upgraded the technical assistance core tools and materials to assist states to upgrade their codes to Standard 90.1-2006.
- By 2010, have supported the upgrading of the 2009 IECC to include improved lighting, envelope and mechanical requirements for commercial buildings.
- By 2011, have supported the upgrading of Standard 90.1-2010, *Energy-Efficient Design of Buildings Except Low-Rise Residential Buildings,* to include:
    - Continuous air barrier and other envelope infiltration requirements;
    - Advanced lighting controls (including daylighting); and
    - Improved mechanical system control and selection.

Federal Sector

- By 2008, issue an upgraded Federal commercial building energy code that will use at least 12 percent less energy than buildings built to 10 CFR 434 (1989).

- By 2010, propose an upgraded Federal commercial building energy code to meet or exceed Standard 90.1-2008.

Table 4-11 Building Energy Codes Tasks

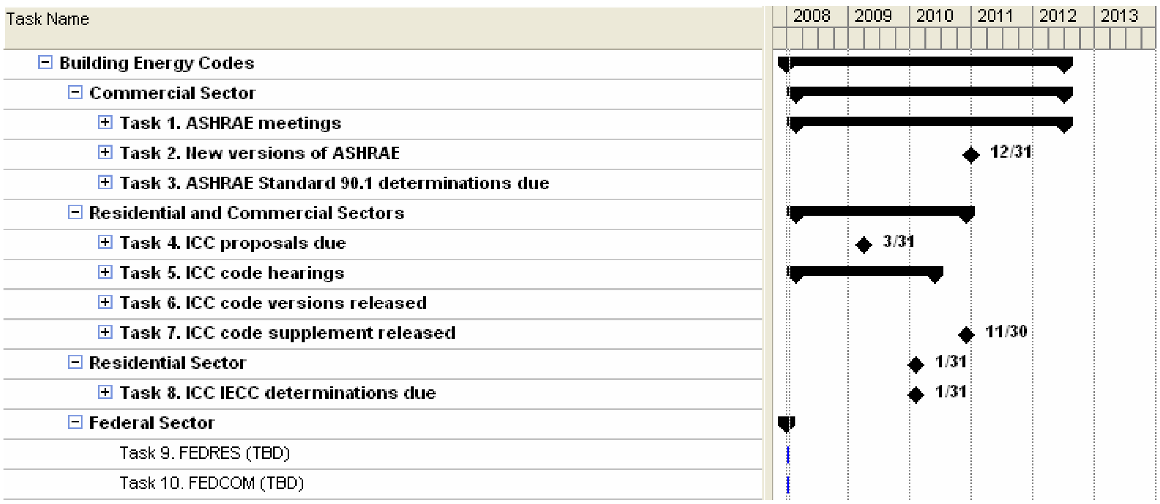
Task	Title	Duration	Barriers
1	ASHRAE meetings	2008-2010	C, D, E
2	New versions of ASHRAE	2008-2010	A, B
3	ASHRAE Standard 90.1 determinations due	2008	A, B
4	ICC proposals due	2008-2009	C, D, E
5	ICC code hearings	2008-2010	A, B
6	ICC code versions released	2009	A, B
7	ICC code supplement released	2008-2010	A, B
8	ICC IECC determinations due	2008-2010	C, D, E
9	FEDRES	TBD	
10	FEDCOM	TBD	

Milestones and schedules for BT's building energy codes efforts are driven largely by the schedules of the voluntary sector code processes. Both ASHRAE and ICC are now on 3-year cycles, with ASHRAE scheduled to deliver new versions of Standard 90.1 at the end of 2010, 2013 and so on. ICC's current cycle is scheduled to deliver new versions in 2009, 2012, and so on, essentially 2 years off of the ASHRAE cycle. ICC also issues a mid-cycle supplementary version of their code for those states interested in somewhat more current requirements. While ASHRAE accepts change proposals at any time under their continuous maintenance policy, the majority of activity with regards to ASHRAE Standards is focused on their semi-annual meetings. ICC code change proposals are only accepted at certain times. For the 2006 IECC, proposed changes were due at the end of August 2004, approximately 16 to 18 months before the code itself is actually published. The schedule is shown in the Gantt Chart (Figure 4-5).

These voluntary sector code efforts also drive BT's determination of energy savings activities (due one year after release of a new version of the baseline code or standard) and Federal standards activities (typically revised after major enhancements in the corresponding voluntary sector standard). Looking out over the next five years, the significant dates in Figure 4-5 can be noted. Significant milestones for Federal standards are not shown because of BT's lack of control over the actual release dates of these rulemakings.

The ASHRAE Standard 90.1 and ICC IECC Determination milestones are the appropriate times for BT to determine if the building energy codes program is meeting its Joule metrics because these will be the times that actual savings on Standard 90.1 (commercial) and the IECC (residential) are prepared. In a sense, these are go/no-go points in that BT can determine to abandon or redouble efforts in building energy codes at these points based on the determinations.

Figure 4-5 Building Energy Codes Gantt Chart



4.3 Technology Transfer Application Centers

The Technology Transfer Application Centers (ACs) are dedicated to incorporating BT's technologies and processes into state and local planning efforts. The application centers will be the visible, on-the-ground delivery mechanism through which BT interacts with the marketplace and achieves the goals and objectives of the TVMI initiatives and other, on-going buildings efforts.

4.3.1 Technology Transfer Application Centers Support of Program Strategic Goals

The strategic goal of the initiative is to establish regional Technology Transfer Application Centers to deliver commercially available and BT developed technologies, processes, and tools that meet DOE EERE priorities, align with efficiency goals of states, utilities, and partnership-based programs. The Technology Transfer Centers will promote BT goals for zero energy buildings as well as other support activities such as advanced energy efficient building standards and codes.

4.3.2 Technology Transfer Application Centers Support of Program Performance Goals

The Technology Transfer Application Centers will support the BT performance goal of accelerating the adoption of efficient technologies through the following objectives and performance goals:

- Create multi-state regional centers with broad participation from and interaction with key target markets
- Coordinate approaches and outreach in advanced energy efficient building technology implementation
- Provide BT and EERE-funded and developed technologies, information and marketing materials
- Encourage adoption of energy efficient building technologies and practices to achieve energy efficiency goals in residential, public, and commercial buildings

4.3.3 Technology Transfer Application Centers Market Challenges and Barriers

Market challenges and barriers for Technology Transfer Application Centers are listed in Table 4-12.

Table 4-12 Technology Transfer Application Centers Market Challenges and Barriers

Barrier	Title	Description
A	Fragmented building industry	The fragmented building industry complicates the process of market transformation. It is difficult to influence all disciplines and functions involved.
B	Lack of skilled practitioners	There is a shortage of skilled practitioners to provide the appropriate and affordable energy-efficient technologies and practices to all segments of the marketplace.

4.3.4 Technology Transfer Application Centers Approach/Strategies for Overcoming Challenges and Barriers

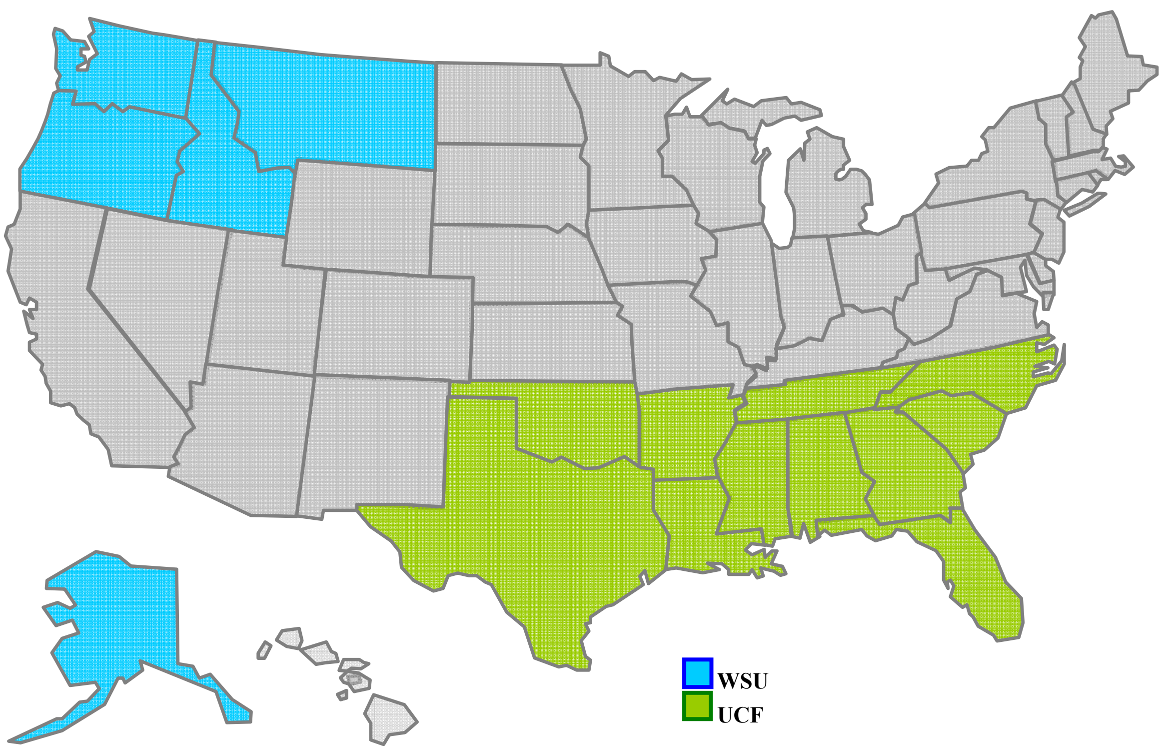
BT will provide seed funding to establish application centers based on the Building America climate regions. Each center will set regional goals to align state, utility and EEPS-based efficiency programs with BT goals for advanced efficiency (defined as at least 30 percent better than international code) and zero energy buildings (contingent upon EERE-wide support from renewables).

In addition, the centers will act as a visible mechanism within the region to coordinate approaches and outreach in program implementation. In particular, the centers will also serve as a conduit for BT programs to regional local governments, colleges and universities, retailers, non-profits, and building industry professionals to market BT programs, technologies and practices and achieve the goals stated above.

The centers will also use BT-developed technical and marketing content to build regional and local technical capacity, host forums from which to conduct trainings or initiate regional efficiency efforts, coordinate efforts at the local level with BT and provide states, and others with a centralized means of obtaining case studies, best practices and other resources critical to addressing building efficiency needs in their climate zone. The centers will disseminate BT programs, technologies, and practices, including those developed under commercial lighting, as well as, technical assistance.

Two pilot application centers were chosen through a competitive solicitation. Using selection criteria, BT chose the Southern Energy Efficiency Center and the Pacific Northwest Building Technologies Application Center as the pilots. The states covered by these pilots are indicated in Figure 4-6, with WSU representing the Pacific Northwest Center and UCF the Southern Energy Efficiency Center.

Figure 4-6 Technology Transfer Application Center States Reached



The Southern Energy Efficiency Center is a partnership between the University of Central Florida's Florida Solar Energy Center, the Southface Institute and Texas A&M's Energy Systems Lab. The center covers a 12 state region in the South and includes the following:

- Extensive project partner interactions and outreach with key DOE target markets
- Project advisors from State Energy Offices (G-12) and steering committee of 30-50 stakeholders

- Comprehensive plan for measuring influence on energy efficiency levels and energy savings that result by completing an energy efficiency measures cost database (baseline data), define baseline energy use patterns within the 12-state region, and use ESL methodology to calculate energy savings

The Pacific Northwest Building Technologies Application Center is a partnership between Washington State University, the Idaho Department of Water Resources, and the University of Alaska Fairbanks. The center covers a five state region in the Pacific Northwest and will focus on extensive partner interaction and outreach with key target markets of interest to DOE in the residential, commercial and public sectors.

The strategies utilized by the two pilot centers to overcome barriers and challenges are listed in Table 4-13.

Table 4-13 Technology Transfer Application Centers Strategies for Overcoming Barriers/Challenges

Barrier	Title	Strategy
A	Fragmented building industry	The Application Centers will use extensive partner interaction and outreach to reach the building industry.
B	Lack of skilled practitioners	The Application Centers will provide technical assistance and training to building industry professionals.

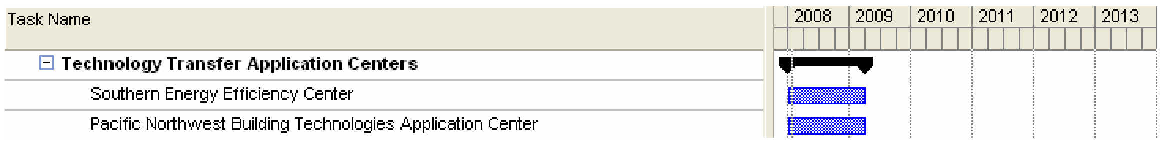
4.3.5 Technology Transfer Application Centers Milestones and Decision Points

The first period of performance for the pilot centers is 18 months and ends in March 2009. At this first decision point, BT will review the results before entering the next budget period. The remaining budget periods will be at 12 month intervals.

Table 4-14 Technology Transfer Application Centers Tasks

Task	Title	Duration	Barriers
1	Southern Energy Efficiency Center	2008-2009	A, B
2	Pacific Northwest Building Technologies Application Center	2008-2009	A, B

Figure 4-7 Technology Transfer Application Centers Gantt Chart



4.4 Commercial Lighting Initiative

The Commercial Lighting Initiative (CLI) promotes reducing energy used for lighting by at least 30 percent in commercial buildings. BT will spearhead this public campaign challenging commercial building owners to improve their building lighting efficiency by using a combination of commercially available technologies, controls, better lighting design, and advanced technologies. To accomplish this, BT will collaborate with national associations, states, utilities, EEPS, manufacturers, retailers, all of whom will support the challenge through financial incentives, providing training and technical assistance to participants and using the BT-developed platform to market advanced lighting technologies and practices to key end user groups.

4.4.1 Commercial Lighting Initiative Support of Program Strategic Goals

Of all the building systems, lighting is the largest energy user—it accounts for 26% of the commercial energy use nationwide and represents a savings opportunity that merits an aggressive and comprehensive approach.[146] Solid State Lighting is the vision of the future and represents the 'brass ring.' However, BT cannot meet the ZEB milestones without also utilizing the best of emerging and underutilized technologies.

The path to ZEB must support the market uptake of such technologies as an interim strategy while also establishing the foundation for follow on activities, particularly for the commercialization of SSL. A healthy portfolio includes not only technology development, but deployment activities designed to break down market barriers and increase uptake of advanced technologies, design practices, and systems integration. The Commercial Lighting Initiative (described herein) has been developed to accomplish this and contribute to the overarching goals in the BT MYP.

4.4.2 Commercial Lighting Initiative Support of Program Performance Goals

The goal of CLI is to spearhead a visible public campaign challenging commercial building owners to improve their building lighting efficiency by at least 30 percent using a combination of commercially available but underutilized technologies, lighting controls, expert lighting design, and integrated systems. The goal is a 30 percent reduction in lighting energy usage below ASHRAE 90.1-2004 in 5.5 billion square feet of commercial space.

[146] BED

4.4.3 Commercial Lighting Initiative Market Challenges and Barriers

A major market barrier to the CLI is perceived quality issues with the efficient technologies.

Table 4-15 Commercial Lighting Initiative Market Challenges and Barriers

Barrier	Title	Description
A	Perceived quality issues in efficient lighting	There are more efficient, commercially available technologies that are currently under-utilized due to perceived lighting quality.

4.4.4 Commercial Lighting Initiative Technical (Non-Market) Challenges and Barriers

Recent market analysis has shown that while there are numerous mandates, policies, and financial messaging targeting beyond code energy savings, there is a profound gap in "how to" technical guidance for end users who wish to implement deep energy savings. These technical challenges and barriers include those listed below in Table 4-15.

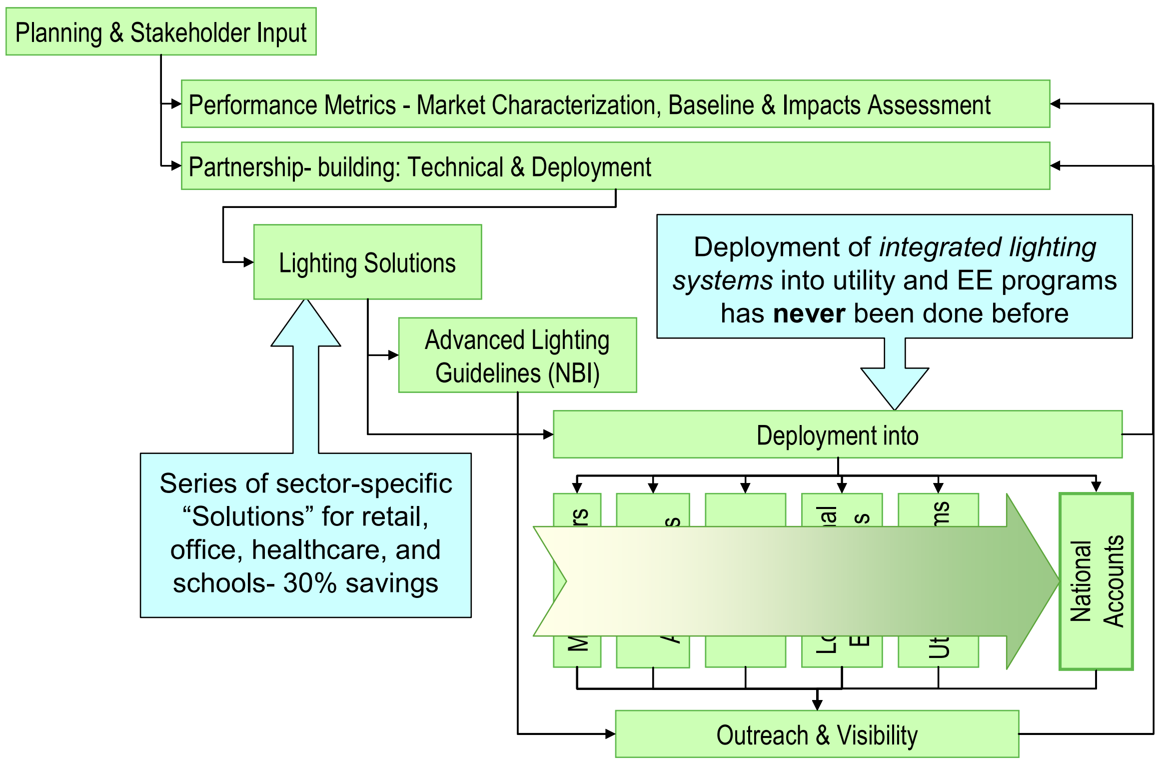
Table 4-16 Commercial Lighting Initiative Technical (Non-Market) Challenges and Barriers

Barrier	Title	Description
B	Lack of actionable solutions	Detailed technical information is often lacking and it is not in performance specification language nor geared toward the A&E audience.
C	Growing set of goals and mandates	With a growing set of goals and mandates, technical guidance on how to achieve these goals is badly needed.
D	Lack of novel and scalable solutions	It has been unclear how to develop and implement efficient lighting technologies, making solutions widely available.

4.4.5 Commercial Lighting Initiative Approach/Strategies for Overcoming Challenges and Barriers

Lighting solutions represent the core product around which the CLI is built and is also the basis for the energy savings. Figure 4-8 below shows the conceptual design of the CLI subprogram.

Figure 4-8 Commercial Lighting Initiative Subprogram Design



The CLI will first develop metrics to determine energy savings and evaluate program success; these will be used to examine periodic progress. From there, technical partnerships will play a critical role in developing lighting solutions. CLI will host a roundtable discussion with key stakeholders to evaluate design vignettes and control strategies developed through charrette and planning activities.

The *Lighting Solutions* will be developed in conjunction with an update to the Advanced Lighting Guidelines (ALG) applications chapter. The patterns, or modules, found in the ALG applications chapter will present the designs at a conceptual level while the *Lighting Solutions* will provide actionable, detailed specifications to bridge the gap between the traditional design guide and high volume implementation.

The *Lighting Solutions* will use numerous strategies to save energy including integration of high performance products, expert electric and daylighting design, and installation and commissioning guidance. The solutions 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. There will also be a custom path option to support rebates for ‘out-of-the-box,’ non-package designs that meet the energy savings target.

Deployment Partnerships will then support the transfer of the *Lighting Solutions* into the four market sectors (retail, office, schools, and healthcare) and will include a large number of strategic partners geared towards maximum impact nationally. A key focus of the Commercial Lighting Initiative is coordinating with various stakeholder groups to market advanced lighting efficiency in the commercial sector. To achieve this, the Commercial Lighting Initiative will work with stakeholders from all aspects of the value chain (e.g. manufacturers, distributors, utilities, energy efficiency program sponsors, NGOs) to participate in the initiative and create consistency in the energy efficient lighting systems used in commercial space.

The strategies utilized by the CLI to overcome the barriers and challenges are listed in Table 4-17.

Table 4-17 Commercial Lighting Initiative Strategies for Overcoming Barriers/Challenges

Barrier	Title	Strategy
A	Perceived quality issues in efficient lighting	CLI is developing lighting design solutions using equipment that is commercially available but underutilized, for near term measurable progress.
B	Lack of actionable solutions	Lighting solutions include detailed technical information in performance specification language, geared toward the A&E audience.
C	Growing set of goals and mandates	Amidst a growing set of goals and mandates, CLI provides badly needed technical guidance on how to achieve these goals.
D	Lack of novel and scalable solutions	Using the concept of green prototype development and widespread implementation, lighting solutions are developed for a series of common types of buildings and made available to the market via strategic partnerships.

4.4.6 Commercial Lighting Initiative Milestones and Decision Points

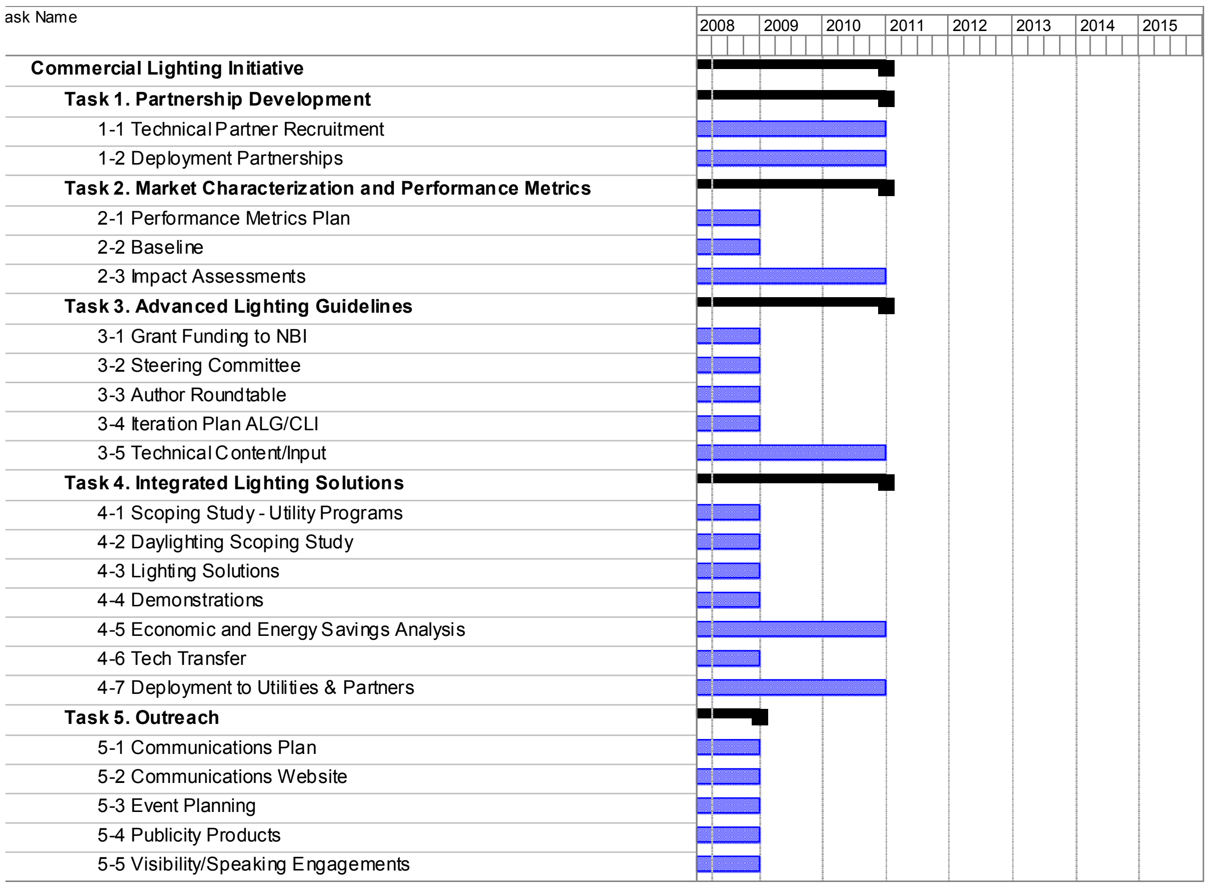
The milestones and decision points are listed in the table below and displayed in the Gantt chart.

Table 4-18 Commercial Lighting Initiative Tasks

Task	Title	Duration	Barriers
1	Partnership Development	2008-2010	A, D
1-1	Technical Partner Recruitment	2008-2010	
1-2	Deployment Partnerships	2008-2010	
2	Market Characterization and Performance Metrics	2008-2010	B
2-1	Performance Metrics Plan	2008	

2-2	Baseline	2008	
2-3	Impact Assessments	2008-2010	
3	Advanced Lighting Guidelines	2008-2010	B, C, D
3-1	Grant Funding to NBI	2008	
3-2	Steering Committee	2008	
3-3	Author Roundtable	2008	
3-4	Iteration Plan ALG/CLI	2008	
3-5	Technical Content/Input	2008-2010	
4	Integrated Lighting Solutions	2008-2010	B, C, D
4-1	Scoping Study – Utility Programs	2008	
4-2	Daylighting Scoping Study	2008	
4-3	Lighting Solutions	2008	
4-4	Demonstrations	2008	
4-5	Economic and Energy Savings Analysis	2008-2010	
4-6	Tech Transfer	2008	
4-7	Deployment to Utilities & Partners	2008-2010	
5	Outreach	2008	A, D
5-1	Communications Plan	2008	
5-2	Communications Website	2008	
5-3	Event Planning	2008	
5-4	Publicity Products	2008	
5-5	Visibility/Speaking Engagements	2008	

Figure 4-9 Commercial Lighting Initiative Gantt Chart



4.5 EnergySmart Schools

The EnergySmart Schools program will work with partners nationwide to upgrade the efficiency of existing schools and build new efficient schools in America.

4.5.1 EnergySmart Schools Support of Program Strategic Goals

The EnergySmart Schools subprogram supports the BT strategic goal of zero energy buildings by:

- Promoting energy efficiency in new and existing K-12 facilities, reducing energy use and costs and improving the learning environment (e.g., recent ASHRAE research shows that lower classroom temperatures and increased ventilation improves student performance by 10-20%);
- Educating school personnel and students on the proper operation and maintenance of energy efficient, healthy high performance buildings; and
- Developing schools that serve as "living labs" to engage the broader community on energy efficiency.

4.5.2 EnergySmart Schools Support of Program Performance Goals

The EnergySmart Schools subprogram aligns with BT performance goals by accelerating the adoption of energy efficient technologies and strategies within a specific type of commercial buildings. The EnergySmart Schools goals that work towards efficiency improvements are:

- 30% improved efficiency in existing schools (over ASHRAE 90.1-1999)
- 50% improved efficiency in new schools and major renovations and additions (over ASHRAE 90.1- 1999)

4.5.3 EnergySmart Schools Market Challenges and Barriers

Table 4-19 lists the market challenges and barriers associated with EnergySmart Schools, which relate to insufficient information and decision-making.

Table 4-19 EnergySmart Schools Market Challenges and Barriers

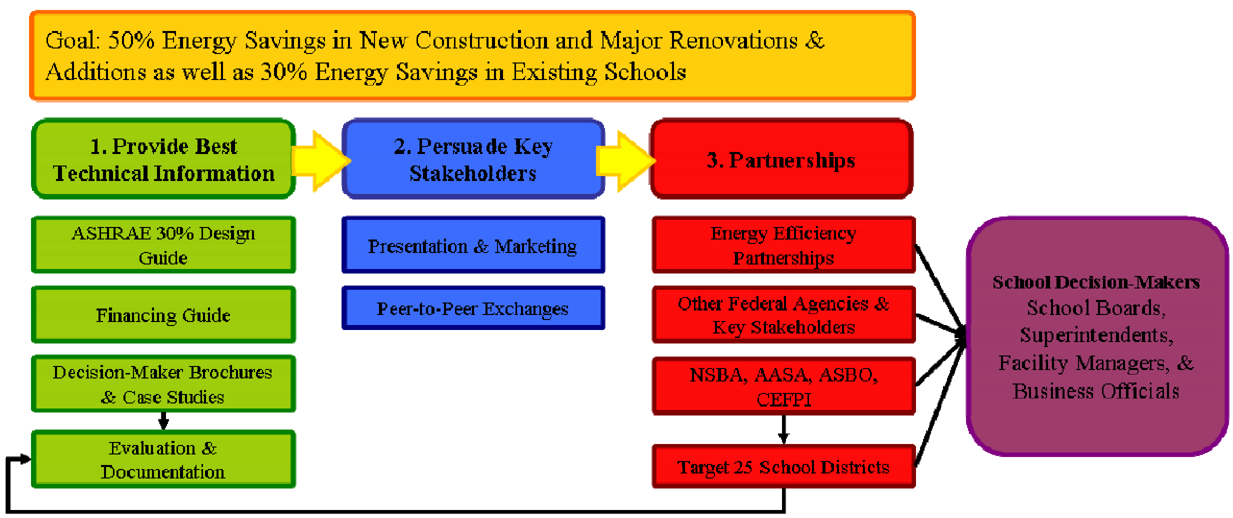
Barrier	Title	Description
A	Lack of connection between improved efficiency and academic and health benefits	Energy efficiency is not the first priority for school decision-makers, benefits need to be tied into improved academic performance and health
B	Lack of awareness of long term cost benefits	Perception of higher start-up costs and lack of awareness of long-term benefits through reduced O&M costs

C	Non design-oriented decision-makers	Design/construction decisions are made by school decision-makers
D	Varied decision making process	Decision-making process varies from state, local, and across school districts

4.5.4 EnergySmart Schools Approach/Strategies for Overcoming Challenges and Barriers

EnergySmart Schools is a public-private partnership that supports improved energy efficiency in K-12 facilities. The goal is to upgrade new schools and major renovations and additions to 50 percent better than code and improve existing schools by 30 percent. This initiative has three main strategic pathways to reach the goal: to provide the best technical information, persuade key stakeholders, and establish partnerships (Figure 4-10).

Figure 4-10 EnergySmart Schools Strategic Pathways



Through this initiative, BT will serve as a catalyst to kick start efficiency upgrades by:

- Brokering relationships and coordinating efforts with key strategic partners;
- Delivering a national message calling for improved energy use in schools; and
- Offering a body of knowledge and technical and marketing tools on energy efficiency and renewable energy for new school construction, renovation, and student curriculum.

The EnergySmart Schools subprogram will address the barriers and challenges through the strategies listed in Table 4-20.

Table 4-20 EnergySmart Schools Strategies for Overcoming Barriers/Challenges

Barrier	Title	Strategy
A	Lack of connection between improved efficiency and academic and health benefits	Speak with school decision-makers about energy efficiency benefits, such as improved academic performance and health
B	Lack of awareness of long term cost benefits	Create financing tools to educate partners on the perception of higher start-up costs and long-term benefits through reduced O&M costs
C	Non design-oriented decision-makers	Train school decision-makers about design/construction decisions
D	Varied decision making process	Educate and inform the decision-making process which varies from state, local, and across school districts

4.5.5 EnergySmart Schools Milestones and Decision Points

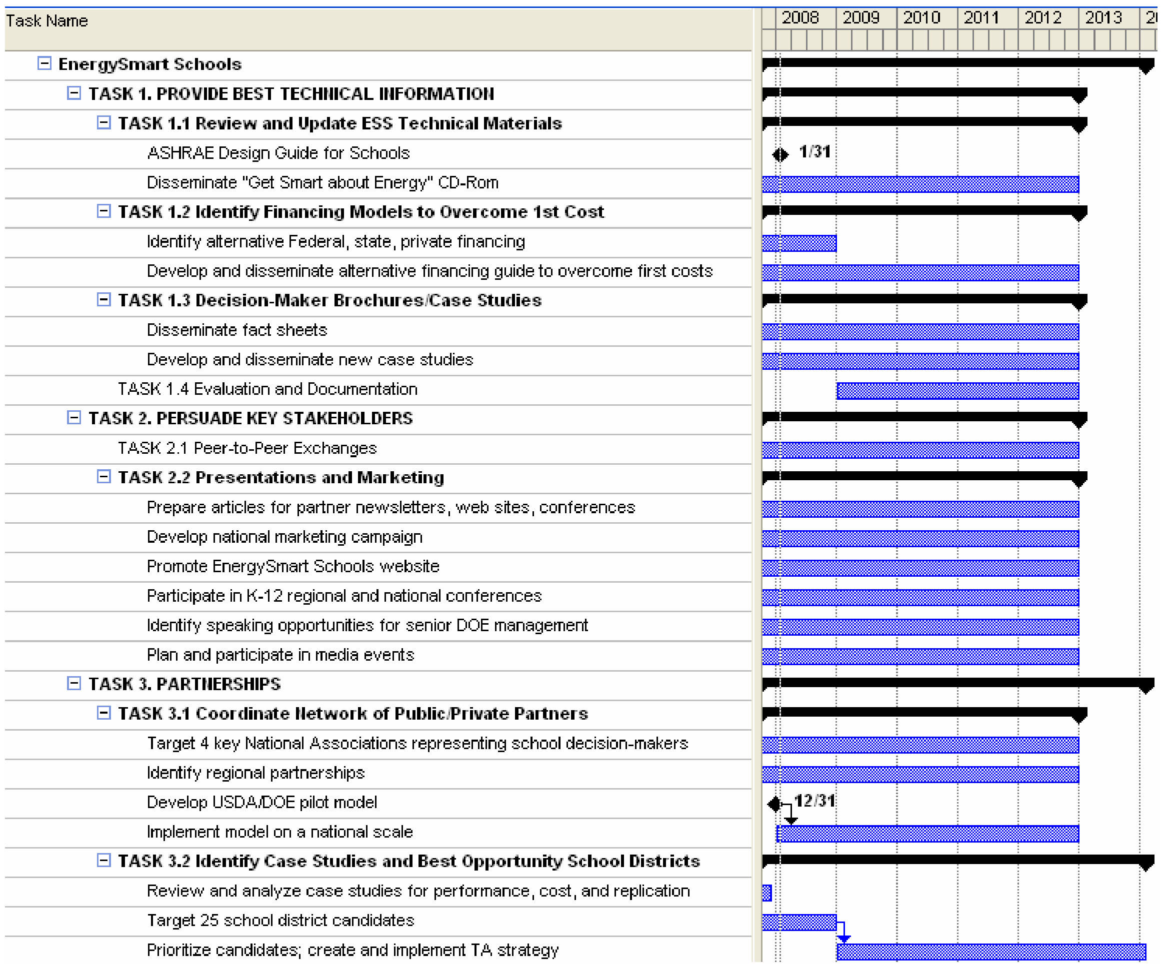
The milestones and decision points are listed in Table 4-21 and displayed in the Gantt chart (Figure 4-11). The key activities for this initiative are listed below:

- Identify areas of opportunity and growth and age and condition of existing stock
- Review existing state-of-the-art school technical materials and package for emerging efficiency markets
- Develop innovative financing opportunities and tools to overcome upfront cost barriers

Table 4-21 EnergySmart Schools Tasks

Task	Title	Duration	Barriers
1	Provide Best Technical Information	2008-2012	A
1-1	Review and Update ESS Technical Materials	2008-2012	A
1-2	Identify Financing Models to Overcome 1st Cost	2008-2012	B
1-3	Decision-Maker Brochures/Case Studies	2008-2012	A, B
1-4	Evaluation and Documentation	2008-2012	B
2	Persuade Key Stakeholders	2008-2012	A, C, D
2-1	Peer-to-Peer Exchanges	2008-2012	C, D
2-2	Presentations and Marketing	2008-2012	C, D
3	Partnerships	2008-2012	C, D
3-1	Coordinate Network of Public/Private Partners	2008-2012	C, D
3-2	Identify Case Studies and Best Opportunity School Districts	2008-2012	A, B

Figure 4-11 EnergySmart Schools Gantt Chart



4.6 EnergySmart Hospitals

TVMI has revitalized the EnergySmart Hospitals subprogram to work with partners nationwide to upgrade inefficient hospitals in America. Hospitals are among the nation's most energy intensive buildings due to their continuous hours of operation, indoor environmental requirements and high-tech, energy intensive equipment, consuming approximately 249 kBTU/ft^2, more than 2.5 times the energy intensity of office buildings (93 kBTU/ft^2).[147]

---

[147] Consortium for Energy Efficiency

4.6.1 EnergySmart Hospitals Support of Program Strategic Goals

BT has defined its central vision as the realization of marketable net-zero energy buildings through the development of conservation technologies and practices and improving hospitals' energy consumption works towards this strategic goal.

4.6.2 EnergySmart Hospitals Support of Program Performance Goals

BT performance goals are supported by the EnergySmart Hospitals subprogram, which works to accelerate the adoption of energy efficient technologies and increase the construction of more energy efficient buildings. The EnergySmart Hospitals initiative will support this goal by:

- Challenging the nation's 8,000 hospitals to improve energy efficiency by 20% over ASHRAE 90.1-2004, with an assumed goal of motivating comprehensive upgrades in 200 of those facilities over the next five years
- Impacting at least 10% of the new large hospital projects, projected over the next 10 years, to improve energy performance by at least 30% over ASHRAE 90.1-2004

4.6.3 Energy Smart Hospitals Market Challenges and Barriers

Impacting hospitals' design and operation is difficult. Hospitals are a unique commercial building type with complex requirements around which efficiency investments must be planned, such as ventilation requirements (rate and outside air) and safe laboratory conditions (e.g., fume hoods, chemical and biohazard management and positive pressure). Additionally, hospitals include several types of facility space within the hospital building or complex (i.e., laboratories, food service, office and retail), each of which demands different efficiency upgrade pathways and technology choices. Upgrades at hospitals must be undertaken in a twenty-four hour environment where patient health and welfare will always take precedence over energy use. However, there is a growing body of evidence that high performance hospitals improve patient recovery and worker retention.

Further, many hospitals are facing investment constraints due to rising health care and obligations to treat the un- or underinsured. Hospital administrators are often burdened with more immediate concerns and rarely have opportunities to focus on longer-term issues, such as energy efficiency.

The market challenges and barriers to implementing EnergySmart Hospitals are summarized in Table 4-22.

Table 4-22 EnergySmart Hospitals Market Challenges and Barriers

Barrier	Title	Description
A	Lack of design and operational resources	Efficient design and operational resources are not available.
B	Financing difficulty	Financing upgrades is often difficult for small, cash-flow negative hospitals.
C	Lack of understanding of profitability impact	The impact of upgrades on energy use and hospital profitability is not understood.
D	Competing mission investments	Efficiency competes with other mission critical investments. The connection of efficiency to mission critical outcomes not understood or publicized.
E	Large plug loads	Plug load is an increasing part of hospital energy costs.

4.6.4 EnergySmart Hospitals Approach/Strategies for Overcoming Challenges and Barriers

EnergySmart Hospitals will help overcome these barriers by providing technical guidance, education and financing tools, as well as raising public awareness and support for hospital upgrades. The large relative size of energy as a percent of hospitals' controllable costs and profit center provides opportunities to reinvest money saved via energy efficiency. There are six strategic elements of the EnergySmart Hospitals to address the barriers and challenges, which are summarized in Table 4-20.

Table 4-23 EnergySmart Hospitals Strategies for Overcoming Barriers/Challenges

Barrier	Title	Strategy
A	Lack of design and operational resources	**1. Design** Develop an integrated whole-building systems approach that enhances energy efficiency, improves indoor environmental quality, optimizes the building's operating conditions and makes hospitals into safe havens during disaster. **2. Operations Support** Provide common approach to technical assessments; develop and distribute best practices and other technical guidance tools used by and distributed through partners.
B	Financing difficulty	**3. Financing** Convene a group of financing experts to examine and create alternative models for financing the upfront costs of upgrades.
C	Lack of understanding of profitability impact	**4. Measuring Results** Develop the ability to measure the program's impact on both energy performance and patient and worker outcomes. Build results and case studies based on verified data gathered by the hospitals and the network of partners that support them.
D	Competing mission investments	**5. Marketing/Outreach** Promote and distribute technical guidance and training. Develop media materials and story lines for use in national press. Conduct highly visible events.
E	Large plug loads	**6. Procurement** Work with stakeholders across supply chain to impact the availability of energy efficient products and equipment.

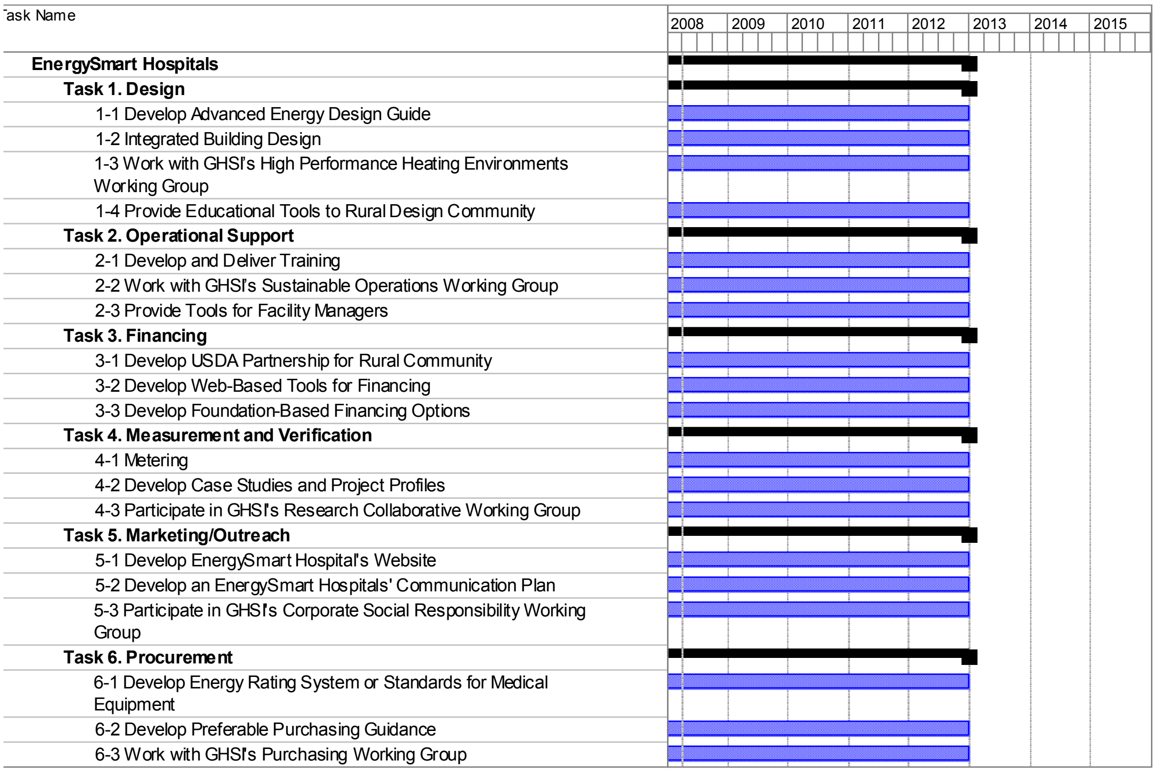
4.6.5 EnergySmart Hospitals Milestones and Decision Points

The tasks for the EnergySmart Hospitals subprogram are listed in Table 4-24.

Table 4-24 EnergySmart Hospitals Milestones and Decision Points

Task	Title	Duration	Barriers
1	Design	2008-2012	A
1-1	Develop Advanced Energy Design Guide	2008-2012	A
1-2	Integrated Building Design	2008-2012	A
1-3	Work with Global Health and Safety Initiative's (GHSI) 'High Performance Healing Environments' Working Group	2008-2012	A
1-4	Provide Educational/Tools to Rural Design Community	2008-2012	A
2	Operational Support	2008-2012	B
2-1	Develop and Deliver Training	2008-2012	B
2-2	Work with GHSI's 'Sustainable Operations' Working Group	2008-2012	B
2-3	Provide Tools for Facility Managers	2008-2012	B
3	Financing	2008-2012	C
3-1	Develop USDA Partnership for Rural Community	2008-2012	C
3-2	Develop Web-Based Tools for Financing	2008-2012	C
3-3	Develop Foundation-Based Financing Options	2008-2012	C
4	Measurement and Verification	2008-2012	D
4-1	Metering	2008-2012	D
4-2	Develop Case Studies and Project Profiles	2008-2012	D
4-3	Participate in GHSI's 'Research Collaborative' Working Group	2008-2012	D
5	Marketing/Outreach	2008-2012	E
5-1	Develop EnergySmart Hospitals' Website	2008-2012	E
5-2	Develop an EnergySmart Hospitals' Communications Plan	2008-2012	E
5-3	Participate in GHSI's 'Corporate Social Responsibility and Public Policy' Working Group	2008-2012	E
6	Procurement	2008-2012	F
6-1	Develop Energy Rating System or Standards for Medical Equipment	2008-2012	F
6-2	Develop Preferable Purchasing Guidance	2008-2012	F
6-3	Work with GHSI's 'Purchasing' Working Group	2008-2012	F

Figure 4-12 EnergySmart Hospitals Gantt Chart



4.7 Building America Challenge

The Building America Challenge (BAC), based on over a decade of Building America research, will challenge builders to reach further while supporting them in their efforts to design, build, and sell high performance homes. The challenge to builders is to construct homes that rate 70 or better on the Home Energy Rating Index and that deliver comfort, quality, durability, and a healthy indoor environment in accordance with Building America performance criteria. The process for meeting the challenge is based on existing consensus standards and procedures that include verification and quality control. The challenge can be met through performance measures or prescriptive solutions to provide different compliance paths for every type of builder.

BT and its partners will offer technical information, resources, and marketing tools to support builders across the nation to meet the challenge on their own or through a partner program. Builders will drive demand through homebuyer education surrounding an easy-to-understand Home Performance Guide (HPG) that is similar to miles per gallon (MPG) for a new car. In addition, a design competition will make high performance home plans more readily available and awards will recognize and reward participation.

4.7.1 Building America Challenge Support of Program Strategic Goals

The Building America Challenge supports the overall zero energy buildings goal by providing a challenge that will give a new home buyer the opportunity to purchase a net-zero energy home[148] anywhere in the United States by 2030.

4.7.2 Building America Challenge Support of Program Performance Goals

The BAC is a public-private initiative, spearheaded by BT, galvanizing the housing industry to move 100,000 high performance homes (with a HERS score of 70 or better) into the marketplace by 2012, while spurring strong consumer demand for these homes.

As the building industry makes progress in constructing more efficient homes, continued progress means raising the bar over time. An ENERGY STAR home built in 1990 would be average at best today. Likewise, a home meeting the Challenge in 2008 could be standard in 2012 as research, codes, and energy prices continue to drive innovation. Therefore, the Building America Challenge subprogram envisions progressive targets to build towards ZEHs, achieving the highest economically feasible energy rating for each target. Approaching adjustments to the program minimum in this manner adds predictability and sends a signal to the industry that the goal is continuous improvement. The specific goals, HERS and number of homes, are listed by year in Table 4-25.

Table 4-25 Building America Performance Goals

Acceleration Toward net-ZEH	2008	2012	2015	2018	2021	2024	2027	2030
Builders Challenge HERS Threshold	70	60	50	40	30	20	10	0
Cumulative # of Homes	35K	216K	367K	530K	700K	888K	950M	1.3M

4.7.3 Building America Challenge Market Challenges and Barriers

The Building America Challenge market challenges and barriers are listed in Table 4-26.

Table 4-26 Building America Challenge Market Challenges and Barriers

Barrier	Title	Description
A	Inability to compare	Homeowners cannot compare energy performance

[148] A net-zero energy home annually produces with on-site renewable sources as much energy as it consumes. On-site renewable sources include energy collected on the site and used in the home (solar and wind). The site includes the footprint of the home and home site plan. The home should provide an expected level of service and comfort. Purchased fuel will be converted to an electrical equivalent at a conversion efficiency of 40%. Co-generation with purchased fuel is not included.

	energy performance of homes	when shopping for a new home.
B	Lack of homebuilder differentiation in competitive market	Energy efficient homebuilders are unable to differentiate themselves from other homebuilders and qualify for financial incentives such as Federal Tax Credits and utility benefits in some areas of the country.

4.7.4 Building America Challenge Technical (Non-Market) Challenges and Barriers

In addition to market barriers, the Building America Challenge has two technical challenges (Table 4-27).

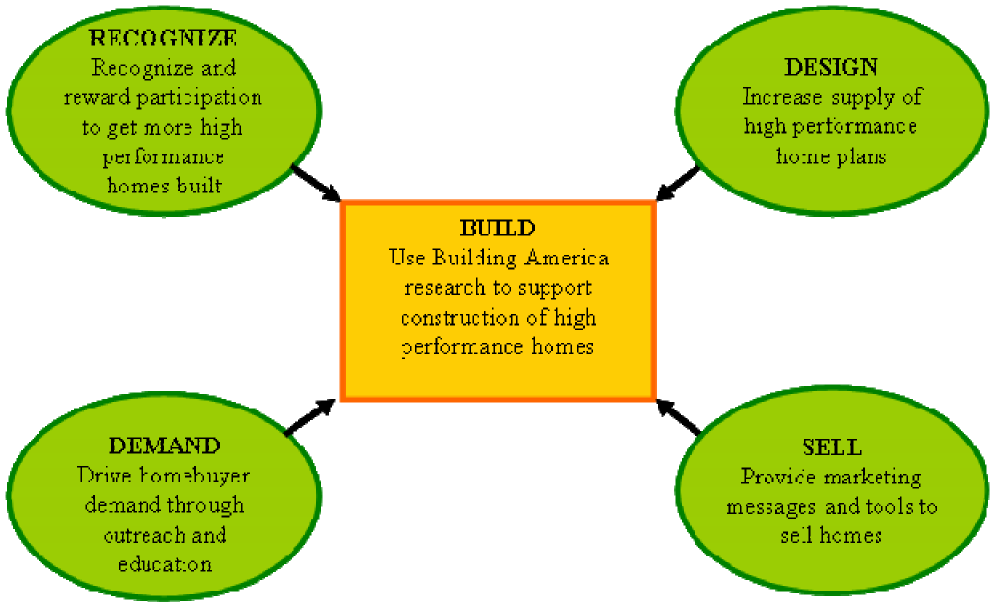
Table 4-27 Building America Challenge Technical (Non-Market) Challenges and Barriers

Barrier	Title	Description
C	Technical inflexibility	A barrier is not having several pathways to meet the technical goal.
D	Lack of mainstream design plans with energy efficiency as the principal design constraint	Some high performance homes are designed by architects to meet the tastes of individual homeowners, but most production homes are highly replicated designs with little focus on energy performance.

4.7.5 Building America Challenge Approach/Strategies for Overcoming Challenges and Barriers

To transform the market and build on partner programs, BT will take an active role in driving homebuyer demand through education and outreach, providing builders with technical information and marketing tools, increasing the supply of high performance home designs through a challenge to designers and architects, and recognizing and rewarding those within the housing industry who are making contributions to getting high performance homes in the market place. The five strategy approach is illustrated in Figure 4-13.

Figure 4-13 Building America Challenge Market Transformation Strategy



Strategy 1: Build High Performance Homes

The Building America Challenge subprogram is working with partners to provide technical information, training and marketing tools to support builders across the nation. Builders choose the technical path that best meets their needs.

A variety of different ways exist to meet the challenge, as long as the home achieves a HERS Index of 70 or better and incorporates Building America performance criteria for comfort, quality, durability, and a healthy indoor environment.

To participate in the Challenge, builders may:

- Utilize climate-specific prescriptive Builder Challenge – Builder Option Packages (BC-BOPs);
- Model performance using software that has been accredited using the RESNET accreditation procedures; or
- Work with partner programs to achieve equivalent levels of performance within the requirements of the partner program.

All homes must have either third-party verification through a HERS Rater or other qualified professional, or demonstrate that they have been built under the oversight of a credible quality assurance and control system.

Strategy 2: Design High Performance Home Plans

A major barrier to achieving the BAC goals is the lack of mainstream design plans with energy efficiency as a principal design constraint. BT will provide builders with designs and strategies to build high performance homes by:

- Providing specifications through Builder Option Packages
- Coordinating with National Association of Homebuilders (NAHB) Research Center to award EnergyValue Housing Awards (EVHA) designers
- Coordinating with Solar Decathlon Pro for designs beyond the current threshold
- Working with designers to make plans available to builders at reasonable cost

Strategy 3: Drive Demand through Outreach and Education

Homebuyers are faced with an abundance of information and choices when purchasing a home, so it is important that information on energy use be straightforward and easy to understand. The central component for delivering an informative message is the whole-house energy use metric, HPG. To help homebuyers understand their home's energy performance relative to existing homes and standard new homes, a tested and verified *score* is placed on a *scale*. The score, the scale, the process, and the procedures are based on RESNET's consensus standards and the HERS Index (www.natresnet.org).

Through outreach and education, the process of looking at the HPG will become intuitive and homebuyers will understand that the closer the home is to zero, the less energy it uses. To make it easier for homebuyers to find this information and to help builders differentiate themselves, the BAC will feature a HPG power panel sticker that will automatically print from HERS accredited software. The HPG power panel sticker also includes information on the key energy features of the home as required by the *International Energy Conservation Code® 2004 Supplement*.[149] In addition, the HPG includes lighting and appliances energy usage because these have a significant impact on high performance homes.

Using credible and compelling marketing messages focused around the HPG and disseminated through national and regional media, BT and its partners will raise awareness of the benefits of high performance homes among homebuyers. These marketing materials will include website and media as well as additional support information.

Strategy 4: Sell Homes by Providing Marketing Messages and Tools

In addition to driving consumer demand through homebuyer education, BT will provide marketing tools to support professionals who are involved in selling high performance homes. This will include online toolboxes and downloadable marketing templates that

[149] Chapter 4, Residential Energy Efficiency, Section 401.3 Certificate

participating builders, sales professionals, and partners can co-brand for use in their own marketing and sales processes. The toolboxes will include messages, logos, and customizable marketing materials and artwork that have been market tested with homebuyers. Additionally, the toolboxes will specify usage guidelines with standard terms and conditions that ensure the integrity of the initiative.

BT will work with the following specific players:

- Congress to renew Federal Tax Credit
- Financial industry- promoting currently available products and developing new products
- Real estate industry such as Ecobrokers and DOE/NAR initiative, appraisers, HERS raters, and NAHB Sales and Marketing to value and sell

Strategy 5: Recognize and Reward Participation

A critical incentive to participating in the Challenge is recognizing and rewarding the efforts of participants and partners. All participants and partners will receive recognition as part of the program marketing efforts. In addition, BT will provide a National Secretarial Award for Extraordinary Achievement and regional awards to achieve local recognition where there is greater visibility to potential homebuyers.

The Building America Challenge uses the strategies in Table 4-28 to overcome barriers and challenges, completing the FY08 tasks in Table 4-29.

Table 4-28 Building America Challenge Strategies for Overcoming Barriers/Challenges

Barrier	Title	Strategy
A	Inability to compare energy performance of homes	The HPG enables homebuyers to compare performance when shopping for a new home and provides homeowners with an easy-to-find record of their home's energy features for resale.
B	Lack of homebuilder differentiation in competitive market	The information on the HPG will be included on a certificate for the homebuyer to give to a lender to demonstrate lower operating costs and in marketing materials to help sell the home.
C	Technical inflexibility	The initiative allows builders to use one of three compliance pathways that fit them best.
D	Lack of mainstream design plans with energy efficiency as the principal design constraint	As the initiative progresses, a Design Challenge will be developed to recognize high performance home designs, and showcase strategies and features that can be used to bring these designs to the mainstream.

4.7.6 Building America Challenge Milestones and Decision Points

Table 4-29 Building America Challenge Milestones and Decision Points

Task	Title	Duration	Barriers
1	Build High Performance Homes	2008-2012	A, C
2	Design High Performance Home Plans	2008-2012	D
2-1	Design Challenge	2008-2012	D
3	Drive Demand through Outreach and Education	2008-2012	A, B
4	Sell Homes by Providing Marketing Messages and Tools	2008-2012	A, B
4-1	Key Audiences and Outreach Partners	2008-2012	A, B
4-2	Toolboxes	2008-2012	A, B
4-3	Website and Targeted Email Campaigns	2008-2012	A, B
5	Recognize and Reward Participation	2008-2012	B

Figure 4-14 Building America Challenge Gantt Chart

5.0 Program Portfolio Management

5.1 Program Portfolio Management Process

The BT Program manages R&D, Equipment Standards and Analysis, and Technology Validation and Market Introduction activities systematically to meet Department and Office of Management and Budget (OMB) requirements. BT's planning and management activities are organized around the Department's and OMB's schedules, as shown in Table 5-1.

Table 5-1 Building Technologies Portfolio Management Process and Schedule

	January – March 2008	**April – June**	**July – September**	**October – December**	**January – April 2009**
Multi Year Planning and Analyses	**MYP Update** Outcomes: Improved MYP that serves as basis for FY09 and FY10 budget, as well as the FY09 AOP		**Program Review Period** Outcomes: Program reviews that incorporate peer review findings and provide basis for MYP update	**MYP Update** Outcomes: Improved MYP that serves as basis for FY09 AOP. Updated MYP may also suggest issues for FY09 budget formulation.	
Budget Cycle	Nomination of issues to be considered in EERE Budget Development	- EERE FY10 budget development - FY10 Internal Review Budget formulation period- Draft budget to EERE/Chief Financial Officer	- Budget review and revision period - FY10 budget to OMB	- FY09 budget appropriation - FY10 passback from OMB	EERE FY10 budget development
Annual Operating Plan (AOP)		- Energy savings calculations for FY09 AOP submittals - AOP evaluation meetings-Completed AOP draft	AOPs revised to include corrective actions that respond to peer review criticisms	FY09 AOP implementation begins	
OMB PART	BT expects to participate in OMB Program Assessment Rating Tool (PART) for FY08.				

Activity	

The schedule drives BT's portfolio management, in which BT follows EERE best practices as set forth in the Program Management Guide.150 The operating principles set forth by EERE require each program to:[151]

- Develop an explicit mission and a vision;
- Establish long-term and short-term goals and objectives to achieve BT's vision and mission;
- Determine strategies to achieve goals and objectives;
- Allocate scarce resources through the budget process among those strategies;
- Track progress and results to ensure that plans are being carried out and the desired outcomes are realized; and
- Review goals and objectives to ensure relevance and that BT is making sufficient progress towards achieving both.

As stated in the guide, the BT Program Manager is responsible for producing a series of plans against which the Program is executed. These plans include:[152]

- Multi-Year Program Plans (MYPP);
- Annual Operating Plans (AOP); and
- Approved Funding Programs (Spend Plans).

These plans fulfill the BT Program's management objectives as illustrated in Figure 5-1. BT believes that the process used to develop the plans is essential in creating functional plans that guide a project throughout implementation. Developing plans and executing against those plans is essential for good program management.

[150] *EERE Program Management Guide*, U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, December 2003. Hereafter, PMG.
[151] PMG
[152] PMG, p. 2-22

Figure 5-1 Program Management Overview[153]

5.1.1 Multi-Year Program Plan Development

Development of the BT MYP is the key tool used in the portfolio decision making process. The key elements of the MYP are listed below:

- Discussion of the program logic, which links program outputs to achievement of objectives and ultimately to outputs in the market;
- Schedule of key milestones to achieve objectives;
- Identification of resources to achieve milestones;
- Decision points for completion, graduation, or termination of projects within activities;
- Identification of inter-relationships between activities and projects; and

[153] PMG, p. 2-23

- Criteria for portfolio balancing and project selection.

In developing the MYP, BT begins with the goals, objectives, and strategies developed during EERE strategic planning. Within these strategies, annual targets and milestones are identified along the critical path to the program objectives and goals. The annual targets and milestones also represent key decision points for determining if the Program is on track toward achieving objectives. This allows the Program to facilitate timely adjustments to the strategies as needed. Targets are managed within and across projects through Stage-Gate methodology.[154]

The MYP identifies baseline conditions, a schedule of key interim targets and milestones, and the final objective for each project. Targets are measurable against the stated objectives. In the Stage-Gate methodology, key decision points, gates, are identified and discussed based on pre-determined gate criteria. Fulfilling the must-meet gate criteria allows the project to proceed to subsequent stages while failing to meet criteria results in stopping the project or repeating the stage. Depending on the evaluation against gate criteria, plans are developed for graduation, completion, or termination of activities within projects, or projects themselves, as BT moves towards overall goal attainment.

Projects are more than a collection of similar activities focused on a particular objective; they provide continuity within a multi-year framework for achieving targets. The projects build to complement each other, achieving longer-term objectives and eventually outcomes that impact the marketplace. After completing the MYP these projects are executed through the AOP.

5.1.2 Annual Operating Plan Development

To accomplish near-term goals and select projects, BT develops an AOP, which describes:

- Tasks to be pursued in the upcoming fiscal year;
- Resource allocations to performers;
- Outputs (annual targets and quarterly milestones) and delivery dates; and
- Causal linkage between program outputs and contributions to program goals and objectives.

The President's Budget Request forms the planning framework within which the AOP is developed. The Budget Request provides substantial detail as to planned activities and potential resources, and establishes the resource levels that constrain statements of need to which proposers respond. Until the budget authorization is complete, the AOP is considered a draft working document.

---

[154] Winning at New Products (Third Edition), Robert G. Cooper, 2001.

The Technology Development Managers (TDMs) determine the projects required in the upcoming fiscal year to achieve the near-term targets, using results from the multi-year planning process. While only Joule[155] targets are displayed in the Budget Request, all projects funded have targets and quarterly milestones. Some of the targets will be achieved by follow-on tasks, building on project tasks funded in prior fiscal years, while others will require the initiation of new projects or new tasks within existing projects. All targets will require the identification of specific tasks, applicable funding requirements, and the timing of the funding obligations.

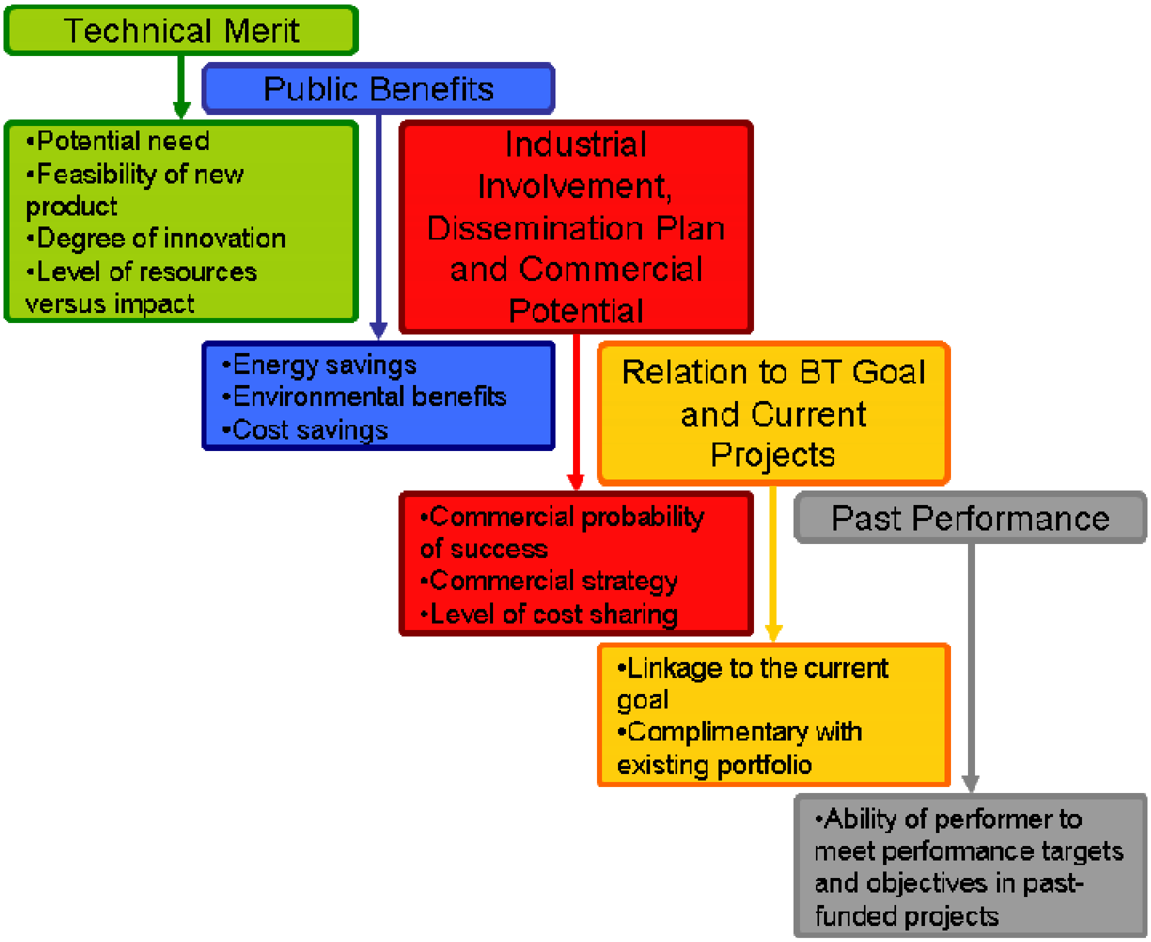
In some project allocations, work performers and/or procurement vehicles will already be identified, and congress directs some activities to be performed by specified entities. However, to the extent possible, BT uses a competitive process to solicit the best projects and most cost-effective methods for achieving performance targets along technical pathways. Competitive solicitations may be formulated as soon as the Administration's budget request is submitted in February. BT also encourages an informal "competition of ideas" among DOE laboratories and contractors to bring forth new ideas that address the needs of technical pathways contained in this MYP.

In implementing the President's Management Agenda, BT uses objective investment criteria for selection of individual project activities (project selection criteria) as well as for prioritizing and integrating the overall portfolio. These combined criteria focus the program's portfolio on technologies that address National Energy Policy goals, provide clear public benefits, and that are unlikely to be developed by the private sector alone. The application of these criteria addresses the need for performance-based public-private partnerships, well-defined comprehensive program plans, and clear "off-ramps" or termination points.

The set of potential projects includes all ongoing R&D projects as well as all new project proposals. R&D resources include manpower, facilities, and financial resources. The allocation decision process is based on established criteria, illustrated in Figure 5-2. Each project must provide data and supporting analysis that allow the project to be evaluated against these criteria. The format, timing, and calculation of benefits of proposals are all part of a standard developed in BT. Incomplete or missing information, or late submission, means that the project cannot be part of the selection pool. Proposals are requested annually during a thirty day period in the April timeframe.

[155] DOE corporate tracking system

Figure 5-2 Project Selection Criteria



In addition to management judgment and discretion, the projects are selected against the established selection criteria. After individual proposals are scored against the selection criteria (May timeframe), the next step in the process is to examine the selected candidates against the portfolio criteria, to assure adherence to established priorities and resource constraints.

The initial proposal selection process is completed in June, so that formulation of the draft AOP can begin. Actual project awards are not made until Congress passes the appropriation bill and the President signs it into law. Ideally, this happens in late August or early September; and at this point, the AOP is finalized.

Next, a spend plan is developed once the final tasks, performers, and resources are known. The spend plan is a simplified version of the AOP, primarily a management tool for procurement, but it provides additional detail regarding specific tasks, performers, and resources identified during previous planning stages. Projects are tracked and evaluated against the AOP, and it is also the source of information for generating Work Authorizations and Program Guidance Letters.

5.1.3 Stage-Gate Process Development

BT has adopted and adapted Stage-Gate Management to increase the pace and yield of its R&D portfolio.[156] Stage-Gate, once fully implemented in both project and portfolio modes, will allow BT to:

- More effectively identify opportunities;
- Commit resources appropriately;
- Assess progress;
- Maintain continued project relevancy to market and policy goals; and
- Act decisively based on appropriate technical, market and policy information delivered in concert at pre-determined points in time.

This approach will eventually provide greater transparency, simplify then streamline fiscal planning, and allow BT to accelerate the achievement of clearly defined technical and market objectives that serve the Program's long-term goals.

In FY06, BT began the process of adapting Cooper's Stage-Gate product development process to the particular needs of a federal applied R&D program. BT conducted Stage-Gate "pilots" on selected projects in FY07, and is using the lessons learned from conducting these pilots to refine the implementation of Stage-Gate in FY08. As of FY08, Stage-Gate principles are applied to the entire BT R&D portfolio.

The Stage-Gate framework for BT is essentially a formalized decision making tool that ensures when DOE moves a concept from a scientific phenomenon to an actual marketable product, the dedication of scarce resources is justified. As a candidate technology advances through the continuum of stages, the TDM must demonstrate to the Gate Review Team that the technology attains the must-meet technical and market criteria at each gate *before* it advances to the next stage. The Gate Review Team may elect, on the basis of stated criteria and deliverables in support of those criteria, to continue the project, terminate it, or "recycle" the project for further consideration. Project funding is also dependent on stage, which ensures the most promising projects receive resources. By constructing this type of framework, DOE aims to ensure that the Department and its contractors are properly reviewing the R&D projects and analyzing criteria that lead to successful commercialization of energy-saving technologies.

[156] See Appendix C for BT's adaptation of the model developed by Robert Cooper, Winning at New Products (Third Edition), 2001.

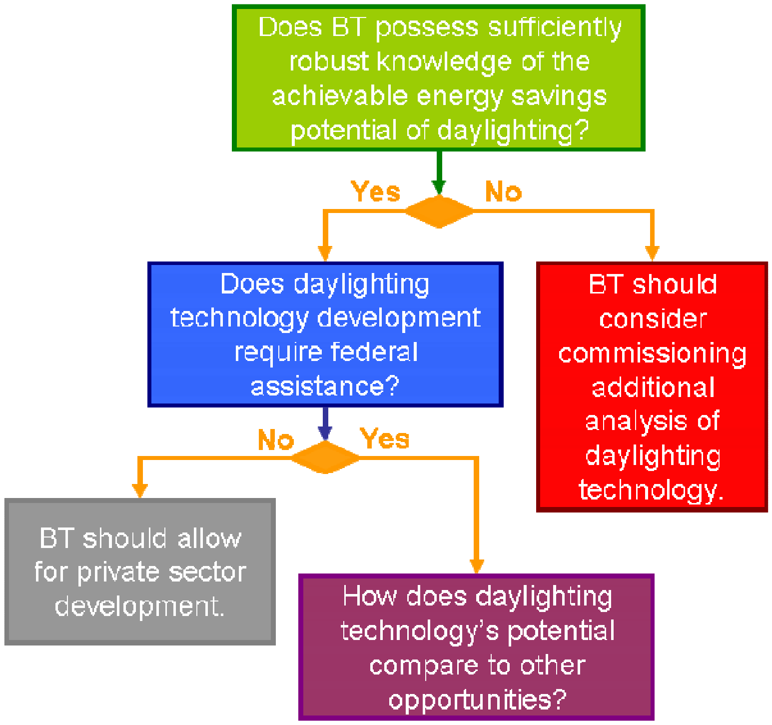
5.2 Program Analysis

Each step in the planning process, from definition of the technical energy savings potential to an evaluation of potential end-user requirements, requires some analysis, and planning invariably occurs with imperfect information. Further analysis can help to reduce or eliminate large unknowns with potentially significant impacts on the goals, objectives, or R&D portfolio. This in turn increases the confidence of technical and market decision-making, and consequently, increases the probability of BT program success. To improve the robustness of decision-making, BT has investigated analysis activities in the following areas as part of its multi-year planning process:

- Applying DOE/EERE risk assessment methods;
- Portfolio analysis, including technology pathways;
- Technology and market analysis; and
- Program benefits, including macroeconomic impacts.

BT is also conducting a crosscutting evaluation of its recently conducted analysis as well as the significant knowledge gaps in its corporate understanding that analysis could improve. The objective of this analysis crosscut is to develop an analysis "multi-year plan" with clearly identified priorities that are tied to potential BT decision making. Figure 5-3 provides an overview of this process, using daylighting technology as an example.

Figure 5-3 BT Knowledge Gap Analysis for Daylighting Technology



5.2.1 Risk Assessment

The BT Program primarily addresses research that requires new types of equipment or materials, techniques for combining recent and existing technologies, or innovative design strategies to integrate efficiency and renewable energy features into new and existing buildings. Resulting technologies, designs, and practices must not only meet energy savings goals but function reliably in day-to-day building conditions without adverse affect on health, safety, comfort, or productivity. The need to meet these multiple and sometimes competing performance requirements substantially increases the technical and market risk of BT projects.

Additionally, the pursuit of a net-zero energy home or building will require technologies that do not exist today, and developing these technologies requires inherently higher risk than incrementally improving current technologies. One example of a high risk technology development program is solid state lighting R&D. Successful development of solid state lighting products requires significant technological breakthroughs in areas such as organic light emitting diodes in order to achieve DOE's aggressive energy performance goals.

5.2.2 Portfolio Analysis

R&D portfolio analysis provides guidance regarding key issues that need to be addressed then balanced while making investments. These usually include major R&D issues and gaps, timing of the investment payoffs, and other concerns that are important to management and stakeholders. The objective of R&D portfolio analysis management is to achieve and maintain the optimum balance of investments, which depends on the specific goals, competence, vision and culture of the BT Program.

In the upcoming year, BT will be considering whether additional portfolio characteristics or analytical approaches could be used to improve the R&D portfolio management or provide additional program insights. Such portfolio characteristics could include:

- Risk Assessment (see 5.2.1) – Understanding technical and implementation risks associated with the project is essential for balancing investments, particularly R&D investments, where the risks and uncertainties are significant. The portfolio should include a range of risks and the balance should reflect the nature of the required R&D and the strategy of the Program.
- Technology Pathways – BT is examining the results from various subprogram analyses, such as Building America's residential Building Energy Optimization Tool (BEopt) and comparing these subprogram analysis results with the performance and cost targets in its Emerging Technologies activities to identify any gaps that might exist. Based on this review, BT has adjusted several areas of research and development to support the long term goal of net-zero energy buildings.

In FY08, BT will continue to refine and establish the technical pathways that lead to this level of performance. BT will also evaluate the technical needs for the integration activities, along with technical needs for pursuing various component, equipment and practice improvement.

- Technology Development Stage (coordinated with the Stage-Gate process) – Research, development, demonstration, commercialization, and then information and data development are typical designations for stages of development. A portfolio should contain projects that focus on the areas of most importance to the Program. For example, some programs do not include upstream research, but instead focus on a mix of development, demonstration, commercialization and informational projects. Other organizations focus on leading-edge research and development and have few investments in downstream commercialization or informational projects.
- Value – The estimated potential value of the project is a key factor in making decisions regarding R&D investment. However, value is not captured by a single term. The value for BT R&D must be comprised of a mixture of elements, such

as energy savings, environmental benefits, increased electric reliability, capital and operating cost savings, economic benefit, alignment of the project with the program's overall strategy, and additional factors that the program management team considers important. These are typically assessed separately and combined into a single value.

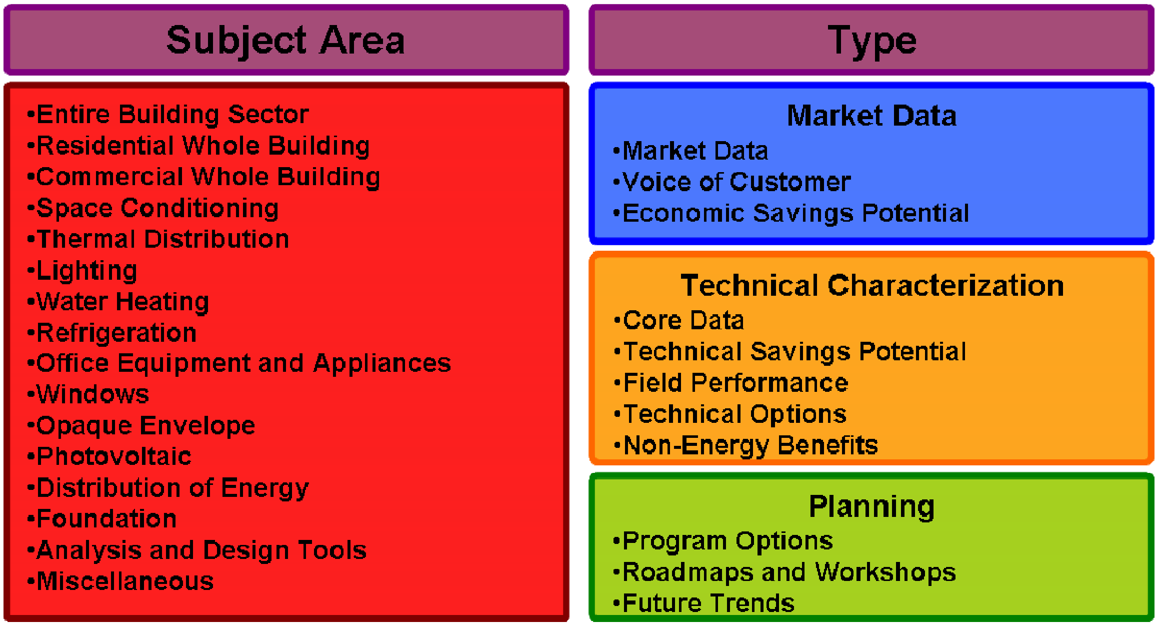
5.2.3 Technology and Market Analysis

Past analyses have guided programmatic decisions regarding which R&D areas to pursue; examples include the reports submitted to Congress in response to Sections 127 and 128 of the Energy Policy Act of 1992. More recently, a series of reports that examine the market for solid-state lighting are helping to suggest program directions for this important initiative. The BT Program Manager also uses tools, such as BEopt, to examine technology pathways and suggest optimized whole building technology packages with the potential of meeting performance targets leading to achievement of ZEB.

Technology and market analysis is the core of some programmatic activities. Appliance standards rulemaking and model building codes development both rely on analysis to determine economically justified levels of codes and standards. In both cases, the analysis determines the target levels for codes and standards, while the actual levels are set in an open and cooperative process with stakeholders and industry.

BT has a long history of conducting technology and market analyses to support BT activity and then publishing results. In support of its multi-year planning process, BT is conducting a cross cut of its analysis activities. The goal of this exercise is to identify analysis, including market analysis, needed to provide a firm foundation for decision making regarding BT's R&D portfolio in FY08 and subsequent years. To aid in this process, BT has developed an analysis taxonomy which characterizes key market and technology assessments– either funded by BT or actively used by BT. Appendix D includes this taxonomy and it is also illustrated in Figure 5-4.

Figure 5-4 BT Analysis and Document Taxonomy



5.2.4 Program Benefits

Estimates of potential benefits resulting from achieving BT Program goals are shown in Table 5-2. In addition to the types of benefits quantified below, building efficiency and renewable technologies often provide non-energy benefits, such as improved lighting quality or improved comfort that then results in increased building occupant productivity. The benefits estimates reported in this table do not include any expected acceleration in the deployment of these new technologies due to the unique field partnerships that provide the basis for the Residential Building Integration R&D or synergies with the EPA ENERGY STAR Home Program.

The assumptions and methods underlying the modeling efforts have significant impacts on the estimated benefits, and results could vary significantly if external factors, such as future energy prices, differ from the baseline case assumed for this analysis.[157] In addition, possible changes in public policy and disruptions in the energy system which may affect estimated benefits are not included in the model. External factors, such as unexpected changes in competing technology costs, could also affect the model's accuracy.

The results shown in the long-term benefits tables are preliminary estimates based on initial modeling of some of the possible program production technologies. These

[157] BT used the EIA business as usual outlook for components of the economy affecting energy use– this includes competing technologies.

estimates provide a useful picture of the potential change in national benefits over time if the technology, infrastructure and markets evolve in an orderly way; however, uncertainty increases as time increases. Estimated benefits assume that individual technology plans and market assumptions obtain results. A summary of the methods, assumptions, and models used in developing these benefit estimates are provided at http://www1.eere.energy.gov/ba/pba/pdfs/41347_AppG.pdf.

Table 5-2 FY2008 GPRA Benefits Estimates for the Buildings Program[158]

	Mid-Term Benefits					Long-Term Benefits			
Metric	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Economic Benefits									
Reduction in average delivered natural gas price (%)	0	1	1	1	2	1	2	4	1
Annual consumer savings (bil $2004)	2	5	8	16	27	60	72	84	71
Annual electric power industry savings (bil $2004)	1	3	7	12	18	16	19	20	17
Reduction in household income spent on energy (%)	0.1	0.2	0	1	1	1	1	2	1
Reduced energy intensity of economy (%)	0	1	1	2	2	2	3	3	3
Environmental Benefits									
Annual avoided greenhouse gas emissions (MMTCE/year)	3	10	32	47	57	72	79	78	77
Cumulative avoided greenhouse gas emissions (MMTCE)	7	44	150	348	621	1023	1404	1795	2181
Reduced cost of criteria pollutant control NPV (bil $2004)	ns	ns	2	4	5	nr	nr	nr	nr
Security Benefits									
Annual avoided oil imports (mbpd)	ns	ns	ns	0.1	0.1	0.1	0.1	0.1	0.1
Reduced oil intensity (%)	ns	ns	ns	0.6	0.6	0.5	0.5	0.4	0.4

ns = not significant relative to model error
nr = not reported or calculated by model

5.3 Performance Assessment

The basic types of performance assessments used by BT include results-based performance reporting using DOE's Joule Performance Measurement Tracking System, R&D Investment Criteria, and PART. The DOE Joule system tracks progress toward annual performance targets through reporting verifiable quarterly milestones tied to targets. Projects that are underperforming are put on a watch list and are required to address deficiencies through tracked action plans. Projects that have succeeded, or have

[158] Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs, FY 2008 Budget Request.

reached a logical maturation, are considered for off-ramps (hand-offs to other governmental, non-governmental organizations or to the private sector). BT is building "off ramps" into its technical pathways by developing sustainable exit strategies to enhance technology transfer and transition to market.

PART, which incorporates key elements of the R&D Investment Criteria, is a guiding system for project evaluation. While these tools are applied at the program level, the data necessary for completing PART are gathered and evaluated at the project level.

BT uses peer reviews by outside independent experts of both program and subprogram portfolios to assess quality, productivity, and accomplishments; relevance of program success to EERE strategic and programmatic goals; and management.[159] BT also uses the peer review process to judge both the merit of individual projects as well as the technical soundness of the overall portfolio. At key intervals comprehensive reviews are conducted, supported by analysis, objective review and recommendations by panels of experts using a merit review and peer review system. The frequency, regularity, depth, and degree of independence of these reviews depend on the nature of the program, degree of technology change or evolution, program's performance, demonstrated results and the interest among stakeholders. In response to peer review results, TDMs formulate Peer Review Implementation Plans that factor into planning, budget and execution decisions by the BT Program Manager. In accordance with EERE guidelines, the entire BT program is reviewed every two years.

The results of these reviews help complete the program management cycle by influencing the strategic planning and multi-year planning processes. Performance is also a criterion in project selections. Performance evaluation is used to reshape plans, reassess goals and objectives, and re-balance the overall portfolio. Performance data for projects (performance against milestones) must be provided by December of each year to ensure inclusion in the planning cycle.

5.3.1 Quality Assurance

BT is developing an enhanced Quality Assurance (QA) plan that will incorporate the Stage-Gate approach. The objective is to establish a general QA framework for BT's R&D effort and a set of preliminary procedures which can be implemented immediately. The plan is intended to be an established, but evolving, BT document which will be updated periodically to add new procedures and refine existing procedures which reflect the experience of BT and other organizations that conduct QA in a research environment.

Research management activities in BT cover all of the following five functions:

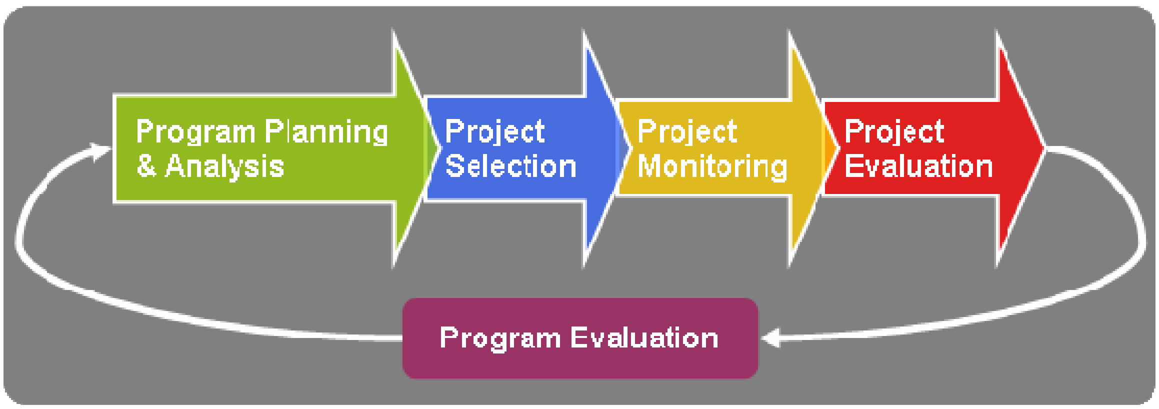
- Program planning and analysis;

[159] *Peer Review Guide,* U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, August 2004.

- Project selection;
- Project monitoring;
- Project evaluation; and
- Program evaluation.

The boundaries between these functions are relatively ambiguous, for example, between project monitoring and project evaluation. The essential relationships among these functions are shown in the framework in Figure 5-5.

Figure 5-5 BT Research Management Activities Framework



5.4 Stakeholder Interactions

Partnership and collaboration with industry, universities, and other government agencies are key aspects of the Program's management approach. By bringing together relevant stakeholders, BT has been able to achieve the collaboration necessary to address many of the barriers to increasing the energy efficiency of buildings and equipment, utilizing whole building design. As mentioned, a critical barrier is the fragmentation of the design, construction, materials, and equipment manufacturers and building operation and maintenance industries, making it difficult to reach a consensus on new technologies, implement new technologies, and coordinate efforts..

The BT Program funds research, development, and demonstration activities linked to public-private partnerships. The current strategy is to concentrate funding on high-risk, pre-competitive research in the early phases of development. As activities progress through the stages of developing technology to achieving technical targets, the Program's cost share will diminish. Ideally, government-sponsored research and development will bring technologies to the point where the private sector can successfully integrate them into buildings and decide how best to commercialize these products. BT has worked with other DOE programs and offices to complement our research and to implement our strategies, as well as with Federal partners, including the Department of Housing and

Urban Development, the Environmental Protection Agency and the National Institute of Standards and Technology, among others.

Additionally, through our competitive solicitation process, BT requires a significant amount of cost-sharing from our partners as part of awards. Building America activity forms teams of architects, engineers, builders, equipment manufacturers, material suppliers, community planners, mortgage lenders, and contractor trades to better integrate building design and construction. Partnerships and cost sharing arrangements with industry, universities, and other government agencies are a key aspect of BT's success in developing the technical capability needed for marketable ZEBs. Bringing together relevant stakeholders builds the critical mass necessary to address many of the barriers to increasing the energy efficiency of buildings.

One particular process used to ensure industry and stakeholder involvement is the development of technology roadmaps, which is a fundamental component of BT's approach (**Error! Reference source not found.**). Roadmaps are used to help align government resources with the high-priority needs identified by industry; they also facilitate cooperation among public and private researchers, State and Federal agencies, and others involved in achieving the technology goals. BT has been active in developing eight technology roadmaps, as well as supporting two others, HVAC and Refrigeration with ARI and Residential Buildings with PATH.

Table 5-3 Technology Development Roadmaps[160]

Sector	Published Date
HVAC and Refrigeration (in cooperation with ARI)	1997
Residential Buildings (in cooperation with PATH)	2000
High Performance Commercial Buildings	2000
Vision 2020: Lighting Technology	2000
Window Industry Technology	2000
Building Envelope Technology	2001
Solid State Lighting	2002
Window and Envelope Updates	2002
Appliances	Under development
Lighting Controls Sub-map	Under development

[160] Roadmap documents are available on-line at: http://www.eere.energy.gov/buildings/info/publications.html.

5.5 Cross-Cutting Issues

5.5.1 Communication and Outreach

The BT Program supports a range of activities designed to facilitate widespread adoption and use of energy-saving technologies and practices. Through building project profiles, developing enabling technologies, regulatory activities, awards and recognition, BT provides the information and assistance needed to help homeowners and business owners, architects and engineers, community planners and consumers all make smart choices about energy. Some examples are listed below:

- Building Projects: Building designers and decision-makers can learn energy technology and green building best practices by visiting the High Performance Buildings database. The Building America projects database provides information on energy-efficient homes built through Building America research projects. Zero Energy Building projects demonstrate the first steps toward designing and constructing homes that generate as much energy as they consume.

- Enabling Technologies: Building Energy Software Tools help researchers, designers, architects, engineers, builders, code officials, and others evaluate and rank potential energy-efficiency technologies and renewable energy strategies.

The High Performance Buildings Database seeks to improve building performance measuring methods by collecting data on various factors that affect a building's performance, such as energy, materials, and land use.[161]

[161] High Performance Buildings Database

ENERGY STAR

In 2007, public awareness of the ENERGY STAR label exceeded 65% and more than 3,2000 buildings earned the ENERGY STAR label. In addition, ENERGY STAR specifications for digital televisions adapters and commercial dishwashers and ice machines are announced.

Consumers saved $13.7 billion in energy costs in 2006 by utilizing ENERGY STAR appliances and equipment.[162]

- Regulatory Activities: The Building Energy Codes subprogram works with other government agencies, state and local jurisdictions, national code organizations, and industry to help develop improved national model energy codes. BT promulgates appliance standards rulemakings and product test procedures to improve the energy performance of products in the marketplace.

- Recognition: ENERGY STAR products and partnerships help businesses and consumers easily identify highly efficient products, homes, and buildings that save energy and money, while protecting the environment. ENERGY STAR works with manufacturers, national and regional retailers, state and local governments, and utilities to establish energy efficiency criteria, develop product labeling guidelines, and then promote the manufacture and use of ENERGY STAR products.

5.5.2 Communications and Deployment

Internal and external communications is key to successful BT deployment efforts. To coordinate cross-program communications on a systematic basis, BT has created a communications team – as an adjunct to the TVMI team – that includes representation from key program focus areas and EERE.

Through these cross-program communications efforts, BT will:

- Facilitate increased information exchange with stakeholders and across program focus areas;
- Identify opportunities to cross-market BT products and tools to serve wider constituencies;
- Increase media coverage in coordination with EERE;
- Further public education through events, lecture series, and other channels in partnership with stakeholder organizations;
- Develop compelling high-level branding messages about BT and energy independence;
- Reinforce consistent messages and formats in all BT public communications to heighten visibility of the Program, its purpose, and its achievements; and

[162] *ENERGY STAR® and Other Climate Protection Partnerships,* 2006 Annual Report.

- Develop high-priority communications projects, including the redesign of the BT website, based on stakeholder feedback.

Achieving the promise of ZEB must, by definition, include the integration of renewable energy technologies with ultra-energy-efficient building technologies. Strategic communications, in turn, must include collaborative efforts between BT and other areas of EERE. Supporting cross-EERE communications efforts – including Energy Towns, the Solar Decathlon, and the EERE public outreach campaign – will be an important focus of the BT communications team.

Significant work has been done in developing and institutionalizing communication protocols, maintaining priority action lists to keep deliverables and deadlines on track, and instituting regular meetings to ensure responsiveness to needs and opportunities as they arise. The communications team is also developing a shared library of communications products and tools (e.g., PowerPoint presentations, informational graphics, fact sheets, and backgrounders) for use by the BT staff, partners, and the EERE Information Clearinghouse.

Key audiences to be addressed in the cross-program communications efforts include States, utilities, Energy Efficiency Program Sponsors, local governments, retailers, manufacturers, financial institutions and banks, insurers, retailers, home builders, associations, universities, and commercial building professionals, as well as trade and mass media organizations.

An effective web presence is needed to support all BT deployment efforts. BT concluded three related web development efforts in 2007:

- Restructuring of the existing BT programmatic web site as a channel for reaching BT program partners
- Development of an educational web site (or sub-site) aimed at a wide range of audiences and encouraging investments in energy-efficient systems, products, and practices
- Development of a searchable library that will underlie both sites and that will contain all relevant BT tools and documents, including documents developed with BT funding by national laboratories and partner organizations. Search categories will be created that allow each audience to readily identify topics of interest without having a detailed knowledge of the BT program structure.

The educational web site will elevate and consolidate all educational materials (Rebuild Solution Center, Building America consumer and builder information, Energy Solutions for Your Building, etc.) on the existing web site, and will be the location of a wide range of special features of interest to end-users including topics like Disaster Recovery. The site will complement – rather than replicate – the consumer-focused information available on Energy Savers, the EERE Consumer site, and ENERGY STAR, providing links to these sites.

APPENDIX A: MYPP Drivers

Numerous legislative, Administration, and Department policies and procedures dictate both the need for, and the process and content of multi-year program planning over and above Program Manager's planning needs. These include:

- Government Performance and Results Act (GPRA)
  - Linkage of budget request to outputs and outcomes and to the Strategic Plan
- President's Management Agenda and OMB Program Assessment and Rating Tool (PART)
  - Provide program justification
  - Set performance goals
  - Link dollars to planned activities
  - Establish targets/milestones
  - Measure progress and resulting benefits
  - Include decision points and end points
- CFO
  - Report quarterly and annual milestones linked to DOE Strategic Goals
  - Management and Evaluation (ME-20) Program Plans
- Congress (House Rpt.108-554 - Energy and Water Development Appropriations Bill, 2005)
  - Beginning with submission of the fiscal year 2007 budget request…submit to Congress detailed five-year budget plans for all major program offices and a consolidated five-year budget plan for the entire Department.
  - Preparation of these five-year program plans and the comprehensive five-year DOE plan to be a Federal function

A program may consult with its contractors in developing its five-year plans, but the actual preparation of these plans is not to be contracted out; this work is to be done by Federal employees of the Department of Energy.

APPENDIX B: Building Technologies Technical Reports and Resources

Below is a list of the various technical reports and resources developed by the Building Technologies Program, and used to inform decisions associated with this Multi-Year Program Plan.

Case Studies

- The Galloway Family Home
- Prairie Crossing Homes
- Consumer Information
- Energy Savers: Cool Summer Tips (Spanish Version)
- Energy Savers: Hot Winter Tips
- Energy Savers: Tips on Saving Energy & Money at Home
- Energy Savers - Cool Summer Tips
- Energy Savers Virtual Tour
- HeatSmart! Homeowners Can Save Money by Conserving Heating Oil

EnergySmart Schools Brochures

- Designing High Performance Schools
- Energy Design Guidelines for High Performance Schools: Arctic and Subarctic Climates
- Energy Design Guidelines for High Performance Schools: Cold and Humid Climates
- Energy Design Guidelines for High Performance Schools: Cool and Dry Climates
- Energy Design Guidelines for High Performance Schools: Cool and Humid Climates
- Energy Design Guidelines for High Performance Schools: Hot and Dry Climates PDF
- Energy Design Guidelines for High Performance Schools: Hot and Humid Climates
- Energy Design Guidelines for High Performance Schools: Temperate and Humid Climates
- Energy Design Guidelines for High Performance Schools: Temperate and Mixed Climates
- Get Smart about Energy: Program Folder (Revision)
- How Parents and Teachers Are Helping to Create Better Environments for Learning
- How School Administrators and Board Members Are Improving Learning and Saving Money
- How School Facilities Managers and Business Officials Are Reducing Operating Costs and Saving Money
- Myths about Energy in Schools
- National Best Practices Manual for Building High Performance Schools

High Performance Building Brochures

- 4 Times Square
- Adam Joseph Lewis Center for Environmental Studies, Oberlin College
- BigHorn Home Improvement Center
- Cambria Office Building — Pennsylvania Department of Environmental Protection
- Clearview Elementary School
- NREL's Solar Energy Research Facility
- NREL's Thermal Test Facility
- NREL's Visitors Center
- Twenty River Terrace
- Zion National Park Visitor Center

Technical Reports

- Advanced Sensors and Controls for Building Applications: Market Assessment and Potential R&D Pathways
- Better Duct Systems for Home Heating and Cooling
- Causes of Indoor Air Quality Problems
- Characterization of Commercial Building Appliances
- DOE Advanced Controls R&D Planning Workshop, June 11, 2003, Washington, D.C.: Workshop Results
- Electricity Consumption by Small End Uses in Residential Buildings
- Electroluminescent Plywood Desk Brochure
- Energy Conservation Using Scotopically Enhanced Fluorescent Lighting in an Office Environment
- Energy Consumption by Office and Telecommunication Equipment in Commercial Buildings, Volume I: Energy Consumption
- Energy Consumption Characteristics of Commercial Building HVAC Systems: Volume I, Primary Equipment
- Energy Consumption Characteristics of Commercial Building HVAC Systems: Volume II, Thermal Distribution, Auxiliary Equipment and Ventilation
- Energy Consumption Characteristics of Commercial Building HVAC Systems: Volume III, Energy Savings Potential
- Energy-Efficient Rehabilitation of Multifamily Buildings in the Midwest
- Energy Savings Potential for Commercial Refrigeration Equipment
- Energy Savings Potential of Solid State Lighting in General Lighting Applications
- Energy Use of Home Audio Products in the U.S.
- Energy Use of Set-Top Boxes and Telephony Products in the U.S.
- Energy Use of Televisions and Videocassette Recorders in the U.S.
- House of Straw - Straw Bale Construction Comes of Age
- HVAC Commercial Heating and Cooling Loads Component Analysis
- HVAC Residential Heating and Cooling Loads Component Analysis
- International Performance Measurement and Verification Protocol: Concepts and Options for

Determining Energy and Water Savings, Volume I

- International Performance Measurement and Verification Protocol: Concepts and Practices for Improved Indoor Environmental Quality, Volume II
- Market Disposition of High-Efficiency Water Heating Equipment
- National Lighting Inventory and Energy Consumption Estimate, Volume 1
- Opportunities for Energy Savings in the Residential and Commercial Sectors with High-Efficiency Electric Motors
- The Promise of Solid State Lighting for General Illumination

Technology Fact Sheets

- Advanced Wall Framing
- Air Distribution System Design
- Air Distribution System Installation and Sealing
- Air Sealing
- Attic Access
- Basement Insulation
- Ceilings and Attics
- Central Heat Pump and Air Conditioner Installation
- Combustion Equipment Safety
- Crawlspace Insulation
- Efficient Lighting Strategies
- Energy-Efficient Appliances
- Energy Efficiency Pays
- Heating and Cooling Equipment Selection
- Improving the Efficiency of Your Duct System
- Insulation
- Passive Solar Design
- Right-Size Heating and Cooling Equipment
- Slab Insulation
- Spot Ventilation
- Wall Insulation
- Water Heating
- Weather-Resistive Barriers
- Whole-House Energy Checklist
- Whole House Fan
- Whole House Ventilation Systems
- Window Selection

Technology Roadmaps

- Frontiers in Solid State Lighting
- High Performance Commercial Building Roadmap
- Vision 2020 Lighting Roadmap
- Windows Industry Technology Roadmap
- Building Envelope Industry Technology Roadmap

APPENDIX C: Building Technologies Program Stage-Gate Framework

	Technology Development Stages						
	Idea Generation	**Applied Research 1**	**Exploratory Development 2**	**Advanced Development 3**	**Engineering Development 4**	**Product Demonstration 5**	**Commercialization and Sales 6**
Technical Activities	**Knowledge-Base Expansion** • Scientific principles formulated and proven • Empirical data and/or theoretical derivation	**Proof of Principle Experiment** • Conduct fundamental lab testing and/or modeling • Collect data to support physical principle • Set performance milestones for Gate 2	**Proof of Technology-Product Definition** • Fabricate lab bread board of concept • Select technologies that have the best market entry potential • Identify and prioritize alternative approaches for performance/energy savings • Set performance milestones for Gate 3	**Proof of Technology- Working Model** • Employ fully functional lab prototypes • Specify applications and approaches • Test prototype on several performance parameters • Conduct proof of "design concept" testing • Set performance & cost milestones for Gate 4	**Engineering Prototype** • Test design features and performance limits, performance mapping • Build field ready prototypes • Perform field testing with customer feedback • Prepare for manufacturing, marketing, certification/code compliance • Set performance & cost milestones for Gate 5	**Production Prototype** • Test design features and performance limits, performance mapping • Build field ready prototypes • Perform field testing with customer feedback • Prepare for manufacturing, marketing, certification/code compliance • Set performance & cost milestones for Gate 6	**Utilization by End User** • Commercialization • Deployment
Deliverables Required for Gate Decisions	• Peer-reviewed paper or journal article • Documentation of proof of concept	• Correlations with building end use • Analytical and/or empirical evidence of technology • Performance viability, preferably lab and/or model data • Written report of above • Possible verification testing at another laboratory	• Performance status and expectation for market entry • Comparison to available technology baseline • Preliminary market assessment a. Cost b. Performance • Estimate of national energy savings potential • Attributes and benefits of approach	• Product specifications defined • Cost/Benefit analysis for owners/operators • Detailed market assessment a. Cost b. Performance c. Market penetration • Estimates of national energy savings potential • Identification of issues and technology status • Technical performance • Market barriers • Public acceptance • Legal – regulatory • Health and safety	• Partnership agreements a. Manufacturing b. Licensing • Resolution of issues from advanced development stage • Field test results and adjustments in design • Evaluation of national energy savings potential • Update detailed market assessment • Cost/Benefit analysis for market	• Partnership agreements a. Manufacturing b. Licensing • Resolution of issues from advanced development stage • Field test results and adjustments in design • Evaluation of national energy savings potential • Update detailed market assessment • Cost/Benefit analysis for market	
Gate Expectations	**Gate 1** ✓ Strategic alignment ✓ Intended customers ✓ Competitive advantage ✓ Technical feasibility ✓ Gov't role?	**Gate 2** ✓ Address priority building end use ✓ Proof of technical performance ✓ Met performance milestones	**Gate 3** ✓ Prove clear advantage over available technology ✓ Met performance milestones	**Gate 4** ✓ Meet owner / operator cost/benefit requirements (1-5 yr. payback) ✓ Demonstrate significant end-user demand ✓ Technology status issues defined ✓ Met performance & cost milestones	**Gate 5** ✓ Ready for owner / operator on multi criteria (economics, safety, etc…)? ✓ Met performance & cost milestones	**Gate 6** ✓ Ready for production and/or application by owner/operator ✓ Met performance & cost milestones	

Adapted from Robert Cooper, "Winning at New Products, Accelerating the Process from Idea to Launch." Perseus Books Group. 3rd Edition. 2001. ISBN: 0738204633

APPENDIX D: Analysis Taxonomy for Characterizing BT Analysis Reports

The Building Technologies Program uses the following table and methodology to characterize its analysis reports by subject area and type.

	Market Data			Technical Characterization					Planning		
	Market Data	Voice of Customer	Economic Savings Potential	Core Data	Technical Savings Potential	Field Performance	Technical Options	Non-Energy Benefits	Program Options	Roadmaps Workshops	Future Trends
Entire Bulding Sector											
Residential Whole Bldg											
ZEH/HPW Option Sets											
Commercial Whole Bldg											
IEQIV											
Controls & Sensors											
Daylighting											
Space Conditioning											
Space Cooling											
Space Heating											
Thermal Distribution											
Lighting											
H2O Heating											
Refrigeration											
Other Equipment & Appliances											
Windows											
Opaque Envelope											
Wall											
Roof											
PV											
Distributed Energy											
Foundation											
Analysis/Design Tools											
Miscellaneuos											