Federal R&D for Net Zero Energy, High-Performance Green Buildings

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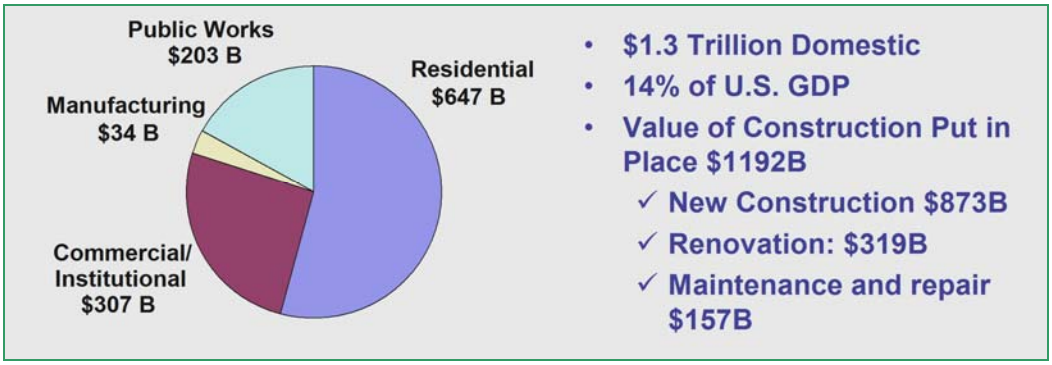
The construction and buildings sector consumes enormous amounts of energy, clean water, and materials. Buildings use about one-third of the world's energy — a proportion that will continue to increase as the population grows and becomes more urban and more affluent (Griffith et al. 2007). In the United States today, the building sector accounts for 40% of the primary energy use, compared to 32% for the industrial sector and 28% for the transportation sector. The use of electric power and heat in the buildings sector also accounts for about 40% of U.S. greenhouse gas emissions. If current trends continue, buildings worldwide will become the top energy consumers by 2025, and are likely to use as much energy as industry and transportation combined by 2050 (DOE 2007).

More effective stewardship of our resources contributes to the security, environmental sustainability, and economic well-being of the Nation. Buildings present one of the best opportunities to economically reduce energy consumption and limit greenhouse gas emissions. Improving how buildings are designed, built, operated, renovated, and recycled could significantly alter how buildings use energy and other basic resources. This challenge will require the development of new, cost-effective building technologies, practices, and standards, the revision and revalidation of building requirements, and the holistic design of energy and resource use within the building, building site, campus, and community.

Construction and Buildings Sector Annual Costs in 2006



The development and adoption of new net zero energy and high-performance building technologies are at the core of addressing this challenge. Today, the industries that create these technologies across multiple business sectors play an increasingly important role in effective resource use and job growth in the United States and worldwide. Improving the global competitiveness of buildings-related industries in the United States will contribute to the economic vitality of our Nation.

Federal research and development (R&D) investments, in concert with academic and private sector R&D activities, play a critical role in the development of new, high-performance and energy-efficient ("green") buildings. Optimizing these R&D investments requires that they be coordinated across the Federal enterprise and aligned with R&D activities in the private sector and academia. In this context, sixteen Executive Branch Federal agencies, the Architect of the Capitol, and the Smithsonian Institution, through the National Science and Technology Council interagency forum, have helped draft this white paper to outline a vision for the technologies required for buildings of the future (Figure 1).

BTRD R&D Vision

Enable designs of new buildings and retrofits of existing buildings that over the life cycle:

- Produce as much energy as they consume (net zero energy) and significantly reduce greenhouse gas emissions.
- Double the service life of building materials, products, and systems and minimize life cycle impacts.
- Halve the use of domestic water (e.g., to 50 gal/day/person or less), maximize water recycling and rainwater harvesting, and minimize stormwater runoff.
- Achieve breakthrough improvements in indoor occupant health, productivity, and comfort.

Figure 1

This paper describes six major building technology goals that define the major transformational advances needed for energy, water, and material use for net zero energy, high-performance green buildings. Inspired by the building research and owner communities, the goals address R&D needs and implementation barriers associated with technologies that could significantly improve building performance and occupant health and productivity. For each goal, focus areas are identified that represent the Federal R&D priorities needed to achieve the goal (see Table 1). At the same time, this paper discusses the relational interdependencies among the broader goals of improving energy efficiency, increasing renewable energy use, reducing greenhouse gas emissions, providing healthy indoor environments, and enabling sustainability of basic resources.

The R&D priorities discussed in this paper reflect the technology advances needed to enable widespread availability of cost-effective, net zero energy and high-performance technologies, practices, and protocols. The priorities also comprise the research needed to overcome barriers to implementation, including fundamental characteristics of the building sector, obsolete or unnecessarily restrictive building codes and regulations, and structural or regulatory disincentives for builders and building owners to invest in green building technologies.

Table 1. Goals and Priorities for Effective Energy, Water, and Resource Use in Buildings

Goal 1. Develop the enabling measurement science to achieve net zero energy, high-performance green building technologies.

- Priority a. Develop rigorous metrics that enable high-performance building goals to be predicted, assessed, monitored, and verified and new energy-efficient technologies, products, and practices to be developed.
- Priority b. Enable widespread adoption of high-performance goals by developing practical tools and processes to address the complex interactions of building components and systems throughout the building life cycle.

Goal 2. Develop net zero energy building technologies and strategies.

- Priority a. Develop building envelope materials, components, systems, and construction techniques to minimize building energy loads.
- Priority b. Develop ultra energy-efficient components and subsystems that minimize energy and satisfy building needs.
- Priority c. Develop supply-side technologies that, when coupled with energy efficiency, can achieve net zero energy buildings and communities.

Goal 3. Develop the scientific and technical bases for significant reductions in water use and improved rainwater retention.

- Priority a. Reduce water use by developing the next generation of water-saving appliances, fixtures, and systems.
- Priority b. Develop analyses and technologies to overcome environmental, health, and technical barriers to widespread water recycling and increased rainwater harvesting.
- Priority c. Develop low-impact development practices to significantly reduce stormwater runoff.

Goal 4. Develop processes, protocols, and products for building materials that minimize resource consumption, waste, and life cycle environmental impacts.

- Priority a. Develop processes that minimize waste generation from building construction, renovation, and demolition.
- Priority b. Extend life cycle assessment data and methods to identify full environmental and public health life cycle impacts of product and material choices.
- Priority c. Develop materials and products with minimal environmental and public health impacts over their life cycles.

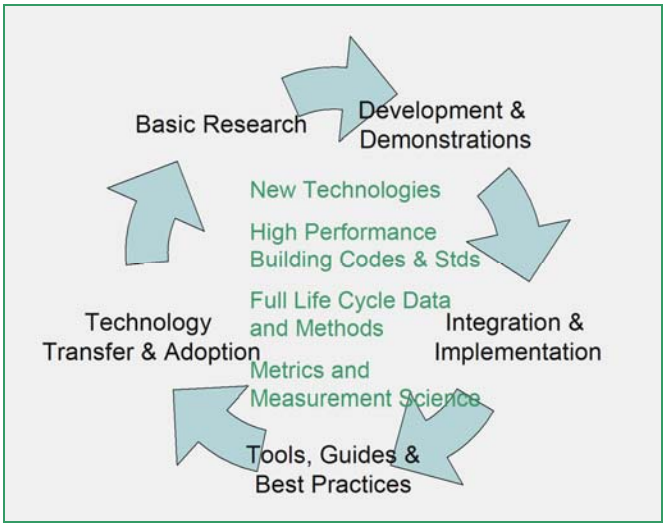
Goal 5. Develop the knowledge and associated energy efficiency technologies and practices needed to promote occupant health, comfort, and productivity.

- Priority a. Develop technologies to improve indoor environmental quality and reduce building energy consumption.

	Priority b.	Develop the knowledge necessary to support scientifically sound and building-specific standards and codes that address the health and comfort of building occupants.
Goal 6.	Enable technology transfer for net zero energy high-performance green buildings.	
	Priority a.	Develop high-performance building design tools and guidance for urban planners, architects, engineers, contractors, and owner/operators.
	Priority b.	Develop tools and guides that enable the use of modern, adaptive performance-based building codes.
	Priority c.	Research and develop effective incentives for adopting and using innovative technologies and practices.

To achieve all the goals identified, the R&D priorities must be considered in the context of the building as a whole, integrated system. Government and industry researchers have found that using currently available, high-performance technologies could reduce a building's energy consumption and carbon dioxide emissions by 30% to 50% (Anderson et al. 2006; Griffith et al. 2007; Levine et al. 2007; USGBC 2007). Furthermore, laboratory studies indicate that new technologies integrated holistically with the building design could reduce energy consumption and carbon dioxide emissions by as much as 70% (Griffith et al. 2007). With this level of improvement in energy efficiency, on-site renewable energy could in some cases supply the remaining energy needs. To the extent that these technologies become cost-effective, they could enable the widespread adoption of net zero energy, high-performance buildings.

Other important considerations for buildings of the future are not addressed in this paper. These include improved structural resiliency, the broader environmental and energy impacts of urban planning and siting, and the associated transportation overhead related to occupants' movements to and from their homes and worksites. The scope of this paper is limited to the development of new technologies, protocols, and practices at the building site, unless they apply without modification to groups of buildings or communities.



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The following Federal agencies contributed to this paper:

- *U.S. Department of Agriculture*
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