1.0 Introduction

As concern for the environmental and societal impacts of modern development increases, Federal decision-makers are being faced with a challenge: how can the government build, operate, and maintain facilities that minimize impacts on the environment and provide a healthy, productive, and secure work places without increasing costs? This document serves as a resource to parties involved in both Federal government and private-sector construction projects to help them dispel mistaken assumptions and to better defend the decision to incorporate the principles of sustainability in their projects. The "business case" for sustainable design and construction focuses on economic benefits, but as the document reveals, some economic benefits are actually derived indirectly from the very environmental and social benefits that sustainable buildings provide.

This section explains the basic philosophical underpinnings of the sustainable design and construction movement, provides some background on sustainable design in a Federal context, and introduces the "triple bottom line" framework – economic, social and environmental – that is used in this document for examining the benefits of sustainable design and construction.

1.1 What is Sustainable Design and Construction?

The concept of ***sustainable development*** grew from the concern that the world population's consumption of resources and production of wastes could exceed the earth's capacity to produce those resources and absorb those wastes. In 1987, the United Nations World Commission on the Environment (the Brundtland report) defined sustainable development as "those paths of social, economic and political progress that meet the needs of the present without compromising the ability of future generations to meet their own needs."

The concept of sustainability includes three goals or "cornerstones":

- **Environmental stewardship** – protecting air, water, land, and ecosystems, as well as conserving resources, including fossil fuels, thus preserving the earth's resources for future generations
- **Social responsibility** – improving the quality of life and equity for individuals, communities, and society as a whole
- **Economic prosperity** – reducing costs, adding value, and creating economic opportunity for individuals, organizations, communities, and nations.

This "***triple bottom line***" framework, as it is often called, shows the three cornerstones as separate components to make sure all three are emphasized. Advocates believe that only by pursuing all three of these interrelated goals will the earth return to a sustainable path. Organizations that apply this framework in their decision-making recognize that by considering the environmental and social impacts of their actions, as well as traditional short-term financial indicators, they may increase their prospects of sustainable, long-term success.

To achieve tangible results, the principles of sustainable development must be translated into practical guidelines that can be applied in the real world. ***Sustainable design*** involves shifting away from processes and products that pollute, use nonrenewable resources, and have other negative consequences for society and moving toward products and processes with minimal environmental and natural resource impact and that provide ***benefits*** to society. Several frameworks have been developed to help designers of all kinds of products, including buildings and facilities, take steps toward the goals of improving societal well-being and minimizing pollution and natural resource depletion.

One of the important sustainable design frameworks for buildings is called ***Leadership in Energy and Environmental Design*** (LEED™). Developed by the U.S. Green Building Council, LEED is a voluntary, consensus-based rating system that awards different levels of "green" building certification based on total credit points earned.[1] LEED gives credits for incorporating specific sustainable design strategies into a building. The design strategy categories (and their potential points, out of a possible total of 69) include the following:

- Sustainable sites (14)
- Water efficiency (5)
- Energy and atmosphere (17)
- Materials and resources (15)
- Indoor environmental quality (13)
- Innovation and design process (5).

The U.S. Green Building Council plans to update the rating system periodically and add new categories of buildings (the currently approved system is for commercial buildings).[2]

The Federal government has also developed various tools and guidelines for increasing the sustainability of buildings and facilities. A major contribution was the development of the "Whole Building Design Guide (WBDG)," a web-based resource providing information and resources to support sustainable design.[3] This guidance was produced and is updated through an interagency effort. Similar to the LEED principles, the fundamental strategies for sustainable design in the WBDG include the following:

- Optimizing site potential
- Minimizing energy consumption
- Protecting and conserving water
- Using environmentally preferable products and materials
- Enhancing indoor environmental quality
- Optimizing operations and maintenance (O&M) practices.

Another concept that underpins sustainable design is integrating the architectural and mechanical features of the facility to minimize energy and resource use and reduce cost while maintaining comfort. When project developers commit early to a high level of building integration, they can more effectively exploit cost-effective tradeoffs. Integrating sustainable design principles early in the process is also important because that is when the project-defining decisions (and major design mistakes) are made (Lotspeich et al. 2002). Sustainable design considerations should be included in solicitations for architectural and engineering services, the Program of Requirements, and the contracts, as well as in the value engineering process (See Case Study 4-3 in Section 4).

> *"By the time 1% of project costs are spent, roughly 70% of the life-cycle cost of the building has been determined; by the time 7% of costs have been spent, up to 85% of life-cycle costs have been determined."*
>
> Lotspeich et al. (2002)

[1] To become "certified," a building must earn between 26 and 32 points; to obtain a "silver" rating – 33 to 38 points; a "gold" rating – 39 to 51 points; and a "platinum" rating – 52 or more points.
[2] More information about the rating system can be obtained from http://www.usgbc.org.
[3] See http://www.wbdg.org/index.asp.

1.2 Sustainable Design and Construction in the Federal Government Sector

The business case for sustainable design takes on special meaning when discussed in the context of the Federal government, whose mission is to protect the well-being of the nation. As a rule, the government wants to provide an example for others to follow by reducing environmental impacts, lowering energy and resource use, and having positive social impacts on its employees and the communities surrounding its facilities.

Government efforts to implement sustainable design have potentially large impacts. The Federal government owns about 500,000 facilities worldwide, valued at more than $300 billion (National Research Council 1998). It spends over $20 billion annually on acquiring or substantially renovating Federal facilities, and it uses over $3.5 billion annually for energy to power, heat, and cool its buildings (Federal Facilities Council 2001). In addition, the government spends almost $200 billion for personnel compensation and benefits for the civilian employees occupying these buildings (U.S. Office of Personnel Management 2003). Building designs that reduce energy consumption while also providing a healthy and pleasant environment for occupants will result in more cost-efficient government operations and lower environmental impacts that affect the public.

> *"The Federal government has many leaders in this field already, and together we can demonstrate that a sustainable building is healthier, more environmentally sound, operationally and economically viable, and the way we should be doing business."*
>
> John L. Howard, Jr.,
> Federal Environmental Executive

The Federal government's building-related energy costs have dropped over 23% per square foot between 1985 and 2001, saving taxpayers $1.4 billion annually.[4] These savings are the direct result of a number of Federal laws and Executive Orders. The Energy Policy Act (EPAct) of 1992 was the latest in a series of laws since 1975 that have recognized the Federal government's own role as a very large consumer of energy and other products. EPAct provided guidance on how to improve energy performance and set goals for Federal energy and water use and required all government buildings to install energy and water conservation measures that have a payback period of less than 10 years.

The Federal commitment to green buildings was further advanced by the promulgation of several key Executive Orders later in the 1990s. In June 1999, the White House promulgated Executive Order 13123, requiring agencies to apply sustainable design principles to the design and construction of new facilities and setting goals for reducing energy use beyond EPAct levels, lowering greenhouse gas emissions and water consumption, and increasing renewable energy and green power purchasing. It also mandated that agencies build showcase facilities with advanced energy-efficiency technologies.

Executive Order 13123 and EPAct emphasize the need for lifecycle[5] cost-effective solutions. In other words, government agencies were asked to compare options based on costs over the lifetime of the facility and its equipment, not just on initial capital outlays. Lifecycle-cost analysis often supports adding sustainable design features because the annual cost savings associated with these features over their lifetimes often offset higher first costs. On the other hand, the cost-effectiveness requirement can be an impediment to some sustainable design features that are more expensive on a lifecycle basis than their traditional counterparts.

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[4] Personal communication with C. Tremper, McNeil Technologies, Springfield, Virginia.

[5] Lifecycle cost represents the first cost plus the replacement costs (discounted to present value)that occur over the lifetime of the equipment, minus the discounted present value of the stream of cost savings.

Despite the lifecycle costing requirements, government project managers still find it hard to include all the sustainable design features they would like to see in building projects. Because O&M costs are appropriated and managed separately from capital expenditures, agencies find it difficult within their normal budgeting process to use lifecycle cost analysis, which intertwines capital and O&M into one comprehensive metric. Capital budgets are usually preset for construction projects, so increasing the budget to include the extra cost of sustainable design features is difficult. Interpretations of how lifecycle costs should be considered in government construction projects vary between agencies and even within agencies.

Nevertheless, as this report documents, Federal agencies have found creative ways to stay within capital budgets while making their buildings "green," and many Federal agencies have developed policies and programs to support sustainable design. Although policies vary from agency to agency, most encourage the use of LEED or some similar system. For example, the Army worked with the U.S. Green Building Council to develop the Sustainable Project Rating Tool (SPiRit), an adaptation of LEED that meets the specific needs of the Army.

1.3 A Framework for Understanding the Benefits of Sustainable Design and Construction

Questions raised about sustainable design often include the following: What does it cost? What are the benefits? To help answer these questions, this document uses the "triple bottom line" benefits framework described in Section 1.1 and applies it to sustainable building design and construction, as depicted in Figure 1-1. The three categories of benefits – economic, social, and environmental – were fully explored, and each type of benefit was documented with hard "evidence," to the extent possible.

Economic benefits to the building owner include first-cost and operating-cost savings. In addition, as Figure 1-1 indicates, environmental and social benefits can lead to economic benefits for building owners. For example, sustainable design efforts to improve the quality of the indoor environment can result in lower absenteeism and higher productivity of building occupants and hence lower personnel costs; and the building's better environmental profile can reduce the time for and cost of permitting the facility. In addition to the building owner, other stakeholders such as neighbors, local and state governments, and society as a whole may reap economic benefits, including lower damage costs from pollution, reduced municipal infrastructure costs, and local/regional economic growth due to the emerging businesses related to sustainable design and construction.

A principal ***social*** benefit of sustainable design is the improved health, satisfaction, and well-being of building occupants. Sustainable design features can also go hand in hand with improved building safety and security. Federal facilities designed using the principles of sustainability can also have positive social impacts on the surrounding community, such as the transfer of pollution prevention and recycling practices to the private sector, increased use of public or alternative transportation, and improved brownfield sites.[6]

[6] Brownfields are abandoned, idled, or underused industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination (http://www.epa.gov/ebtpages/cleabrownfields.html).

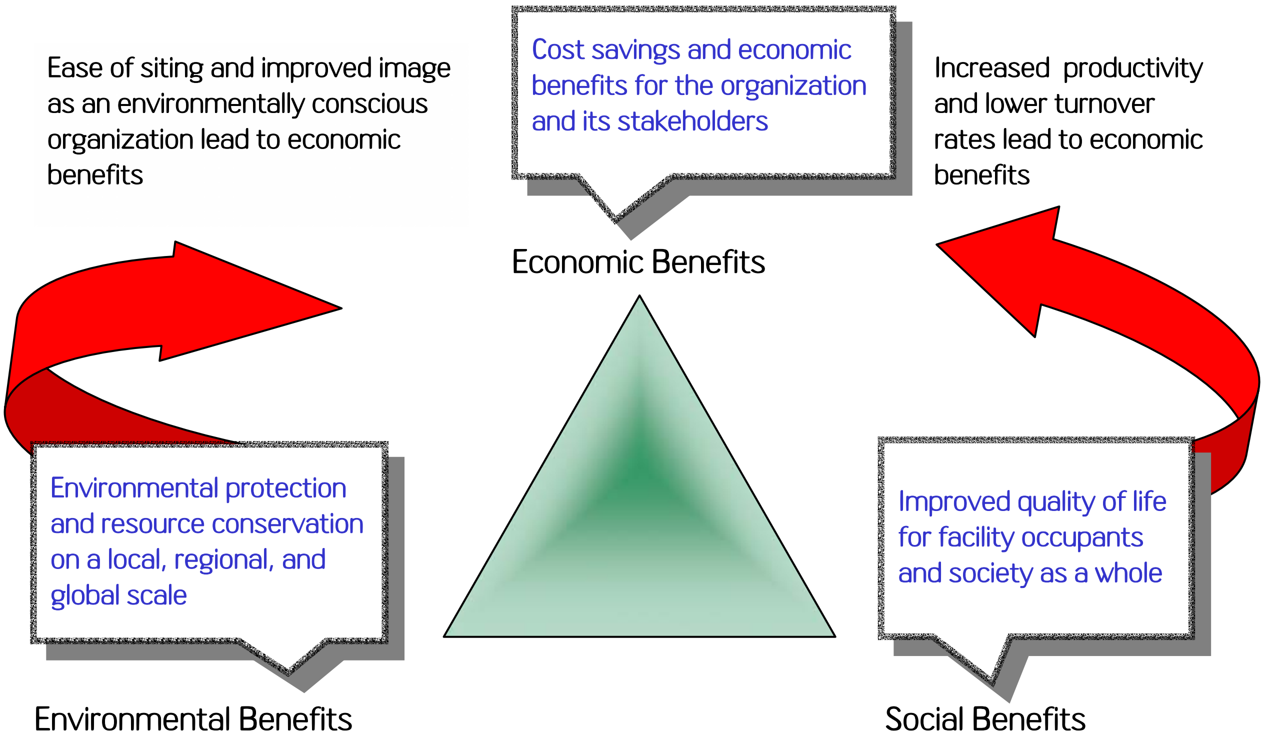

Figure 1-1. "Triple Bottom Line" Benefits of Sustainable Design

Environmental benefits have been a main driver behind the sustainable design movement. Sustainable facilities typically use lower amounts of fossil fuels, create less air pollution and greenhouse gas emissions, result in less waste for disposal in landfills, consume less water and other natural resources, use fewer virgin building materials, disturb less land, and are more sensitive to existing ecosystems.

Three principal forms of "evidence" of the benefits of sustainable design form the basis for the documentation presented in this document:

- First, under Federal Energy Management Program's (FEMP's) direction, the Pacific Northwest National Laboratory (PNNL) and the National Renewable Energy Laboratory (NREL) conducted engineering cost analyses to estimate the potential cost savings associated with various sustainable features in buildings. One challenge encountered when developing the business case is that there is no comprehensive source of data on the costs of sustainable design features. To address this challenge, this study developed "typical" costs based on available data from various sources, including vendors of sustainable building products. Cost savings were estimated for a "prototype" two-story 20,000-ft^2 office building hypothetically located in Baltimore, Maryland.[7] The analysis estimated lifecycle cost savings associated with improving energy-efficiency, commissioning the building, reducing water consumption, using sustainable landscaping approaches, using underfloor systems to reduce churn costs, and choosing sustainable building materials.

[7] Baltimore was chosen because it has both a moderately high heating and cooling load. A moderately small office building was chosen because that size represents the 75th percentile within the current stock of office buildings in the U.S. government and a similarly large percentage of private-sector buildings.

In Sections 2, 3 and 4 of this document, the portions of the text that discuss this prototype building analysis are identified with the "green building" icon (left).

- Second, the document contains numerous real-world case studies that illustrate the benefits of sustainable design. These case studies document benefits achieved in both government and private-sector building projects.

- Third, the document includes summaries of research studies that rigorously examined benefits such as improved occupant productivity, health, and well-being associated with various sustainable design features.

The results of this data-gathering exercise show that a strong business case for sustainable design exists. Table 1-1 summarizes the economic, social, and environmental benefits of the six principal elements of sustainable design, which correspond closely to the categories in the LEED rating system and the WBDG.

The next three sections of this document expand on each of the columns in the figure and provide the available evidence for the economic (Section 2), social (Section 3), and environmental (Section 4) benefits shown in Table 1-1. The table indicates which subsection discusses each type of benefit. The final section of the main body of the document (Section 5) describes the kind of data and information that could be gathered to make the business case for sustainable design and construction even stronger than it is today. Section 6 lists the references cited in this study.

Several appendixes provide additional detail and data and are included at the end of the document. Appendix A expands Table 1-1 into a much more detailed list of sustainable design features and their economic, social, and environmental benefits. Appendix B provides details on the energy analysis conducted for the prototype building analysis. Appendix C describes the results of an exercise, similar to the prototype building analysis, which examined the costs and benefits of the range of sustainable design features in a building at the Tennessee Valley Authority. Appendixes D and E summarize the analysis of sustainable siting and water-saving features, and the sustainable materials analysis, respectively. Appendix F contains a detailed discussion of the body of research conducted on occupant productivity, health and comfort, and satisfaction.

Table 1-1. Benefits of Sustainable Design and Construction

Element	Economic Benefits	Social Benefits	Environmental Benefits
Sustainable siting	Reduced costs for site preparation and clear-cutting, and parking lots and roads. *See Section 2.1.* Lower energy system cost due to optimal orientation. *See Section 2.1.* Less landscape maintenance costs. *See Section 2.4.*	Improved aesthetics (e.g., better appearance of site to neighbors). Increased transportation options for employees. *See Section 3.4.*	Land preservation. Lower resource use. Protection of ecological resources. Soil and water conservation. Reduced energy use and air pollution. *See Sections 4.1 and 4.3.*
Water efficiency	Lower first cost (for some fixtures). *See Section 2.1.* Reduced annual water costs. *See Section 2.3.* Lower municipal costs for wastewater treatment. *See Section 2.8.*	Preservation of water resources for future generations and for recreational and agricultural uses. Fewer wastewater treatment plants and associated annoyances. *See Section 3.4.*	Lower potable water use and pollution discharges to waterways. Less strain on aquatic ecosystems in water-scarce areas. Preservation of water resources for wildlife and agriculture. *See Section 4.3.*
Energy efficiency	Lower first costs when systems can be downsized as the result of integrated energy solutions. *See Section 2.1.* Up to 70% lower annual fuel and electricity costs; reduced peak power demand. *See Section 2.2.* Reduced demand for new energy infrastructure, lowering energy costs to consumers. *See Section 2.8.*	Improved thermal conditions and occupant comfort satisfaction. *See Section 3.2.* Fewer new power plants and transmission lines and associated annoyances. *See Section 3.4.* Improved safety and security. *See Section 3.3.*	Lower electricity and fossil fuel use, and the accompanying reduced air pollution and carbon dioxide emissions. *See Section 4.1.* Decreased impacts of fossil fuel production and distribution. *See Section 4.3.*
Materials and resources	Decreased first costs due to material reuse and use of recycled materials. *See Section 2.1.* Lower costs for waste disposal and decreased replacement cost for more durable materials. *See Section 2.4.* Lower municipal costs for new landfills. *See Section 2.8.*	Fewer landfills and associated nuisances. Expanded market for environmentally preferable products. Decreased traffic due to use of local/regional materials. *See Section 3.4.*	Reduced strain on landfills. Reduced use of virgin resources. Healthier forests due to better management. Lower energy use for material transportation. Increased local recycling market. *See Sections 4.2 and 4.3.*
Indoor environmental quality	Organizational productivity improvements from improved worker performance, lower absenteeism, and reduced staff turnover. *See Section 2.6.* Lower disability/health insurance costs and reduced threat of litigation. *See Section 2.7.*	Reduced adverse health impacts. Improved occupant satisfaction and comfort. Better individual productivity. *See Sections 3.1 and 3.2.*	Better air quality inside the facility, including reduced volatile organic emissions, carbon dioxide, and carbon monoxide. *Discussed in the context of health impacts in Section 3.1.*
Commissioning and O&M	Reduced energy costs. *See Section 2.2.* Reduced costs of dealing with complaints. *See Section 2.7.* Longer building and equipment lifetimes. *See Section 2.7.*	Increased occupant productivity, satisfaction, and health. *See Sections 3.1 and 3.2.*	Lower energy consumption, as well as air pollution and carbon dioxide emissions and other environmental impacts of energy production and use. *See Section 4.1.*