4.0 The Environmental Benefits of Sustainable Design

Buildings consume a significant amount of our natural resources and have a wide range of environmental impacts. These environmental concerns are a key driver behind the sustainable design movement. Various estimates indicate that buildings use 30% of the raw materials consumed in the United States (EPA 2001). Considering what buildings are made of – steel, concrete, glass, and other energy-intensive materials – buildings have a high level of "embodied" energy. Based on lifecycle assessments, the structural and envelope material of a typical North American office building has 2 to 4 gigajoules per square meter (175 to 350 kBtu/ft^2) of embodied energy (Building Green Inc. 2003). Producing these materials depletes nonrenewable resources and has environmental effects, and these impacts intensify the more frequently buildings are demolished and replaced.

> *"Typically, embodied energy [in a building] is equivalent to five to ten years of operational energy."*
>
> William Bordass, quoted in Building Green Inc. (2003)

Building operations also contribute significantly to environmental pollutant levels in the United States and abroad. As a whole, U.S. buildings use 36% of U.S. energy demand, 68% of the country's electricity (more than half of which is generated from coal), and nearly 40% of U.S. natural gas consumption (DOE 2002). As a result, U.S. buildings are accountable for 48% of the nation's SO_2 emissions, 20% of the NO_x, and 36% of the CO_2 (DOE 2002). Buildings also produce 25% of the solid waste, use 24% of the water, create 20% of the water effluents, and occupy 15% of the land (EPA 2001). In addition, U.S. builders produce between 30 and 35 million tons of construction, renovation, and demolition waste (DOE 2002).

Federal facilities contribute a notable portion of these building impacts; for example, Federal buildings are estimated to emit 10.5 million metric tons of CO_2 (in carbon equivalents) (DOE 2001), which is about 2% of the total emissions from U.S. buildings and is equivalent to the total emissions of Peru.[46]

From a complete lifecycle assessment perspective, construction, operation, and demolition or reuse of buildings involve a chain of economic activities that provide the goods and services necessary to build, maintain, and eventually retire or convert the asset. Each of these activities carries an implicit "ecological footprint" of resource consumption and waste generation. For example, the footprint associated with a ton of steel includes impacts of mining, transportation, and manufacturing operations, including a considerable amount of energy consumed in converting iron ore to steel and transporting the steel to its point of use. Table 4-1 lists the sources of pollution and other negative environmental impacts related to constructing, operating, and demolishing buildings.

Applying sustainable design principles can significantly reduce these impacts. The following sections describe three categories of environmental benefits attributable to sustainable buildings: lower air pollutant and greenhouse gas emissions to the atmosphere (Section 4.1), reduced volumes of waste (Section 4.2), and decreased use of natural resources and lower impacts on ecosystems (Section 4.3). Each section is illustrated with a case study.

[46] http://cdiac.esd.ornl.gov/trends/emis/per.htm.

Table 4-1. Examples of Environmental Impacts of Buildings

Construction	Operation	Demolition
Materials Use • Depletion of nonrenewable resources • Pollution and byproducts from materials manufacture • Construction materials' packaging waste **Site Preparation and Use** • Disturbance of animal habitats • Destruction of natural vistas • Construction-related runoff • Soil erosion • Destruction of trees that absorb CO_2 • Introduction of invasive exotic plants • Urban sprawl (for greenfield sites) and associated vehicle-related environmental impacts (e.g., tailpipe emissions as well as impacts of highway, road, and parking lot construction) • Water quality degradation from using pesticides, fertilizers, and other chemicals	**Energy Use** • Air pollution: emissions of SO_2, NO_x, mercury, and other heavy metals and particulate matter from power plants; the building's energy consumption; and transportation to the building • Greenhouse gas (CO_2 and methane) emissions, which contribute to global warming • Water pollution from coal mining and other fossil fuel extraction activities, and thermal pollution from power plants • Nuclear waste, fly ash, and flue gas desulfurization sludge from power plants that produce the electricity used in buildings • Habitat destruction from fuel extraction **Building Operations** • Runoff and other discharges to water bodies and groundwater • Groundwater depletion • Changes in microclimate around buildings and urban heat island effects • Ozone-depleting substances from air conditioning and refrigeration • Light pollution in the night sky • Water consumption • Production of wastewater that requires treatment • Production of solid waste (garbage) for disposal • Degradation of indoor air quality and water quality from using cleaning chemicals	• Demolition waste (used steel, concrete, wood, glass, metals, etc.) • Energy consumption for demolition • Dust emissions • Disturbance of neighboring properties • Fuel use and air pollutant emissions associated with transporting demolition waste

4.1 Lower Air Pollutant and Greenhouse Gas Emissions

One set of environmental benefits from greening buildings that can be fairly easily estimated is lower air pollutant and CO_2 emissions. Emissions are reduced by decreasing energy use through energy-efficient design, use of renewable energy, and building commissioning. Table 4-2 shows the average amounts of emissions that are released per Btu of natural gas and electricity used (these are called "emission coefficients"). The coefficients also indicate the amount of pollution that would be reduced per unit of energy saved.

Table 4-2. Emission Coefficients for Energy Consumption in Commercial Buildings

	SO_2 Million Short Tons Per Quad	NO_x Million Short Tons Per Quad	CO_2 Million Short Tons Per Quad
Natural gas	Negligible	0.08	15.8
Electricity (per delivered quad)	0.97	0.45	55.62
Source: DOE (2002). (1 short ton equals about 0.91 metric ton.)			

In the hypothetical prototype building, annual emissions would be reduced by 0.16 short tons of SO_2, 0.08 tons of NO_x and 10.7 short tons of CO_2[47] (based on site electricity reduction of 167 million Btu and a natural gas savings of 86 million Btu). This reduction is small compared with national emission levels[48] or even emission levels in a city such as Baltimore. However, given that buildings contribute 48% of SO_2, 20% of NO_x, and 36% of CO_2 nationwide (DOE 2002), a widespread adoption of sustainable design techniques in new and retrofit buildings would eventually affect national and regional pollution levels.

Reducing SO_2 and NO_x is particularly important in areas (such as Baltimore) that are not achieving air quality standards. Large urban areas with intense traffic and areas affected by emissions from large industrial sources and power plants can have ambient air pollution levels that exceed the amounts determined by the EPA to protect human health and welfare ("National Primary and Secondary Ambient Air Quality Standards," 40 CFR 50). Although buildings are not typically a target of specific emission regulations, some states such as New York encourage emission reductions from nonregulated sources through a program of "emission reduction credits." Through this program, a regulated source can pay a nonregulated source for emission credits earned by reducing emissions through energy-efficiency measures, fuel switching, or other means.[49] When aggregated, the lower emissions from small sources of NO_x (such as gas-fired heating systems in buildings) in cities can help reduce ozone-related pollution (smog). In addition, cutting electricity consumption helps decrease emissions of NO_x and SO_2 from power plants (usually located in rural areas), thereby helping to reduce regional environmental problems, such as acid rain.

Reducing fuel and electricity consumption also lowers CO_2 emissions, a greenhouse gas that is linked to climate change. Decreased use of natural gas should also reduce methane emissions to the atmosphere (methane is another greenhouse gas). The effects of the buildup of greenhouse gases in the atmosphere may include sea level rise, weather changes (e.g., increase in violent weather patterns), and impacts on agriculture. Although climate change is likely to occur gradually over a long time period, energy-efficiency measures implemented now will slow the pace of the greenhouse gas buildup and its potential effects.

Case Study 4-1 describes how a photovoltaic energy system has lowered air pollution emissions in an area with serious air quality problems – the Los Angeles Basin.

[47] Expressed in tons of carbon in CO_2.
[48] National emissions of SO_2, NO_x, and CO_2 from buildings were about 9 million tons, 5 million tons, and 564 million tons (carbon equivalents), respectively.
[49] See http://www.dec.state.ny.us/website/dar/boss/ercindex.html.

Case Study 4-1: Post Office in Marina Del Rey Improves Air Quality

This case study demonstrates how innovative energy systems can reduce emissions. The area in which this facility is located – the Los Angeles Basin – is plagued with high ozone levels (smog). The project demonstrates one of the innovative technologies that produce electricity without any emissions. Incentive programs available in some locations from various sources can reduce the first costs of advanced technologies, resulting in very reasonable economics.

Project Description: The U.S. Postal Service (USPS) recently installed a large-scale photovoltaic (PV) system at its Marina Del Rey Processing and Distribution Center in Los Angeles. The center has over 400,000 ft^2 of floor area and high energy consumption and costs.

Approach to Sustainable Design: This facility is proactively seeking solutions to energy management, especially given California's volatile energy situation over the past two years. The USPS worked with Lawrence Berkeley Laboratory (in a technical advisory role), the Los Angeles Department of Water and Power (DWP), and DOE's FEMP to examine costs, energy savings, and key financial incentives from using PV systems at this site. The team determined that a rooftop solar power array would generate significant electricity to help offset peak demand utility costs.

The system was attractive not only because it saves energy but because it is also expected over its lifetime to reduce emissions: 2600 lb of NO_x emissions and 4075 tons of CO_2, equivalent to removing emissions from over 1000 cars or planting over 200,000 trees. The USPS is also considering PV for other postal facilities.

Sustainable Features: The PV technology installed at the facility consists of a 127-kW system from 845 modules that are lightweight and integrated in the building's roof over an existing roof membrane. The solar array is 50 ft by 300 ft and covers most of the facility's flat roof. The system produces clean power silently and is not visible to people on the ground.

The PV system uses silicon technology to convert sunlight directly into electricity. The output from the PV modules is direct current, which is converted to the required alternating current using an inverter and transformer. The system allows the current to be directly connected to the building's electric service panel. In addition to producing electricity, the PV panels provide R-20 value thermal insulation to decrease the building's energy consumption and reduce heating and air conditioning costs. The panels also extend the roof's life by protecting the roof membrane from ultraviolet rays and thermal conditions.

The system is linked to a new energy management system that monitors power output from the solar cells. When the system detects a decline in power output, for example, during cloud cover, it automatically modifies the operation of the building's chiller to compensate without affecting employee comfort.

Financial Considerations: The system's original first cost was about $1 million. The Los Angeles DWP provided a $684,000 rebate, and FEMP provided a Distributed Energy Resources Grant of $125,000. The net system cost to the USPS was about $226,000. The estimated annual cost savings are $25,000 to $28,000, resulting in a simple payback period of about 8 years.

Sources: Personal communication with J. Lin, PowerLight Corporation, Berkeley, CA; FEMP (2002).

4.2 Reduced Volumes of Solid Waste

The United States produces more than 230 million tons of municipal solid waste per year, consisting of paper, yard waste, plastics, metals, etc.[50] The 30 to 35 million tons of construction, renovation, and demolition waste that U.S. builders produce include wood (27% of total) and other materials such as cardboard and paper; drywall/plaster; insulation; siding; roofing; metal; concrete, asphalt, masonry, bricks, and dirt rubble; waterproofing materials; and landscaping materials (DOE 2002). As much as 95% of building-related construction waste is recyclable, and most materials are clean and unmixed (DOE 2002).[51]

In addition, building occupants produce municipal solid waste every day, in the form of used paper, plastic and glass containers, food waste, etc. Much of this can be recycled.

Several sustainable design principles reduce waste, which in turn reduces the strain on landfills. In addition, using recycled materials in building construction encourages development of new industries that produce recycled products, further reducing waste disposal needs and the use of virgin materials.

The main sustainable design principles that reduce waste include the following:

- **Storage and collection of recyclables.** The building design should provide space for collecting and storing materials such as paper, glass, plastic, and metals that will be recycled.
- **Construction waste management.** During construction, the contractor can recycle or productively use construction, demolition, and land-clearing wastes and divert these wastes from landfill disposal.
- **Recycled content.** Designers can select environmentally preferable materials that include recycled materials. (Designers should use standards developed by government agencies or other reliable sources.)
- **Waste prevention.** Designers can eliminate unnecessary finishes and make choices that use standard-sized or modular materials. In addition, designers should consider product durability in the design process. When products need to be replaced less frequently, less demolition waste is produced and fewer virgin resources are needed for replacements.

Case Study 4-2 describes how both the volume of waste and construction costs were reduced through an effective construction waste management program.

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[50] http://www.epa.gov/epaoswer/non-hw/muncpl/facts.htm.

[51] Original sources cited in DOE (2002) include *First International Sustainable Construction Conference Proceedings*, "Construction Waste Management and Recycling Strategies in the U.S.," Nov. 1994, p. 689; *Fine Homebuilding,* "Construction Waste," Feb./Mar. 1995, pp. 70-75; National Association of Home Builders, *Housing Economics*, Mar. 1995, pp. 12-13; and *Cost Engineering*, "Cost-Effective Waste Minimization for Construction Managers," Jan. 1995, Vol. 37/No. 1, pp. 31-39.

Case Study 4-2: Construction Waste Management and Other Recycling Measures Reduce Costs and Waste at EPA's New England Regional Laboratory

This case study demonstrates that using construction waste management, other recycling efforts during construction, and central recycling during building operation not only reduces the strain on local landfills but lowers construction costs.

Project Description: The New England Regional Laboratory (NERL), located in North Chelmsford, Massachusetts, is one of ten EPA regional laboratories that conducts environmental monitoring, analytical support, and data assessment. The 71,000-ft^2 building incorporates an environmental testing laboratory, as well as office and meeting spaces. This facility won a "Closing the Circle" Award and a U.S. Green Building Council LEED Gold Rating.

Approach to Sustainable Design: The new laboratory, which opened in September 2001, was designed and built using sustainable principles. The lab was supported by government agency sustainability advocates, GSA, and EPA, as well as a sustainability-conscious developer and contractor. The goal was to use the best commercially available materials and technologies to minimize consumption of energy and resources and maximize use of natural, recycled, and nontoxic materials.

The design construction team diverted more than 50% of its construction and demolition debris from the waste stream by recycling, processing excavated rock outcroppings into crushed stone that was also used on site, and reusing furniture and laboratory equipment from the former facility to furnish the new building while redistributing unused supplies to other buildings and organizations. The facility used fly-ash content concrete and many other recycled-content materials (insulation, carpet, floor tiles, mulch, compost made from yard trimmings or food waste, and recycled plastic benches and picnic tables).

Sustainable Features: The team maximized the use of natural site features, such as solar energy, natural shading, and drainage. The team's principal goals were achieving energy efficiency and maximizing renewable energy sources, so they incorporated a wide range of technologies and strategies, including lighting controls, skylights, light tubes, extra insulation, high-efficiency chillers and motors, green power, and PV awnings that supply 2 kW of electricity to the electric grid. Water-efficiency measures included Xeriscape concepts for landscaping, an onsite well for laboratory uses, and low-flow sinks with electronic sensors.

Commercial power is provided by Green Mountain Power of Vermont via 100% renewable energy sources. Green Mountain Power has committed to generating or purchasing wind-powered electricity that matches the electrical consumption of NERL, an estimated 2 million kWh per year. Using green power will reduce pollution by an estimated 3.46 million lb/yr of CO_2, 17,600 lb/yr of SO_2, and 6,200 lb/yr NO_x over conventional power sources.

Financial Considerations: The project team documented the cost savings from the construction waste management program. A concerted effort was made to minimize construction debris and to maximize recycling and reuse of anything that would become a waste stream. The team hired Graham Waste Services, a licensed hauler and processor of recyclables and solid waste.

Any waste that was generated during construction was carefully segregated into separate, clearly labeled bins that Graham Waste Services supplied. Bins were checked regularly for extraneous materials that could contaminate any of the loads. The estimated amounts of materials recycled during construction, the percent of the total waste stream recycled (by volume), and the associated cost savings (resulting from avoided disposal costs) were as follows:

- Clean wood: 330 cubic yards, 21% of the recycled waste stream volume, for a $2200 savings
- Cardboard: 10 cubic yards, 6% of the recycled waste stream volume, for a $250 savings
- Gypsum wallboard: 210 cubic yards, 13% of the recycled waste stream volume, for a $1400 savings
- Metal: 90 cubic yards, 6% of the recycled waste stream volume, for a $600 savings
- Concrete: 80 cubic yards, 5% of the recycled waste stream volume, for a $5760 savings
- Total savings: $10,210.

Note: In addition, 780 cubic yards of general refuse were recycled, but this did not lead to any cost savings.

Sources: Personal communication with B. Beane, EPA Region 1 in North Chelmsford, Massachusetts; and the documentation supporting the White House Closing the Circle Awards 2002 Nominations for Recycling, Affirmative Procurement, and Model Facility Awards.

4.3 Decreased Use of Natural Resources and Lower Ecosystem Impacts

Many sustainable design principles help reduce impacts on natural resources and ecosystems. Some key examples are as follows:

- Sustainable siting approaches consider alternatives to greenfield construction, including using existing facilities (e.g., urban redevelopment) and brownfield sites, and avoid building on prime agricultural land, floodplains, and habitats for threatened species or near wetlands, parklands, and cultural or scenic areas. The principles also include designing to reduce potentially detrimental conditions, such as slopes that can erode; avoiding adverse impacts on adjacent properties; and carefully considering the building placement amid existing trees on the site. Sustainable siting may also consider reducing the building's (or the site's) footprint to preserve the amount of open space. These measures
    - Protect threatened species, wetlands, cultural areas, and pristine natural areas
    - Remediate contaminated land (when a brownfield is used)
    - Preserve soil resources, trees, and open space in already developed areas.

- Siting near public transportation involves locating the facility near rail stations or bus lines and providing covered, wind-sheltered seating or waiting areas for public transport. Use of public and alternative transportation also can be fostered by installing bicycle storage and showers, alternative-fuel refueling stations, and preferred parking for carpools. In addition to reducing

air pollution from personal vehicles, these measures
  - Reduce land disturbance for new roads
  - Use less material for new roads.

- Erosion and sedimentation control, stormwater management, and sustainable landscaping involve developing a sediment and erosion control plan to prevent soil loss during construction, using natural water management approaches instead of traditional sewers, and designing a self-sustaining landscape. This approach can involve planting watershed buffers; using drought-resistant plants native to the region; avoiding plants needing chemical treatment and fertilizers or causing allergic reactions; designing natural drainage systems; and using techniques that allow water infiltration through surfaces (e.g., using porous paving surfaces for parking lots), which allows stormwater to filter through plantings and soil. These measures
  - Prevent sedimentation of streams
  - Reduce dust and particulate matter emissions during construction
  - Reduce disruption of natural water flows
  - Reduce runoff into natural water systems
  - Restore natural plant species to the region.

- Light pollution reduction is achieved by reducing dependence on high-wattage electrical lighting at night by using solar lighting and light-colored or reflective edges along driveways and walks and by designing night lighting to prevent direct-beam illumination from leaving the building site. These measures preserve nighttime habitats for nocturnal species.

- Water reduction measures include using low-flow faucets and showerheads, and improved fixtures and fittings that reduce water use (e.g., pressure-assisted or composting toilets and no-water urinals); low-water landscaping; improved cooling towers that use closed-loop cooling approaches; captured rain water for landscaping, toilet flushing, and other appropriate uses; and treatment and use of graywater, excess groundwater, and steam condensate. The water-efficiency and sustainable siting approaches for the prototype building, described in Section 2.1 and 2.2, which included use of low-flow faucets, no-water urinals, dual-flush toilets, and sustainable landscaping, would save over 233,000 gallons of water annually (equal to 70% of the base case building's consumption, including water used both inside the building and outside for landscape maintenance). Water reduction measures in buildings
  - Decrease extraction of potable water from groundwater reserves (e.g., aquifers), water bodies, and reservoirs
  - Reduce strain on aquatic ecosystems in water-scarce areas
  - Preserve water resources for wildlife and agriculture
  - Decrease impacts from wastewater treatment plants (e.g., effluent discharges).

- Energy efficiency measures not only reduce air pollution emissions associated with energy use (discussed in Section 4.1) but also decrease the need for nuclear and fossil fuels. These measures
  - Reduce the need for on-land disposal of nuclear waste, fly ash, and flue gas desulfurization sludge from power plants
  - Reduce habitat destruction and other environmental impacts from fuel extraction processing and transportation (e.g., coal mines typically disturb large tracts of land).

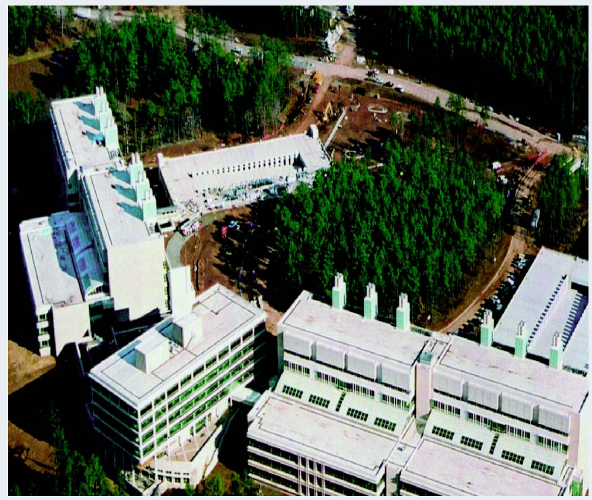
- Rapidly renewable materials (e.g., bamboo, cork, and wheat straw boards) and certified wood
  - Reduce the use and depletion of long-cycle renewable materials
  - Improve forest management and biodiversity.

- Design for reuse means designing a flexible building that can have many uses and that can be reconfigured in the future as needs change. As time progresses, this practice should reduce the need to demolish old buildings and construct new ones. These measures lower resource consumption (e.g., building materials such as steel, concrete, and glass, which are energy-intensive commodities).

Case Study 4-3 describes the efforts undertaken to develop a new multibuilding campus in a way that minimized disruption of the natural environment.

Case Study 4-3: EPA's Campus Protects Natural Resources at No Additional First Cost

This case study shows how a state-of-the-art lab and office complex can be a "model for environmental stewardship" without increasing costs. By forming a multidisciplinary design team and integrating environmental principles into the value engineering process, EPA created a 100-year building with estimated 40% energy savings, 80% construction waste recovery, 100% stormwater treatment through native plants and wetlands on site, daylight in offices, clean indoor air, flexible labs, and more – all with no extra budget for building "green." The case also shows that conserving energy and water, using a low-impact site design, minimizing materials, and making other substantive choices have clear economic benefits and that sustainable design features with little financial payback can be afforded by making tradeoffs in other areas.



Project Description: The laboratory/office complex is located on over 130 acres of land in Research Triangle Park in central North Carolina. The new facilities have one million gross square feet of floorspace, including 635,000 net square feet of office and laboratory space for 2200 employees. The complex has four 5-story lab buildings, connected by three 30-foot atria to three 3-story office buildings. The main building also includes a central five-story office tower with cafeteria, conference center, auditoriums, and a library. The lab and office buildings are situated alongside a lake and follow the curve of the shore. The campus also includes a computer center and child-care facility.

Approach to Sustainable Design: Because it had not undertaken a project of this magnitude before, the EPA looked to the GSA and the Army Corps of Engineers for design assistance and construction management. Working with these agencies and the chosen architecture firm (Hellmuth, Obata + Kassabaum), the Clark Construction Group, and the Gillbane Building Company (a GSA contractor providing construction administration and quality assurance), EPA developed a team approach to defining environmental objectives and tracking progress toward them. Project leaders made a clear commitment to design and build a green building. They felt the EPA facility should symbolize the EPA's environmental mission. Green design criteria were written into the solicitations for the architectural and engineering services, the Program of Requirements and the contracts. Working together, green advocates, architects, engineers, and building users developed innovative approaches after systematically reviewing a wide range of options. At every step along the way, the team raised questions about and re-evaluated assumptions.

Sustainable Features: The sustainability of the building's and site's designs was studied in depth. The designers used natural methods for landscaping and stormwater treatment. To protect more than 9 acres of onsite wetland areas, designers used a buffer zone about 100-feet wide along the lake edge and allowed no development except for a network of walking and jogging trails. A tree survey resulted in redesigned roads, saving large oak trees that have been there since the early part of the 20th century. Also, the size of the road was decreased from four to two lanes to minimize disruption to the natural areas and reduce costs. A parking structure was built instead of disrupting acres of natural woodland for an onsite paved parking lot.

The building design includes sunshading, tight building envelopes, high-performance glass, a high level of daylighting, occupancy sensors and daylight dimming, high-efficiency chillers and boilers, variable frequency drives, an outside air economizer cycle, and high-efficiency fume hoods. The buildings also used low-flush toilets and urinals, low-flow aerators and showerheads, and water-efficient cooling towers. Many recycled materials were used: recycled-content asphalt, rubber flooring, ceramic tiles, insulation, wood fiberboard gypsum wallboard, and more. Materials were also selected to be durable (the building was designed to last 100 years). About 80% of all construction waste was recycled, which diverted about 10,000 tons of material from local landfills. Careful attention was paid to ventilation, selection of materials and finishes, and construction procedures to minimize air quality degradation inside the building.

Financial Considerations: Throughout the project, the team examined the cost of green design and the cost of various options. For example, multiple skylight options for the atrium in the buildings were considered, and the options' first costs and energy costs over a 20-year life were compared. EPA also chose to engage in focused value engineering reviews. Although value engineering is often seen as the enemy of good design in general and green design in particular, EPA transformed the traditional value engineering process into an exercise in balancing cost, function, and environmental performance by including designers and sustainability advocates on the value engineering review team and encouraging interdisciplinary brainstorming.

The value engineering process was especially important at this site because during the appropriations process, the U.S. Senate asked EPA to review the project again to see if the total cost could be reduced. Working with the designers, the value engineering team not only reduced the total project cost by about $30 million (resulting in a final cost of $225 million) but also produced a greener building. Given the pressure to reduce costs, many of the environmental features that required a first-cost increment (e.g., the above-ground parking garage designed to minimize disruption to 15 acres of natural woodlands) could have easily been eliminated. However, the team reviewed the project budget as a whole and chose to eliminate other features that were not considered critical to meet their environmental goals. For instance, over 200 doors were eliminated to save costs. To lower the cost increment of the above-ground parking garage, the amount of onsite parking was reduced by 25%, and alternative transportation methods were encouraged. In effect, the design team put a higher value on the 15 acres of natural woodland than on building design features they considered less important to quality of life.

Some of the environmentally motivated strategies that reduced cost included the following:

- Replacing four-lane roads with two-lane roads (and burying the electrical and communication lines under the road) greatly decreased the road and utility footprint, preserved the site woodlands and wetlands, reduced construction cost by $2 million, and lowered maintenance and repair costs.
- Replacing curb and gutter and oil-grit separators with grassy swales and water quality and bio-retention ponds reduced construction costs by $500,000.
- Changing the atrium skylight from all glass to one-third glass, one-third insulated translucent panels, and one-third solid panels to improve energy performance, indoor environmental comfort, and light quality saved $500,000 in construction costs and $50,0000 in annual energy costs.
- Installing 250 specialized fume hoods and exhaust systems that reduce total air flow demand by 50% and eliminating dozens of fans lowered construction cost by $1.5 million and annual energy costs by $1 million.

When benchmarked against other laboratory/office buildings, the annual energy use in the facility was estimated to be 40% lower than a similar facility, with a savings of more than $1 million per year.

Sources: Communication with C. Long and P. Schubert, EPA's Research Triangle Park; EPA (1997, 2001); and DOE's High Performance Buildings Database at http://www.eere.energy.gov/buildings/highperformance/case_studies/overview.cfm?ProjectID=30.