# Appendix A: Matrix of Benefits of Sustainable Design

This appendix provides information on the benefits of various sustainable design features. The benefits are listed in the matrix (Table A-1) for each sustainable design feature. The features are categorized into six primary categories:

1. Sustainable siting
2. Water efficiency
3. Energy efficiency
4. Sustainable materials and resources
5. Indoor environmental quality
6. Commissioning and operation & maintenance (O&M).

These correspond closely to the categories in the Leadership in Energy and Environmental Design (LEED™) rating system and the *Whole Building Design Guide*[1] discussed in Section 1 of the main body of this document. Thus, this matrix combines the "triple bottom line" benefits framework with six principal elements of sustainable building design. Some of the benefits accrue to the facility owner, and other benefits accrue to other parties such as employees, local governments, the local community/economy, or the public at large. When applicable, those are designated in the table.

Although the list of benefits is extensive, it may not be completely comprehensive. Some of the benefits of sustainable design will be discovered as more experience is gained with living and working in sustainable buildings.

[1] See http://www.wbdg.org/index.asp.

## Table A-1. Possible Benefits of Sustainable Design, by Feature

| Sustainable Design Feature | Benefits Category | | |
|---|---|---|---|
| | **Economic** | **Social** | **Environmental** |
| **Sustainable Siting** | | | |
| **Site selection.** Analyze alternatives, including use of existing facilities. Do not build on prime agricultural land, flood-plains, and habitats for threatened species; near wetlands; or on parklands. Consider urban redevelopment and brownfield redevelopment sites (which require cleanup). | *Facility*:<br>• Lower site preparation costs<br>• Potential for reduced costs of litigation and time delay (e.g., because threatened species are not present not at the site)<br>*Local government*:<br>• Lower infrastructure development costs to support existing rather than greenfield sites<br>*Local economy:*<br>• Reduced tourism losses | *Society:*<br>• Preservation of natural areas, agricultural land, and parkland for future generations | *Society:*<br>• Decreased use of virgin resources<br>• Protection of threatened species and wetlands<br>• Remediation of contaminated land (when brownfield is used)<br>• Reduced erosion and flood damage<br>• Reduced impact on fisheries and forests |
| **Site analysis and harmonious building-site relationship.** Inventory and analyze the ecological context, urban and historical context, and natural and cultural attributes. Organize mass, orientation, topography, and outdoor spaces to employ passive solar principles; provide outdoor spaces; etc. Design to reduce potentially detrimental conditions, such as slopes that can erode. Avoid adverse impacts on adjacent properties. Carefully consider the placement of existing trees on site. | *Facility*:<br>• Possible reduction in first costs (reduced size and cost of mechanical systems)<br>• Reduction in operating costs (fuel costs)<br>*Local government:*<br>• Elimination of unnecessary infrastructure expenditures due to good assessment of site resources | *Society:*<br>• Improved aesthetic and functional quality of site and building for both occupants and neighbors | *Society:*<br>• Reduction in energy consumption and emissions due to optimal orientation, etc.<br>• Conservation and restoration of ecological and cultural resources<br>• Reduced negative microclimate and environmental effects in local vicinity |
| **Facilitation of alternative transportation use.** Locate facility near rail station or bus lines. Provide covered, wind-sheltered seating or waiting areas for public transport. Provide bicycle storage and showers. Install alternative-fuel refueling stations. Provide preferred parking for carpools. | *Facility*:<br>• Slightly lower capital cost due to reduced parking lot size (could be offset by additional costs for showers, and refueling stations)<br>*Employees:*<br>• Potentially lower commuting costs (using public transport rather than personal cars) | *Employees:*<br>• More transportation options | *Society:*<br>• Lower energy use and air pollution from vehicles<br>• Reduced land disturbance for new roads |

| Sustainable Design Feature | Benefits Category | | |
|---|---|---|---|
| | **Economic** | **Social** | **Environmental** |
| **Erosion and sedimentation control and stormwater management.** Develop sediment and erosion control plan. Prevent loss of soil during construction. Prevent sedimentation of storm sewer or receiving streams. Plant watershed buffers. Allow infiltration via porous surfaces. Filter stormwater through plantings and soil. Use natural drainage systems. | *Facility*:<br>• Decreased cost of storm drainage construction by using more natural methods<br>• Reduced cost of landscaping after construction is completed (because topsoil is saved)<br>*Local/state government*:<br>• Reduced cost of stream cleanup and water treatment plants | *Neighbors/local community:*<br>• Less disturbance during construction | *Society:*<br>• Less loss of soil during construction<br>• Prevention of sedimentation of storm sewers or receiving streams<br>• Reduced dust/particulate matter during construction<br>• Less disruption of natural water flows<br>• Reduction of runoff into natural water systems |
| **Reduced site disturbance during construction.** Limit site disturbance around the building perimeter, curbs, walkways, and main utility branch trenches. Reduce the development footprint to exceed open space requirements in local zoning rules. | *Facility:*<br>• Potentially decreased cost of clear-cutting and subsequent relandscaping<br>• Decreased site infrastructure costs | *Neighbors/local community:*<br>• Less disturbance during site preparation<br>• Retention of vegetation and scenic vistas<br>• More greenspace for use by occupants and/or community | *Society:*<br>• Preservation of trees and other vegetation<br>• Increased habitat for natural species; biodiversity |
| **Sustainable landscape and exterior design.** Use self-sustaining landscape design and site maintenance procedures. Restore habitats. Use plants native to the region. Consider drought-resistance plants. Avoid plants needing chemical treatment and fertilizers or causing allergic reactions. Consider using "green roofs." | *Facility:*<br>• Reduced maintenance costs, water use, fertilizer, and fossil fuel use due to "naturally manicured" landscaping<br>• Possibly decreased heat/cooling loads due to vegetated roof | *Neighbors/local community:*<br>• More aesthetic natural exterior appearance of building to neighbors and occupants | *Society:*<br>• Reduced impact on microclimate<br>• Lower threat of negative ecological impacts resulting from use of non-native plant species |
| **Light pollution reduction.** Allow no direct-beam illumination to leave building site. Use light-colored or reflective edges along driveways and walks to reduce dependence on high-wattage electrical lighting at night. Use solar lights. Use security lighting with motion sensors to reduce use of lights at night. | *Facility:*<br>• Possibly lower cost of electricity for lighting (depending on design) | *Neighbors/local community:*<br>• Less disturbance to natural night sky conditions<br>• Improved security of building | *Society:*<br>• Preservation of nocturnal habitat |

| Sustainable Design Feature | Benefits Category | | |
|---|---|---|---|
| | **Economic** | **Social** | **Environmental** |
| **Water Efficiency** | | | |
| **Water use reduction.** Use captured rainwater for landscaping, toilet flushing, etc. Treat and re-use graywater, excess groundwater, and steam condensate. Use low-flow fixtures and fittings (pressure-assisted or composting toilets, waterless urinals, etc.) and ozonation for laundry. Use closed-loop systems and other water reduction technologies for processes. | *Facility:*<br>• Decreased water costs<br>• Potential for O&M savings<br>*Local government:*<br>• Less wastewater treatment infrastructure needed (fewer taxes to pay for infrastructure) | *Society:*<br>• Preservation of natural water resources for future generations | *Society:*<br>• Reduced use of potable water<br>• Reduced generation of wastewater; lower discharge to natural waterways |
| **Energy Efficiency** | | | |
| **Space layout.** Fully utilize opportunities for passive solar heating/cooling. Optimize natural ventilation and daylighting. Enhance penetration of daylight to interior spaces. Provide inviting staircases to encourage their use rather than elevators. | *Facility:*<br>• Diminished heating, cooling, and lighting loads and reduced energy costs<br>• Increased operating efficiency due to right sizing of equipment<br>• Possibly lower capital costs due to reduced size/cost of mechanical systems through more efficient design features, appropriate sizing, and optimal integration<br>• Potentially higher occupant productivity due to daylighting<br>*Society/utility companies:*<br>• Avoidance of electricity generation and transmission/distribution construction costs | *Employees:*<br>• Improved quality of interior space (a secondary benefit of many energy-efficient design features) | *Society:*<br>• Lower electricity use, fossil fuel use, and air pollution/carbon dioxide ($CO_2$) emissions and other environmental impacts of electricity production and fossil fuel use<br>• Decreased impacts of fuel production and distribution (for fuels used in the building or in production of electricity for the building) |

| Sustainable Design Feature | Benefits Category | | |
|---|---|---|---|
| | **Economic** | **Social** | **Environmental** |
| **Building envelope.** Design envelope to provide good thermal and moisture control while supporting passive solar and natural ventilation design strategies. Detail walls to provide best vapor barriers and low outside air infiltration. | *Facility:*<br>• Diminished heating, cooling, and lighting loads and reduced energy costs<br>• Increased operating efficiency due to right sizing of equipment<br>• Possibly lower capital costs due to reduced size/cost of mechanical systems through more efficient design features, appropriate sizing, and optimal integration<br>*Society/utility companies:*<br>Avoidance of electricity generation and transmission/distribution construction costs | *Employees:*<br>• Improved quality of interior space (a secondary benefit of many energy-efficient design features) | *Society:*<br>• Lower electricity use, fossil fuel use, and air pollution/carbon dioxide ($CO_2$) emissions and other environmental impacts of electricity production and fossil fuel use<br>• Decreased impacts of fuel production and distribution (for fuels used in the building or in production of electricity for the building) |
| **Lighting and sun control.** Use glazing to supply daylighting but control glare. Use roof monitors and high clerestory windows. Specify photocell-dimming sensors to adjust light. Use separate switches to turn off lights in individual areas. Use light shelves and other techniques to bring light deeper into the building. Supplement daylighting with high-performance lighting that improves visual quality while reducing electrical use. Use low-ambient lighting levels with task lights, where appropriate. Use occupancy sensors, dimmers, photocells, and lumen maintenance controls. | *Facility:*<br>• Reduced electricity consumption/ costs<br>• Lower cooling loads due to lower heat gains from electrical lighting; hence, reduced energy costs and lower capital costs for cooling system<br>• Potentially higher occupant productivity due to daylighting and visual quality<br>*Society/utility companies:*<br>• Avoidance of electricity generation and transmission/ distribution construction costs | *Employees:*<br>• Improved quality of interior space | *Society:*<br>• Lower electricity use and the associated air pollution/$CO_2$ emissions<br>• Decreased impacts of fossil fuel production and distribution |

| Sustainable Design Feature | Benefits Category | | |
|---|---|---|---|
| | **Economic** | **Social** | **Environmental** |
| **Systems and equipment.** Optimize mechanical systems to work with the building layout, orientation, envelope, etc. Consider HVAC zoning, distribution systems, heat recovery systems, modular boilers, and ice storage. Do not use chlorofluorocarbon/hydrofluorocarbon (CFC/HCFC) refrigerants. Develop integrated systems designs that consider interaction of systems with overall building layout, envelope, etc. Include efficient power distribution systems, electrical equipment, motors, transformers, etc. Consider use of raised floor and underfloor HVAC with personal controls | *Facility:*<br>• Reduced energy costs<br>• Reduced capital costs due to downsizing of equipment<br>• Lower churn costs (if raised floor is used)<br>• Better productivity (if personal controls are implemented) | *Employees:*<br>• Improved occupant comfort | *Society:*<br>• Lower electricity use and the associated air pollution/$CO_2$ emissions<br>• Decreased impacts of fossil fuel production and distribution<br>• Protection of the ozone layer (due to avoidance of CFCs/HCFCs) |
| **Renewable energy.** Consider using photovoltaic, solar heat and hot water, geothermal heat pumps, etc. Consider entering into green power or renewable credit contracts. | *Facility:*<br>• Lower annual energy costs<br>*Local economy:*<br>• Potential for emerging businesses related to renewable energy | *Society:*<br>• Promotion of market for renewable energy products | *Society:*<br>• Lower electricity use and the associated air pollution/$CO_2$ emissions<br>• Decreased impacts of fossil fuel production and distribution |
| **Energy load management.** Use energy management systems, monitoring, and controls to continuously calibrate, adjust, and maintain energy-related systems. | *Facility:*<br>• Operational savings (can offset higher first costs)<br>• Reduced capital cost of mechanical systems because control systems reduce the need for oversizing | *Employees:*<br>• Improved comfort, health, and safety | *Society:*<br>• Improved energy efficiency, hence lower electricity and fossil fuel use and lower emissions<br>*Employees:*<br>• Better indoor air quality |

| Sustainable Design Feature | Benefits Category | | |
|---|---|---|---|
| | **Economic** | **Social** | **Environmental** |
| **Sustainable Materials and Resources** | | | |
| **Storage/collection of recyclables.** Provide a system for collecting and storing materials such as paper, glass, plastic, and metals for recycling | *Facility:*<br>• Possibly lower waste disposal costs<br>*Local community:*<br>• Local recycling business opportunities<br>*Local government:*<br>• Lower landfill construction costs | *Employees:*<br>• Opportunity for building occupants to feel they are "making a difference," which can be an opening for other actions<br>*Society:*<br>• Expanded market for recycled and environmentally preferable products | *Society:*<br>• Reduced strain on landfills<br>• Reduced use of virgin natural resources |
| **Building and resource re-use.** Reuse building shell from existing buildings and fixtures from demolished buildings. Use salvaged/refurbished materials. | *Facility:*<br>• Decreased first costs due to re-use of materials<br>*Local government:*<br>• Less waste disposal; lower need for new waste disposal facilities | *Society:*<br>• Expanded market for salvaged materials | *Society:*<br>• Reduced strain on landfills<br>• Reduced use of virgin natural resources |
| **Construction waste management.** Recycle or productively use construction, demolition, and land clearing wastes. Divert these wastes from landfill disposal. | *Facility:*<br>• Possible decrease in construction first costs due to lower waste disposal costs | *Society:*<br>• Expanded market for recycled and environmentally preferable products | *Society:*<br>• Reduced strain on landfills<br>• Reduced use of virgin natural resources |
| **Recycled content.** Select environmentally preferable materials that include recycled materials (use standards developed by government agencies or other reliable sources). | *Facility:*<br>• Possible decrease in first costs of construction due to lower price of recycled materials (in some cases) | *Society:*<br>• Expanded market for recycled and environmentally preferable products | *Society:*<br>• Reduced strain on landfills<br>• Reduced use of virgin natural resources |

| Sustainable Design Feature | Benefits Category | | |
|---|---|---|---|
| | **Economic** | **Social** | **Environmental** |
| **Waste prevention.** Use modular materials. Select products for durability. Eliminate unnecessary finishes and other products. | *Facility:*<br>• Possible decrease in first costs of construction due to less use of materials<br>• Longer lifetime of building and building features due to increased durability of materials used<br>• Decreased operating costs (including replacement and waste disposal costs) by using more durable materials that need to be replaced less often | *Society:*<br>• Less nuisance associated with landfills | *Society:*<br>• Reduced strain on landfills<br>• Reduced use of virgin natural resources |
| **Local/regional materials.** Obtain materials, whenever possible, from local resources and manufacturers. | *Local economy:*<br>• Success of local businesses | *Local economy:*<br>• Employment opportunities | *Society:*<br>• Lower energy consumption and resulting air pollutant air emissions due to less freight transportation |
| **Rapidly renewable materials** (bamboo, cork, wheat straw boards, etc.); certified wood. | *Facility:*<br>• Possible reduction of first costs<br>*Society:*<br>• Emerging businesses | *Society:*<br>• Preservation of forests for future generations | *Society:*<br>• Reduced use/depletion of long-cycle renewable materials; better forest management; biodiversity |
| **Design for re-use.** Design buildings for flexible uses so they can be reconfigured in the future as needs change. | *Facility:*<br>• Lower lifecycle capital construction requirements<br>• Lower churn costs | *Society:*<br>• Less disturbance due to new construction | *Society:*<br>• Lower resource consumption (on a lifecycle basis) |

| Sustainable Design Feature | Benefits Category | | |
|---|---|---|---|
| | **Economic** | **Social** | **Environmental** |
| **Indoor Environmental Quality** | | | |
| **Indoor air quality.** Control pollutant sources (from neighboring buildings, soil such as radon and methane, and excessive dampness). Use low-emission materials (paint, carpet, fabrics). Allow new materials to ventilate before occupancy. Include good ventilation systems and operable windows, where appropriate. Specify systems that feature economizer cycles. Consider underfloor air ducting. Use $CO_2$ sensors. Use control systems, including personal workstation control, if possible. Eliminate tobacco smoke. | *Facility:*<br>• Organizational productivity improvements (reduced absenteeism)<br>• Lower workman's compensation, disability, health, and liability insurance costs<br>• Reduced threat of litigation<br>*Employees:*<br>• Lower health care costs to occupants | *Employees:*<br>• Reduced adverse health impacts (especially respiratory disease/discomfort)<br>• Improved personal productivity | *Employees:*<br>• Better air quality inside the facility<br>*Society:*<br>• Reduced volatile organic compound emissions to the atmosphere due to use of low-emission materials |
| **Good visual quality.** Appropriately use windows, skylights, shading devices, and light shelves. Avoid glare. Combine ambient and task lighting. Use high-frequency ballasts. Give occupants adequate visual access to outdoors and to the organization of the building. Use pleasing surface colors and reflectivity. | *Facility:*<br>• Reduced energy costs (by using daylighting) | *Employees:*<br>• Satisfaction with work environment<br>• Improved personal productivity | *Society:*<br>• Lower energy use and emissions due to use of daylighting and energy efficient lighting |
| **Noise control.** Reduce noise at the source during design phase (e.g., through orientation, building layout, selection of mechanical, plumbing, and ductwork). Use acoustic buffers; floating floor slabs; and sound-insulated wall, floor, and ceiling penetrations. Achieve good room acoustics by configuring rooms, using white noise, etc. | *Facility:*<br>• Lower cost of dealing with complaints | *Employees:*<br>• Satisfaction with work environment<br>• Improved personal productivity | |
| **Systems controls.** Provide maintenance staff and users with level of control over automated building systems appropriate to their level of technical expertise. Provide individual occupant controls when possible (in conjunction with underfloor systems) | *Facility:*<br>• Possible decrease in operational costs<br>• Decreased churn costs due to underfloor systems | *Employees:*<br>• Thermal and visual comfort of occupants<br>• Improved personal productivity | *Society:*<br>• Decreased energy use and resulting environmental impacts due to better control of energy systems |

| Sustainable Design Feature | Benefits Category | | |
|---|---|---|---|
| | Economic | Social | Environmental |
| **Commissioning and O&M** | | | |
| **Commissioning and O&M.** Use third-party assessments to ensure that the installed systems work as designed. Develop O&M manuals and train staff. | *Facility:*<br>• Fewer equipment breakdowns and downtime costs<br>• Lower lifecycle replacement costs<br>• Reduced costs of dealing with occupant complaints | *Employees:*<br>• Occupant satisfaction with building<br>• Health/safety of building occupants | *Society:*<br>• Lower energy consumption and air pollutant emissions<br>*Employees:*<br>• Better indoor air quality |
| **Sustainable housekeeping and maintenance.** Clean and maintain all building equipment to ensure proper functioning. Check for water leaks and make repairs. Check for signs of mildew and mold growth. Use nontoxic, natural cleaning/maintenance chemicals. Periodically or continuously monitor indoor air quality. | *Facility:*<br>• Possibly lower operating expenses (e.g., reduced water consumption)<br>• Less chance of sick building syndrome and associated legal costs. | *Employees:*<br>• Improved indoor environmental quality<br>• Better health of occupants | *Society:*<br>• Reduced chemical influx into the environment (by using natural cleaning products)<br>• Lower water use (due to leak monitoring) |