STATE OF THE ART REVIEW FOR SUSTAINABLE BUILDING DESIGN AND INNOVATION TECHNOLOGIES

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Abstract
The design, construction, or renovation of high-performance sustainable buildings requires careful consideration during the planning, design, construction, renovation and operation phases of the buildings life. This evaluation examines the integration of all building components and systems to determine how they best work together in a sustainable manor to save energy, reduce environment impact and provide a quality indoor environment for occupants. Components of the building process are evaluated for the planning and design process, the construction process, and operations and maintenance of buildings. Specific sustainable practices for storm water management and water efficiency are described. Economic benefits and cost analysis methods for sustainable buildings are described. Four examples of sustainable building design applications are presented from the United States and Europe. Recommendations for furthering the development of high performance sustainable buildings are presented.

Key Words: Sustainable development, energy conservation, water management, green materials, design integration, recycling, life cycle analysis and construction waste management

1. Introduction

Buildings fundamentally impact people's lives and the health of the planet. In the U.S., buildings use one third of our total energy, two-thirds of our electricity, one-eighth of our water, and transform land that provides valuable ecological services. Building atmospheric emissions from the use of energy lead to acid rain, ground-level ozone, smog, and global climate change. The goal of sustainable design is to create high-performance buildings with a small environmental footprint. This goal has evolved from a variety of concerns, experiences, and needs…..

- Energy efficiency gained importance during the 1970s oil crisis.
- Recycling efforts in the U.S. in the 1970s onward became commonplace and came to the attention of the building industry.
- In the 1980s, the "sick building syndrome" concept emerged and concern for worker health and productivity became an issue. The concern for toxic material emissions also became an issue that needed to be addressed.
- Projects in water-scarce areas began to focus on water conservation.
- Early green designs usually focused on one issue at a time, mainly energy efficiency or use of recycled materials.
- Green building architects in the 1980s and 1990s began to realize that the integration of all the factors mentioned here would produce the best results and, in essence, a "high performance" building.

The designing, constructing, or renovating of high-performance sustainable buildings requires a whole building approach. This approach differs from the traditional design/build process, as the design team examines the integration of all building components and systems and determines how they best work together in a sustainable manor to save energy and reduce environmental impact.

2. Sustainable Design of Buildings

Sustainable buildings are intended though out their life time to have a beneficial impact on their occupants and their surrounding environment. Such buildings are optimally integrated on all parameters— initial affordability, timeliness of completion, net life-cycle cost, durability, functionality for programs and persons, health, safety, accessibility, aesthetic and urban design, maintainability, energy efficiency, and environmental sustainability. Failure on any one parameter invariably undermines other parameters of the building in question and of the system of buildings and connected service systems in the community. The benefits of sustainable design can be summarized as follows:

- The local and global environment benefits from protecting air quality, water quality, and overall biodiversity and ecosystem health.
- Economic benefits are experienced in building operations, asset value, worker productivity, and the local economy.
- Occupants benefit from health and safety features. This also relates to risk management and economics. The U.S. EPA found that average Americans spend more than 90% of their time indoors, and indoor air quality can be two to five times worse than outdoor air quality.
- Community and municipal benefits include: lessened demand for large-scale infrastructure such as landfills, water supply, stormwater sewers, and their related development and operational costs; and decreased transportation development and maintenance burden (roads) and increased economic performance of mass transit systems.

There is a good deal of uncertainty about the cost of sustainable building features. This is probably due to seven main factors: 1) compared to design and construction cost-estimating generally, environmentally sustainable cost-estimating is a relatively new field with a smaller data base; 2) there are regional cost differences, driven by local abundance/scarcity of LEED certified professionals, and as a result designers and construction contractors bid higher when they don't understand the project; 3) there are regional differences in the availability and cost of environmentally-friendly materials; 4) as discussed below, costs go up when environmental sustainability is not included at the very start of the building planning and design process; 5) as also discussed below, costs go up, for both construction and maintenance, when key stakeholders are not trained in environmentally sustainable building features; 6) upfront vs. life-cycle cost tension; and 7) uncertainty about the short- and long-term performance of "green" sustainable building materials.

Urban areas have some unique challenges that generate particular environmental issues such as; Storm water Runoff, Air Quality, Heat Island effects, Traffic and Parking problems, the need for Open Space and Recreation, creation of Urban Villages (walk-ability, live-work, quality of life), and a good quality Indoor Environment (90% of our time is indoors).

3. Integrated Building Planning and Design Process.

A critical element for a successful sustainable building policy and program is an integrated building planning and design process. Integrated building design is a process of design in which multiple disciplines and seemingly unrelated aspects of design are integrated in a manner that permits synergistic benefits to be realized. The goal is to achieve high performance and multiple benefits at a lower cost than the total for all the components combined. This process often includes integrating green design strategies into conventional design criteria for building form, function, performance, and cost. A key to successful integrated building design is the participation of people from different specialties of design: general architecture, HVAC, lighting and electrical, interior design, and landscape design. By working together at key points in the design process, these participants can often identify highly attractive solutions to design needs that would otherwise not be found. In an integrated design approach, the mechanical engineer will calculate energy use and cost very early in the design, informing designers of the energy-use implications of building orientation, configuration, fenestration, mechanical systems, and lighting options.

Consider integrated building design strategies for all aspects of sustainable design: improving energy efficiency, planning a sustainable site, safeguarding water, creating healthy indoor environments, and using environmentally preferable materials. Major design issues should be considered by all members of the design team—from civil engineers to interior designers—who have common goals that were set in the building program. The procurement of A&E services should stress a team-building approach, and provisions for integrated design should be clearly presented in the statement of work (SOW). For example, the SOW should stipulate frequent meetings and a significant level of effort from mechanical engineers to evaluate design options.

The design and analysis process for developing integrated building designs includes:

- Establishing a base case—for example, a performance profile showing energy use and costs for a typical facility that complies with code and other measures for the project type, location, size, etc.
- Identifying a range of solutions—all those that appear to have potential for the specific project.
- Evaluating the performance of individual strategies—one by one through sensitivity analysis or a process of elimination parametrics
- Grouping strategies that are high performers into different combinations to evaluate performance.
- Selecting strategies, refining the design, and reiterating the analysis throughout the process.

Finding the right building design recipes through an integrated design process can be challenging. At first, design teams often make incremental changes that are effective and result in high-performance buildings—and often at affordable costs. However, continuing to explore design integration opportunities can sometimes yield incredible results, in which the design team breaks through the cost barrier.

Whenever one sustainable design strategy can provide more than one benefit, there is a potential for design integration. For example, windows can be highly cost-effective even when they are designed and placed to provide the multiple benefits of daylight, passive solar heating, summer-heat-gain avoidance, natural ventilation, and an attractive view. A double-loaded central corridor, common in historic buildings, provides daylight and natural ventilation to each room, and transom windows above doors provide lower levels of light and ventilation to corridors. Building envelope and lighting design strategies that significantly reduce HVAC system requirements can have remarkable results. Sometimes the most effective solutions also have the lowest construction costs, especially when they are part of an integrated design.

The building design begins with an analysis of the required spaces. With an eye toward the sustainability and energy-efficiency targets established in pre-design, the individual spaces should be clearly described in terms of their function, occupancy and use, daylight and electric light requirements, indoor environmental quality standards, acoustic isolation needs, and so on. Spaces then can be clustered by similar function, common thermal zoning, need for daylight or connection to outdoors, need for privacy or security, or other relevant criteria.

It is not only environmental performance that suffers from lack of an integrated planning and design process. All the other building parameters also suffer (initial affordability, timeliness of completion, net life-cycle cost, durability, functionality for programs and persons, health, safety, accessibility, social equity, aesthetic and urban design, maintainability, and energy efficiency). Integrated Design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants may be organized into five broad areas:

- Sustainable site planning
- Safeguarding water and water efficiency
- Energy efficiency and renewable energy
- Conservation of materials and resources
- Indoor environmental quality

An integrated building planning and design process must insure that all the stakeholders are present throughout the planning and design process, even into the construction phase. Failure to do so inevitably results in delays, change orders, higher costs, and inferior buildings. In some cases, community representatives should be brought into appropriate phases of the planning and design process.

4. Economic Benefits and Cost Analysis

Sustainable buildings can reduce project costs. Green Sustainable Building projects that are well integrated and are comprehensive in scope can result in lower or neutral project development costs. Rehabilitating an existing building can lower infrastructure and materials costs. Integrated design can use the payback from some strategies to pay for others. Energy-efficient building envelopes can reduce equipment needs – downsizing some equipment, such as chillers, or eliminating equipment, such as perimeter heating. Using pervious paving and other runoff prevention strategies can reduce the size and cost of stormwater management structures.

Economic benefits of sustainable buildings include a competitive first cost. The concept of integrated design allows for high benefit at low cost by achieving synergies between disciplines and between technologies. Sustainable Designs lead to reduced utility bills and O&M costs. Sustainable design also will optimize life cycle economic performance and reduce liabilities. Energy and water-efficient buildings have been able to reduce their operating costs significantly. Use can be cut to less than half than that of a traditional building, or even better, by employing aggressive and well-integrated green design concepts.

Disagreements about costs focus on two central issues: 1) whether environmentally sustainable buildings require an up-front design and construction premium, and if so how large; 2) how the life-cycle costs of environmentally sustainable buildings compare with those of other buildings.

Healthy indoor environments can increase employee productivity according to an increasing number of case studies. Since workers are by far the largest expense for most companies (for offices, salaries are 72 times higher than energy costs, and they account for 92% of the life-cycle cost of a building), this has a tremendous effect on overall costs (See *Green Developments* by the Rocky Mountain Institute for more information).

Studies have shown that student performance, as well as energy performance, is better in schools built according to green design principles. More than 17 million Americans suffer from asthma, and 4.8 million of them are children. Ten million school days are missed by children each year because of asthma, which is exacerbated by poor IAQ. Employees in buildings with healthy interiors have less absenteeism and tend to stay in their jobs. The Internationale Nederlanden (ING) Bank headquarters in Amsterdam uses only 10% of the energy of its predecessor and has cut worker absenteeism by 15%. The combined savings equal $3.4 million per year.

4.1 Cost Analysis

Since there will usually be a number of acceptable suitable design alternatives for any project, cost/benefit analyses help you select the ones that have the best savings potential.

- Simple Payback Analysis
- Standardized Payback Equations
- Life-Cycle Cost Analysis
- Selecting the "Best" Alternatives
- Weighing Societal Impacts

Depending on the aggressiveness of the design, experience has shown that it costs no more than 10% more to build high-performance buildings. Some high-performance buildings cost less to construct. Sometimes additional upfront costs can be justified because the investment will reduce operating costs through the life of the building. The added cost, if any, of system investment each year is compared to the cost of fuel saved each year. Total energy costs are, on average, about 50% less than those for conventionally designed buildings. In many cases, the right-sizing of mechanical systems through passive solar design offsets the costs for additional windows or controls.

In analyzing alternative building energy efficiency improvements, conversions, or purchases, cost/benefit analysis is used to determine if and when an improvement will pay for itself through energy savings, and to set priorities among alternative improvement projects. Cost/benefit analyses may be conducted using a simple payback analysis or a more sophisticated analysis of total life-cycle costs and savings. Since most electric utility rate schedules are based on both consumption and peak demand, your analyst should be skilled at assessing the impacts of both.

Before beginning any cost/benefit analyses, you must first determine acceptable design alternatives that can meet the heating, cooling, lighting, and control requirements of the building being evaluated. The criteria for determining whether a design alternative or alternative fuel is "acceptable" should include reliability, safety, conformance with building codes, occupant comfort, noise levels, refueling issues, and even space limitations.

4.1.1 Simple Payback Analysis

A highly simplified form of cost/benefit analysis is called simple payback. In this method, the total first cost of the improvement is divided by the first-year energy cost savings produced by the improvement. This method yields the number of years required for the improvement to pay for itself. For new construction, it can be used to evaluate conventional construction to energy-efficient design alternatives.

In simple payback analysis, you are assuming that the service life of the energy efficiency measure will equal or exceed the simple payback time. Simple payback analysis provides a relatively easy way to examine the overall costs and savings potentials for a variety of project alternatives. However, it does not consider a number of factors that are difficult to predict, yet can have a significant impact on cost savings. These factors may be considered by using a more sophisticated life-cycle cost analysis.

As an example of simple payback, consider the lighting retrofit of a 10,000-square-foot commercial office building. Relamping with T-8 lamps and electronic, high-efficiency ballasts may cost around $13,300 ($50 each for 266 fixtures) and produce annual savings of around $4,800 per year (80,000 kWh at $0.06/kWh). The simple payback time for this improvement would be $13,000/$4,800 annually = 2.8 years. That is, the improvement would pay for itself in 2.8 years, a 36% simple return on the investment (1/2.8 = 0.36).

4.1.2 Standardized Payback Equations

You can take advantage of a building energy measurement and verification guideline that standardizes procedures for quantifying energy savings from energy-efficiency projects. The International Performance Measure Measurement and Verification Protocol, can be used as a guideline to reduce risk and standardize paperwork. It also enables loans to be bundled together and sold on a secondary market, like mortgages.

4.1.3 Life-Cycle Cost Analysis

Life-cycle costing (LCC) is an analysis of the total cost of a system, device, building, or other capital equipment or facility over its anticipated useful life. LCC analyses allow a comprehensive assessment of anticipated costs associated with a design alternative. Factors commonly considered in LCC analyses are initial capital cost, operating costs, maintenance costs, financing costs, the expected useful life of equipment, and future equipment salvage values. The result of the LCC analysis is generally expressed as the value of initial and future costs in today's dollars as reflected by an appropriate discount rate. The Rebuild America Life-Cycle Cost Calculator can be used to help calculate the net present value of two alternatives and compare them using this cost-benefit method.

The first step in performing an LCC analysis is to establish the general study parameters for the project, including the base date (the date to which all future costs are discounted), the service date (the date when the new system will be put into service), the study period (the life of the project or the number of years over which the investor has a financial interest in the project), and the discount rate. When two or more design alternatives are compared or when a single alternative is compared against an existing design, the variables compared must be the same to assure that the comparison is valid. It is meaningless to compare the LCC of two or more alternatives if they are computed using different study periods or different discount rates.

4.1.4 Selecting the "Best" Alternatives

Generally, all project alternatives should be initially screened using simple payback analyses. A more detailed and costly LCC analysis should be reserved for large projects or those improvements that entail a large investment, since a detailed cost analysis would then be a small part of the overall cost. Both simple payback and LCC analyses will allow you to set priorities based on measures that represent the greatest return on investment. In addition, these analyses provide a preliminary indication of appropriate financing options:

- Energy efficiency measures that have a short payback period of 1 to 2 years are the most attractive economically and should be considered for implementation using operating reserves or other readily available internal funds.
- Energy efficiency measures that have payback periods from 3 to 5 years may be considered for funding from available internal capital investment monies, or may be attractive candidates for third-party financing through energy service companies or equipment leasing arrangements.
- Frequently, short payback measures can be combined with longer payback measures of 10 or more years to increase the number of measures that can be cost-effectively included in a project. Projects that combine short- and long-term paybacks are recommended to avoid "cream-skimming" (implementing only those measures that are highly cost effective and have quick paybacks) at the expense of other worthwhile measures. A selected set of measures with a combination of payback periods can be financed either from available internal funds or through third party alternatives.

If simple payback time is 10 or more years, economic factors are very significant and LCC analysis is recommended. In contrast, if simple payback occurs within 3 to 5 years, more detailed LCC analysis may not be necessary, particularly if price and inflation changes are assumed to be moderate. Under this assumption, a simple payback analysis will often be within 15% to 20% of the payback time estimated from a detailed LCC analysis. In general, detailed LCC analyses may not be justified if the payback of the improvement is less than five years.

In any cost analysis, it is very important to include avoided cost as part of the benefit of the retrofit. When upgrading or replacing building equipment, the avoided cost of maintaining existing equipment should be considered a cost savings provided by the improvement.

4.1.5 Weighing Societal Impacts

Some factors related to building heating, air conditioning, and lighting system design are not considered in either simple payback or LCC analyses. Examples include the thermal comfort of occupants in a building and the adequacy of task lighting, both of which affect productivity.

Conventional cost/benefit analyses also normally do not consider the societal benefits from reduced energy use (e.g., reduced carbon emissions, improved indoor air quality). In some cases, these ancillary benefits are assigned an agreed upon monetary value, but the values to be used are strongly dependent on local factors. In general, if societal benefits have been assigned appropriate monetary values by a local utility, they are considered in savings calculations. However, your team should discuss this issue with your local utility or consultants working on such values in your area.

5. Sustainability Considerations during Construction

Construction sustainability guidelines can be set to lessen the impacts of building construction on the environment. Examples of actions that can be considered include:

- Specify equipment, materials, and products based on performance, not measurements.
- Use recycled materials to reduce use of raw materials and divert material from landfills.
- Use local and regional materials as much as possible.
- Minimize site impact by specifying location of trailers, equipment, storage, traffic.
- Monitor construction site energy and water use.
- Develop a construction waste management and recycling plan.

5.1 Construction

Construction design documents define the contractor's responsibilities during construction, but they typically focus on the design elements of the finished product. They rarely set environmental guidelines to be followed during the construction phase. The integrated design team should work with the construction contractor to adopt sustainability guidelines to be followed during construction.

Contractors seldom follow environmental guidelines during the construction process unless this guidance is built in as a written part of the contract, plans, and drawings for the building. Integrating construction guidelines with other sustainability guidelines is an essential part of the whole building design process. To develop and implement the guidelines, work with the team, including the architect, engineers, and contractors. Creating the guidelines as a team is helpful for educating contractors about sustainability issues and getting their early commitment to follow sustainability guidance. Environmental guidelines for the construction process should include construction specifications, material specifications, indoor air quality (IAQ) requirements, and specific measures for reducing environmental impact and energy and water use on the site during construction.

The building's impact on energy and environment begins during the construction phase. A sustainable approach to construction leads to reduced resource use, reduced disturbance of the site, and can also lower costs. Attention to environmental issues during construction also leads to a safer, healthier working environment for those people constructing the building, and later for those who occupy it.

5.2 Construction Specifications

Include these guidelines in writing in the construction contract and incorporate the guidance into plans, drawing, and specifications.

1. Specify equipment to match the intent of the design.
2. Specify equipment, materials and products based on performance, not measurements.
   - Insulation should be specified by thermal resistance (R-Value), not by thickness.
   - Lighting equipment should match watt densities from the design analysis.
3. When purchasing materials, evaluate the life cycle costs, not just the purchase price.
4. Educate your contractor about sustainability practices through charrettes and through ongoing monitoring and communication.
5. Create a written system for evaluating and monitoring how your contractor is meeting written sustainability requirements.

5.3 Purchasing Construction Materials

Define the lowest environmental impact when specifying construction materials. Questions to ask include:

1. Where was the material shipped from?
2. What is the material made of, and can it be recycled or reused when the building is renovated or demolished?
3. Are you ordering the least amount of material necessary?
4. What is the durability and replacement cost of the material?

Material Specifications:

- Use recycled materials to reduce the use of raw materials and divert material

from landfills. Use at least 5%-10% salvaged or refurbished materials, and specify that a minimum of 25%-50% of your building materials contain at least 20% post-consumer recycled content material, or a minimum of 40% post-industrial recycled content material.
- Use local and regional materials as much as possible, in order to reduce natural resources necessary from transporting materials over long distances. Specify 20%-50% of building materials be manufactured within 500 miles of the building site.
- Use rapidly renewable materials, in order to reduce the depletion of virgin materials and reduce use of petroleum-based materials. Specify 5% of total building materials be made form rapidly renewable building materials.
- For components of the building made from wood, such as flooring and framing, use a minimum of 50% wood-based materials certified in accordance with the Forest Stewardship Council Guidelines.

Select materials with volatile organic compound (VOC) limits. Specifically:
- Select adhesives that meet or exceed the VOC limits of South Coast Air Quality Management District Rule #1168.
- Select sealants that meet or exceed the Bay Area Air Quality Management District Reg 8, Rule 51.
- Select paints and coatings that meet or exceed the VOC and chemical component limits of Green Seal requirements.
- Select carpet systems that meet or exceed the Carpet and Rug Institute Green Label Indoor Air Quality Test Program.
- Select composite wood and agrifiber products that do not contain added urea-formaldehyde resin.

5.4 Reducing the Site Environmental Impact
- Document a site's existing natural, historical, and cultural features and make specific plans to preserve them.
- Specify locations for trailers and equipment.
- Specify which areas of the site should be kept free of traffic, equipment, and storage.
- Prohibit clearing of vegetation beyond 40 feet from the building perimeter.
- Explain methods of protecting vegetation, such as designating access routes and parking.
- Require methods for clearing and grading the site that are as low impact as possible.
- Examine how runoff during construction may affect the site. Consider creating storm water management practices, such as piping systems or retention ponds or tanks, which can be carried over after the building is complete.

5.5 Indoor Air Quality During Construction
During construction, dust, VOCs, and emissions from equipment permeate the building site and the building itself. Poor indoor air quality (IAQ) can damage the health of workers and occupants of nearby buildings. It is important to take specific measures to protect IAQ on the site during construction, and after.
- Create a written plan for the contractor to use in managing air quality on the construction site.
- Put up barriers to keep noise and pollutants from migrating.
- Ventilate the site through the building's HVAC system, once installed, and with temporary exhaust systems before installation.
- Increase the amount of outside air coming into the building while under construction, to reduce pollutants.
- Create controls such as scheduling construction activities at the end of the day, to ventilate over night while site and surroundings are unoccupied.
- Be aware of air quality throughout the project, not just during times of activities that create high amounts of airborne pollutants and emissions.
- Regularly monitor IAQ with tests and inspections and adjust the ventilation

and scheduling if necessary to improve IAQ
- Prevent poor IAQ by selecting materials and products designed for less off gassing, such as low VOC paints and sealants and formaldehyde-free particle board
- Keep the site and interiors clean and free of debris, in order to keep dust down. Storing polluting materials in a specified storage area will protect the building from pollutants.
- Meet or exceed the minimum requirements of the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guideline for Occupied Buildings Under Construction, 1995.
- Protect stored on-site or installed absorptive materials from moisture damage.
- Replace all filtration immediately prior to occupancy. Filtration should have a Minimum Efficiency Reporting Value (MERV) of 13 as determined by ASHRAE 5.2.2-1999.
- Conduct a minimum two-week building flush-out with new filtration media at 100% outside air after construction ends and before occupancy, or conduct a baseline IAQ testing procedure consistent with current EPA Protocol for Environmental requirements, Baseline IAQ and Materials, for Research Triangle Park Campus, Section 01445.

5.6 Energy and Water Use

- Monitor the contractor's energy and water use. Set limits, or place the utility and water bills in the contractor's name to encourage conservation.
- Use lighting during construction only in active areas of the site. This saves energy and protects the night sky from light pollution.
- Turn all lights off when work is at a halt. Security lighting can run on motions sensors.
- Use energy-efficient lamps such as compact fluorescents, for temporary and permanent lighting schemes.
- Use renewable energy technologies or green power, if locally available, to power equipment and vehicles.
- Use low-flow fixtures for water siphons you install for construction.
- Use rainwater or reuse greywater from the construction site.

5.7 Construction Waste Management

- Make sure the infrastructure for recycling of construction and demolition materials is in place and operating at the beginning of the project. Set up an on-site system to collect and sort waste for recycling, or for reuse, and monitor the system consistently throughout all phases of construction.
- Create a recycling plan that sets goals to recycle or salvage a minimum of 50% (by weight) of construction, demolition, and land clearing waste. Aim for a minimum of 75%.
- Select products and materials with minimal or no packaging, if possible.
- Purchase materials in the sizes you will need them, rather than cutting them to size.

Consistently track and monitor the amount of waste production during construction and measure it against pre-existing goals and guidelines.

6. Sustainability through Renovation

Renovating an existing building is often an environmentally beneficial choice. You're avoiding building on undeveloped land and you are using existing infrastructure like roads, water and sewer lines, and electrical connections.

There are many ways to incorporate sustainability concepts in building renovation projects. Renovation projects may range from a simple relighting program to gutting the building to its shell and rebuilding its interior or adding a significant new addition to an existing building. Before beginning the project, asses the orientation of the building and consider ideas on how to sustainably integrate the building renovation project with the site and to evaluate how the project may affect the site. For example, will the renovation project change the site storm water runoff characteristics?

Software simulation tools can model proposed renovations to analyze how much energy they will save. Some of the simplest ways to add energy efficiency to retrofit projects include using efficient lighting, appliances, and equipment. Improved controls can also reduce HVAC and electrical use. Working with an energy service company can help you to achieve your retrofit goals. For retrofit projects, consider:

- Day lighting strategies, such as making atria out of courtyards or adding clerestories, along with modification of the electric lighting system to ensure energy savings
- Heat control techniques, such as adding exterior shades or overhangs
- Using passive solar heating strategies to allow modification of HVAC systems—perhaps down-sizing if the passive strategies reduce energy loads sufficiently.

When renovating older buildings, determine whether passive features that have been disabled can be revitalized. Boosting wall insulation levels in existing buildings is difficult without expensive building modifications. One option for existing buildings is adding an exterior insulation and finish system (EIFS) on the outside of the current building skin. With EIFS, use only systems that include a drainage layer to accommodate small leaks that may occur over time—avoid barrier-type systems.

Roof insulation can typically be increased relatively easily during re-roofing. At the time of re-roofing, consider switching to a protected-membrane roofing system, which will allow reuse of the rigid insulation during future re-roofing—thus greatly cutting down on landfill disposal.

6.1 Example of Renovation by Saving Structural components and Reusing Building Material

This case study is one in a series developed by the Massachusetts Department of Environmental Protection (DEP) to highlight techniques for saving money and protecting the environment through reuse and recycling of construction and demolition material.

Project Description: Clarke Distribution Corporation, Milford, Massachusetts
Clarke, a wholesale distributor for several lines of luxury kitchen appliances, renovated and expanded its distribution center in 2004 (figure 1). The Center is located in a rural area in central Massachusetts. Consigli Construction Inc. was the lead contractor for the project. The Institutional Recycling Network (IRN), a commercial recycling cooperative, provided waste reduction planning assistance and managed recycling logistics.

6.1.1 Ceiling Tiles and Doors: The project recycled six tons of ceiling tiles through the Armstrong Ceiling Recycling Program. Armstrong recovers the mineral fibers from discarded ceiling tiles to use in making new tiles. Armstrong's program is available to demolition projects and to building owners who choose Armstrong ceiling systems in their renovation projects. Consigli removed the ceiling tiles, stacked them and IRN provided the transportation. Armstrong provides a "Recycling cost comparison worksheet" on its web site that allows users to compare the cost of recycling versus disposal.

Clarke also donated 20 wood doors and 20 metal doors to a non-profit organization, the Building Materials Resource Center (BMRC), a reused building materials retailer. Clarke received a tax credit for the donation, Consigli saved disposal costs and BMRC sold these products at a reduced cost to low-income homeowners for use in their homes.

6.1.2 Cost Savings: Table 1 shows a breakdown of the cost savings due to source separation and recycling:

Material	Tons	Recycling Cost	Avoided Disposal Cost*	Savings
Ceiling Tiles	6	$625	$708	$83
Asphalt	970	$2,367	$114,460	$112,093
Concrete	1,267	$4,092	$149,506	$145,414
Metal	19	$785	$2,242	$1,457
Cardboard	0.86	$105	$101	(-$4)
TOTAL	2,263	$7,974	$267,017	$259,043

Table 1: Comparison of recycling and disposal of C&D material for this project and the resulting savings by using recycling of material

**Cost that would have been paid if material were disposed, asphalt & concrete are typically recycled.*
Cost savings does not include reuse of 7,225 tons of ledge.
Disposal costs based on local rates.

6.1.3 Team Approach to Waste Reduction Planning: Before construction started, staff from Clarke, Consigli and the Institutional Recycling Network walked through the facility to identify potential waste reduction opportunities. They developed a waste reduction plan that guided the entire waste reduction process from planning to development and construction. The plan identified several recycling opportunities, including:

- Clarke's CEO used his business contacts to identify a new home for a 9,000 square foot refrigeration unit that would have otherwise been disposed.
- Rather than purchasing new loading dock leveling units, weighing two tons each, Clarke authorized Consigli to reuse 6 out of 10 of the existing units.

<u>Project Team</u>

- *Building Owner*
  Clarke Distribution Corporation, 397 Fortune Boulevard, Milford, MA 01757
- *Contractor*
  Consigli Construction Inc., 197 Main Street, Milford, MA 01757Contacts: Tom Burns, Project Manager, and John Laperle, Superintendent
- *Recycling Services*
  Institutional Recycling Network, 7 South State Street, Suite 2, Concord NH, 03301
- *Building Material Reuse*
  Building Materials Reuse Center, 100 Terrace Street, Boston, MA 02120, Armstrong

7. Sustainable Stormwater Management Strategies

7.1 Application of Bioretention Areas

- Parking lot island landscaping features adapted to treat stormwater runoff.
- Surface runoff is directed into shallow, landscaped depressions with pollutant removal layers.
- Typically, the filtered runoff is collected in a perforated underdrain and returned to the storm drain system, but the system can be enhanced for partial exfiltration.
- The system should be sized between 5% and 10% of the impervious draining area.
- These areas can be designed to hold plowed snow.

7.2 Dry Extended Detention Pond

- Vegetated, open channel management practice
- May be an option as a snow storage facility to promote treatment of plowed snow

- Swale with engineered soil matrix and under drains to promote filtration
- Recommended for sites with a minimum drainage of 10 acres
- Least expensive stormwater treatment practice, on a cost per unit area treated
- Best long-term performance track record (least clogging problems)

7.3 Infiltration Trench (narrow and deep)

- Generally applied to sites less than five acres with relatively high impervious cover
- Soil infiltration rate ranges between 0.5 and 3 inches per hour
- Best applied to drainage areas less than 10 acres
- Soil infiltration rate should range between 0.5 and 3 inches per hour
- Can be optimized for seasonal operation and to accommodate snow melt

The design of all stormwater detention areas should be for the "dry" condition for most of the year. Stormwater retention areas should not be designed to be wet year round since that may encourage development of wetlands and/or breeding areas for pests.

8. Water Efficiency Considerations

Water efficiency is the planned management of potable water to prevent waste, overuse, and exploitation of the resource. Effective water-efficiency planning seeks to "do more with less," without sacrificing environmental performance. There are two basic approaches to potable water efficiency in the landscape:

Water Efficiency in the Landscape

- Reduce water use associated with irrigation and landscaping.
- Recycle or use water with gray water or process recycling systems.

Reduce water use associated with irrigation and landscaping. This can be accomplished to varying degrees by one or a combination of the following:

- Preserve, encourage or reintroduce native or drought-tolerant vegetation that is already optimized for naturally occurring precipitation levels.
- If plants are desired that need water, group them by similar watering and soil type needs.
- Irrigate efficiently (see irrigation tips).

Recycle or use water with graywater or process recycling systems. Reclaimed wastewater, sometimes called irrigation quality or IQ water, is another possible source for irrigation water. Reclaimed water is from a wastewater treatment plant that has been treated and can be used for nonpotable uses such as landscape irrigation, cooling tower, industrial process uses, toilet flushing, and fire protection. It must be scrupulously isolated from potable water distribution, and all IQ hose bibs must be clearly marked as "nonpotable." The following considerations can be used to improve the efficiency of irrigation applications of collected water from buildings:

- Use ultra-low-volume distribution devices.
- Irrigate after on-site inspection or electronic sensing of moisture requirements, rather than just by a time clock.
- Water requirements vary greatly by season, and as the landscape matures, less irrigation is required.
- Automatic irrigation controllers should have rain switches that override the "on" signal when sufficient rain has fallen or soils are moist.

Rainwater harvested from building roofs can be used for irrigation. Graywater is untreated wastewater generated within the facility from shower and bath, laundry, and bathroom sinks (not from toilets, urinals, kitchen sinks, or dishwashers). Graywater can be used for below-ground irrigation, but it is not recommended for above-ground irrigation.

9. Sustainable Operation and Maintenance of Buildings

When a new building is ready for occupancy, the operation and maintenance of the building will impact energy use and occupant comfort. As much care should be paid to the operation of the building as was paid to the building planning, design, and building component choices. Energy-efficient lighting is one of the most cost-effective options available for reducing energy costs in buildings.

For existing buildings, effective operation and maintenance procedures provide opportunities for energy savings. Building components can be replaced with energy-efficient models. Facilities staff can be trained to cut energy use. And performance needs to be measured.

The best efforts to reduce negative environmental impacts in the built environment are doomed to failure unless well-crafted operations and maintenance (O&M) procedures are implemented. Furthermore, even the best O&M procedures are of no use unless they are understood and followed by building O&M personnel.

Facility managers play the key role in ensuring that this happens. An "integrated team" approach can be a big help. In this process, O&M personnel are active participants in the design of a facility and the development of O&M procedures. This "integrated team" promotes useful procedures that are efficient and—most important—faithfully executed.

Building operation and maintenance programs specifically designed to enhance operating efficiency of HVAC and lighting systems can reduce energy bills by 5% to 20% without significant capital investment. The EPA and DOE want to help commercial building owners capture these savings. They have developed fifteen O&M Best Practices for Energy Efficient Buildings booklet with strategies that facility managers, energy managers, and property managers can use to integrate energy-efficient operation into their organizations' O&M programs and to obtain support from senior management.

Addressing O&M considerations at the start of a project can contribute greatly to improved working environments, higher productivity, and reduced energy and resource costs. The following sections of this guide provide a variety of O&M information on the important systems typically found in Federal facilities. Other O&M-related information also can be found in various places in the earlier sections of this guide.

There are tremendous opportunities in most existing buildings and facilities to improve O&M procedures and make them more environmentally responsible. With new buildings, there are opportunities during design and construction to facilitate easy, low-environmental-impact O&M. With all buildings there are opportunities to derive multiple benefits. Energy savings and improved indoor air quality can be achieved by tuning up older oil-fired boilers, for example. Improved indoor air quality and less hazardous effluent from a building can be achieved by switching to more benign cleaning chemicals. If implemented effectively, the multiple benefits of O&M practices should include reduced operating costs.

To create an effective O&M program, the general procedures should be followed:

- Ensure that up-to-date operational procedures and manuals are available.
- Obtain up-to-date documentation on all building systems, including system drawings.
- Implement preventive maintenance programs complete with maintenance schedules and records of all maintenance performed for all building equipment and systems.
- Create a well-trained maintenance staff and offer professional development and training opportunities for each staff member.
- Implement a monitoring program that tracks and documents building systems

performance to identify and diagnose potential problems and track the effectiveness of the O&M program. Include cost and performance tracking in this analysis.

Specific elements of an effective O&M program include:

9.1 HVAC Systems and Equipment

Energy consumption and conservation are tied heavily to O&M procedures. HVAC equipment must be well maintained for the complex array of chillers, boilers, air handlers, controls, and other hardware to function at peak performance. Easy access to HVAC systems for ongoing maintenance and repair is critical (be sure that this is considered during design). A well-thought-out, well-executed O&M program can provide huge savings in equipment and energy costs.

9.2 Indoor Air Quality (IAQ) Systems and Equipment

Air ventilation and distribution systems should be well maintained and frequently checked for optimal performance. Coordination between air distribution systems and furniture layouts is especially important. In addition, regular inspection for biological and chemical contaminants is crucial. Poor IAQ lowers productivity, can cause illness, and has resulted in numerous lawsuits.

9.3 Cleaning Equipment and Products

Using biodegradable and least-toxic cleaning products and equipment can reduce both O&M costs and pollution to air and wastewater streams while improving both indoor air quality and worker productivity. The need for chemical cleaning products can also be reduced through environmentally conscious design and material choices. New requirements for cleaning contracts must be clearly specified. The EPA Cleaning Products Pilot Project can help you find environmentally preferable cleaning products.

9.4 Materials

Facilities should maintain an attentive and proactive stance with regard to the environmental impacts of their material choices. Every day new products, systems, and equipment become available that have fewer adverse environmental impacts. All these choices should be carefully scrutinized in terms of O&M.

9.5 Water Fixtures and Systems

Routine inspections and maintenance programs for water fixtures and systems are crucial. Population growth and development have reduced the availability of high-quality, potable water in many regions of the country. Along with increased water prices, reduced supply often leads to usage restrictions. An O&M program will reduce operating costs when it verifies that fixtures and systems are functioning effectively and ensures that leaks or components are quickly repaired.

9.6 Waste Systems

Recycling and waste-reduction programs and their supporting hardware need frequent attention and maintenance in order to function at peak performance.

9.7 Landscape Maintenance

Use of native plantings can reduce landscape O&M requirements and costs significantly. Although natural vegetation may take several years to become established, once it is established there is usually less need for water. Integrated pest management can also reduce overall O&M costs by reducing the need for hazardous chemicals and pesticides.

10. Standard for Rating Sustainable Facilities.

Sustainability performance standards measure the impact of a building upon the environment through its entire lifecycle and specifically upon the built and natural environment's continued ability to support healthy life. The building's life-cycle includes its *construction* (including environmental impacts through the acquisition and transportation of materials, construction methods, location, site work, etc.), *operations* *and maintenance* (including environmental impacts on human health, water/air/soils, energy resources, etc.), and *demolition* (including many of the same environmental impacts listed above, together with waste management).

An performance standard is needed to objectively measure the environmental sustainability of a building's life cycle, to make the most cost-effective choice among an array of environmental investments possible in a particular building, to compare the environmental performance of different buildings, to be accountable to stakeholders for the environmental investments made in buildings, and to participate in a broader social effort (national and international) towards environmental sustainability. Energy optimization is also an integral part of environmental performance.

The LEED evaluation for sustainable commercial buildings is the most used system in the United States. The letters stand for Leadership in Energy & Environmental Design. It has become the leading system for designing, constructing, and certifying the world's greenest buildings. The LEED's model takes a whole-building approach that encourages and guides a collaborative, integrated design and construction process. The intent is to optimize environmental and economic considerations throughout the planning, design, construction and operation of a building with a life cycle viewpoint. There are four levels of LEED certification based on a point system shown below:

- LEED Certified 26 - 32 points
- Silver Level 33 - 38 points
- Gold Level 39 - 51 points
- Platinum Level 52+ points (69 possible)

11. Training

In order to plan, design, construct, maintain, and operate programs in environmentally sustainable buildings, people must be adequately trained. Having LEED-certified professionals work on the design and construction is not enough; County staff must have LEED and energy management training appropriate for their level of involvement in the buildings. Failure to do so will result in delays, cost increases, design conflicts, and higher operations and maintenance costs for the buildings. While all occupants of LEED-certified building need some level of building orientation, those more extensively involved in building design and construction should have more formal training.

12. Example High Performance Sustainable Buildings

12.1 Arlington County Virginia Sustainable Building Policy Since the early 1960s, Arlington has targeted specific areas for development using its General Land Use Plan. Concentrate high density development along Metro corridors. These areas surrounded by less densely developed suburban-type neighborhoods. This approach has proven to be a very effective planning tool. Gives Arlington its unique character - walkability, public transit accessibility, neighborhoods with distinct character and allows for economic development. Offers opportunity to work and live in the same community. Arlington's land use and develop plan for buildings and other public and private infrastructure provide easy access to transit for those commuting into DC. A large number of people also commute into Arlington as well.
Through careful land use planning this results in a dense urban high rise environment, usually mixed offices, ground level retail, apartments, and hotels around Metro, bus routes, and main roads. It also preserves quiet residential neighborhoods and a network of linear parks that follow stream valleys. There are also old train lines that have been converted to bike trails along several stream valleys. As with any urban community, Arlington is facing a variety of environmental challenges. Some of these local impacts include, stormwater runoff, heat islands in high rise areas, traffic congestion, and constant demand for parking, streams and parkland.

Currently there are six County projects that are being designed to achieve LEED silver status as sustainable buildings. The include a community center serving teens and senior citizens, a school and community center, and Parks Department operations buildings. The Walter Reed Community Center is leading the way. The goal is to achieve Gold LEED certification. This project used an integrated design process from the beginning and involved working closely with architects, engineers, users, employees, neighbors, etc. This facility here will serve teens with a game room, ball courts, indoor gym area, and organized activities. The Center also houses a senior day program with arts and crafts, kitchen facility, nursing station, and organized activities. A further purpose is to serve as a meeting place for community groups, special events, County committees, and other County programs.

On the private sector side, the Arlington County Board is requiring all site plans for construction projects to submit a LEED Scorecard to determine how "green" projects are even if they aren't going for a high level of certification. All major projects are encouraged to meet at least a LEED Silver rating. Any construction in a metro corridor gets a point for locating near transit and most get a point for urban redevelopment. Arlington requires office buildings to include bike racks and shower facilities. The sustainable building program allows developers to apply for additional density up to .25 FAR and/or 3 stores, if they meet at least silver LEED requirements. This gives builders and building owners additional leasable space which in Arlington is a strong financial incentive. All new major construction projects are now planning for LEED silver or higher. Arlington does maintain a database that tracks overall greenness as development evolves within the county. The pressure to build and increased density levels within the county continues and there is recognition of the need to consider cumulative impacts in planning for future development.

Builders and building owners are also focusing a lot of effort on indoor environmental quality. Through the LEED certification process better use of indoor materials, efficient heating, cooling and ventilation system design, energy efficiency and generous areas of day-lighted space lead to a healthy office environment. Sustainable buildings have proven to be a good marketing tool in the competitive lease market. Arlington building owners with sustainable high performance facilities can advertise environmental friendly, healthy indoor working environments, and non-toxic space to perspective customers.

12.1 Rosslyn Center Place Project: Center Place is a million-square foot, mixed-use development in Rosslyn, Arlington County that will be LEED certified silver or better and have the first and will house the only publicly-accessible observation decks overlooking Washington's monuments. The project's principal features are two massive, tall tower structures that will be the tallest buildings in Virginia and the Washington DC area when completed (see figure 3). One will be for office space and the second for apartments. The two-level observation deck on the 28th and 29th floors of the Office tower will be a unique public amenity for Arlington residents and tourists to enjoy panoramic views of the national monuments and surrounding area from a unique vantage point (figure 4) . It's expected to draw up to 450,000 visitors annually. The deck is part of the JBG Companies' proposed Central Place project. The observation deck will be atop a commercial office tower located at Wilson Boulevard, one of two glass towers that will comprise the JBG project. The re-development will redefine Rosslyn's "Central Place". I is also a candidate for demonstration/application of new technologies and systems for the next generation of sustainable high performance buildings.

The form and materials of the two glass towers reflect a sense of transparency, lightness and quiet elegance. The glass and metal residential building will rise to 380 feet and has been designed to match the drama and quality of the office tower at the opposite end of the site. The office building will contain trophy level office space, with impressive views for the public and corporate tenants. The top 60 feet of the residential building has been reserved for the highly anticipated public observation deck, which will crown the development.

An open air landscaped park between the two towers will be approximately 18,400 square feet in size and directly opposite the Rosslyn Metro station. The park is designed to function as a "town square," surrounded by pedestrian level retail (figure 5). Landscape Architect Michael Vergason's flexible plaza design allows for both daily enjoyment and large public events and festivals. Kathleen Webb, a JBG principal who is project manager for Central Place, says the plaza will help activate the community. It is designed to be inviting, pedestrian-friendly and easy-to-get-to. The plaza will connect N. Moore and Lynn Streets at the Moore Street level, directly across from the

Rosslyn Metro entrance, to provide east-west connectivity through the heart of Rosslyn for Metro commuters and visitors alike. The plaza will be flanked by the two soaring glass and metal towers with retail spaces opening onto the park from the base of each tower. The JBG Companies' other Rosslyn developments include new retail at International Place (1735 N. Lynn Street), 1801 N. Lynn Street, distinguished by Ned Kahn's liquid pixels artwork, and the soon-to-be-completed design work of Jim Freed at Waterview.

The project is just now completing two years of community review by the Rosslyn Working Group. Initially, In October 2004, the Arlington County Manager officially appointed a group of planners, designers, and citizens including members of the Rosslyn Renovation Urban Design Committee to review and plan the JBG project's height, architecture and urban design. Central Place is identified in the Rosslyn Sector Plan as the organizing element of Rosslyn's urban core, with a vision that it will be "hub" of pedestrian activity providing streetscape, shopping, eateries, art and open space. The JBG design incorporates key components of the Rosslyn Plan and also addresses the County-commissioned study by the Urban Land Institute. This project is intended to further develop Rosslyn as a major destination in the Washington region.

12.2 Achieving Desired Indoor Air Quality for Oklahoma City surgical suites:

St. Anthony Hospital in Oklahoma City was founded in 1898, and is a private, not-for-profit, multi-campus hospital and regional referral center. The 615-bed tertiary care facility provides general and acute care services including cardiology, oncology, behavioral medicine, surgery, kidney transplantation, orthopedics, and a variety of other disciplines. With approximately 2,600 employees, the hospital administration understood the need to update their facility and equipment to compete with other hospitals for doctors, staff, and patients. Thus a lO-year, $220 million renovation is underway to enlarge the facility and incorporate the latest in medical technologies and sustainable green technology into the renovated structure (figure 6).

The first major phase of the renovation was a complete overhaul of the surgery center. Designers worked closely with hospital personnel and design engineers to ensure the best system was installed. There was an innovative, collaborative team effort to create the best possible facility and to investigate every possible option before settling on the final approach. The desiccant technology showed the best combination of performance, operating cost, and first cost. The system has been operating for some time now and has exceeded expectations in every way. The architects and engineers working on the surgery project included the physicians and surgeons throughout the entire design process. It was important to St. Anthony's that the building's designers valued the input from the physicians, because ultimately they know what is best for them and their patients.

Humidity is a constant challenge in surgical environments. Surgeons need the operating rooms to have both a low temperature and a low relative humidity. This ensures that surgical surfaces and instruments remain free of moisture, discouraging bacteria growth. For some surgical procedures, low temperature reduces the metabolic rate to lessen the impact of the surgery. Low humidity is also required to avoid "fogging" of optic systems used in minimally invasive surgical procedures. Any failure to maintain those conditions is completely unacceptable.

Cooling-based systems are inefficient because they must cool the air to the desired dew point in order to provide the humidity required. This requires a very low leaving air temperature and low temperature refrigeration systems. Additionally, they overcool the air and require substantial reheat to keep the rooms from getting too cold. These systems are costly to operate and may not provide the desired conditions under all circumstances.

This $30 million project required a new chiller plant, boiler plant, air-handling systems, and an active desiccant system. The desiccant dehumidification system at St. Anthony provides the desired temperature and humidity without the need for special refrigeration systems and without the inefficiency of cooling and reheating. This ensures better indoor air quality and a more comfortable environment for doctors and patients. The hospital has been successfully recruiting surgeons since the completion and opening of the new surgery facility.

12.3 Simulation helps Finnish office workers stay warm in winter, cool in summer

This 150,000-sq-ft building is the headquarters for Pfizer Oy, the Finnish subsidiary of Pfizer Inc. The building was designed as a high performance green facility which uses an active chilled beam cooling system for office spaces and displacement ventilation for the lobby (figure 7). The designers were concerned about thermal comfort inside the building because of the large surface area of windows and skylights and the large atrium. While many people think of Finland as a very cool climate, the Helsinki area actually has a greater solar thermal load during the summer than Paris. Keeping the atrium warm was difficult in the winter because of the large window and skylight area and keeping the atrium cool in the summer months was challenging because skylight and windows provide a significant solar heat source to the atrium:'

To address this issue simulation results for different air distribution solutions were used to diagnose a system for air distribution that would be effective throughout the building. One general problem was that air velocities were too high for comfort in a number of occupancy zones. Temperatures were too high in certain areas of the atrium during the summer due to the large amount of solar thermal loading through the skylights. We also noticed that optimization of supply air distribution in offices was I important for thermal comfort:'

The airflow problems and the heat distribution in the atrium were addressed by evaluating a number of different diffuser configurations. Using computer simulation modeling a diffuser design was found that reduced airflow to comfortable levels while improving thermal distribution to the point that the temperature remained within an acceptable range in all occupied areas of the atrium under summer conditions. A variety of different window heating systems were also modeled to find an acceptable solution for the winter environment.

The use of computer simulation significantly improved the indoor air quality of this building while avoiding the expense that would have otherwise been required to modify the HVAC system after it had already been installed.

13. Summary

The environmental impact of buildings is very important. This is an area that needs more attention on a national and local basis. Approximately 65% of the US total electric consumption is from buildings. This represents more than 36% of the total US primary energy usage. Approximately 30% of the total US greenhouse gas submissions are from buildings. There is approximately 36 billion tons annually of construction and demolition waste generated from US buildings. This represents approximately 2.8 pounds per person per day in the US. The consumption of potable water in US buildings is approximately 36 billon gallons per day representing 78% of total treated water consumption in this country included in this is 5 billion gallons per day for toilet flushing alone.

Sustainable buildings are intended though out their life time to have a beneficial impact on their occupants and their surrounding environment. Such buildings are optimally integrated on all parameters— initial affordability, timeliness of completion, net life-cycle cost, durability, functionality for programs and persons, health, safety, accessibility, aesthetic and urban design, maintainability, energy efficiency, and environmental sustainability. Failure on any one parameter invariably undermines other parameters of the building in question and of the system of buildings and connected service systems in the community. Examples of Sustainable Building components include:

- Low-VOC paint
- Low-VOC carpet tiles
- Low-flow restroom fixtures
- Recycled content tiles
- Waterless urinals
- Motion sensors
- Green Roof

There are clear economic benefits of sustainable buildings which include a competitive first cost. The concept of integrated design allows for high benefit at low cost by achieving synergies between disciplines and between technologies. Green Designs lead to reduced utility bills and O&M costs. Sustainable design also will optimize life cycle economic performance and reduce liabilities. Energy and water-efficient buildings have been able to reduce their operating costs significantly. Use can be cut to less than half than that of a traditional building, or even better, by employing aggressive and well-integrated green design concepts.

A critical element for a successful sustainable building policy and program is an integrated building planning and design process. Integrated planning and design refers to an interactive and collaborative process in which all stakeholders are actively involved and communicate with one another throughout the design and construction practice. This allows the architect and engineer to work together to ensure that building components work synergistically. Experience across the nation shows that environmentally sustainable features are often not incorporated. In other cases they are included at much higher costs, when environmental performance issues are not considered from the very outset of the planning and design process.

It is not only environmental performance that suffers from lack of an integrated planning and design process. All the other building parameters also suffer (initial affordability, timeliness of completion, net life-cycle cost, durability, functionality for programs and persons, health, safety, accessibility, social equity, aesthetic and urban design, maintainability, and energy efficiency).

Integrated Design and construction practices that significantly reduce or eliminate the negative impact of buildings on the environment and occupants may be organized into five broad areas:

- Sustainable site planning
- Safeguarding water and water efficiency
- Energy efficiency and renewable energy
- Conservation of materials and resources
- Indoor environmental quality

Indoor air quality is also a critical part of high performance sustainable buildings. Healthy indoor environments can increase employee productivity according to an increasing number of case studies. Since workers are by far the largest expense for most companies (for offices, salaries are 72 times higher than energy costs, and they account for 92% of the life-cycle cost of a building), this has a tremendous effect on overall costs. Studies have shown that student performance, as well as energy performance, is better in schools built according to green design principles. More than 17 million Americans suffer from asthma, and 4.8 million of them are children. Ten million school days are missed by children each year because of asthma, which is exacerbated by poor IAQ. Employees in buildings with healthy interiors have less absenteeism and tend to stay in their jobs.

The LEED evaluation for sustainable commercial buildings is the most used system in the United States. The letters state for Leadership in Energy & Environmental Design. It has become the leading system for designing, constructing, and certifying the world's greenest buildings. The LEED's model takes a whole-building approach that encourages and guides a collaborative, integrated design and construction process. The intent is to optimize environmental and economic considerations throughout the planning, design, construction and operation of a building with a life cycle viewpoint.

14. Recommendations for further Development of High Performance Sustainable Buildings

1) Better define the criteria (target levels) for indoor pollution levels for human occupancy. Develop the technical bases for creating performance based standard for risk assessments and identify action to implement new knowledge into practice (research risk identification process, how to reduce the risk once identified, containment or dilution). Build on sustainability research findings and recommendations from organizations such as the World Health Organization (WHO), the US USIDR levels, the EPA IRIS data base of human health effects from exposure to various substances in the environment, and Japanese organizations to identify technologies designed to: 1) sense hazardous pollutants, 2) mitigate these pollutants, and 3) identify pollution sources **(**material sources, maintenance sources).

2) Minimize energy use in new building designs and retrofitting of existing buildings by using: 1) sustainable building materials, 2) energy efficient building envelopes including green roofs, 3) reuse of energy (heat), 4) efficient appliances and equipment, 5) recycled material research to assess the characteristics of these material properties, 6) water conservation and wastewater management systems, and 7) improving building management systems for green systems for operation and maintenance.

3) Demonstrate promising materials and systems in actual buildings to facilitate the more rapid transfer of this technology into use by the building industry

Establish a strong working relationship with the building industry and conduct planned demonstrations in buildings of materials and systems that meet the sustainability needs of the building in an effective, efficient and environmentally sensitive manner. The time lag and risks of technology transfer can often be reduced through demonstration projects that involve the effected industry.

4) Develop a systems approach to address the complex set of problems and issues for the next generation of sustainable buildings

Buildings are a complex mix of materials and systems that need to work together to provide safety, comfort, and efficiency to their occupants and owners. To introduce new materials, systems and other components into the next generation of high performance sustainable buildings will require a full understanding of these interactions and the ability to model and simulate these new parameters with in the total building context.

5) Identify and quantize procedures for assessing new materials

Conduct research and development efforts to understand the mechanical, environmental and other by-products from new materials made from recycled materials. This would include understanding the burning characteristics of this new and growing family of "sustainable construction materials". The broader use and smart application of these new sustainable materials will be dependent on these studies.

6) Identify and apply technologies that meet US and Japan sustainability goals that can be used in demonstration projects

Example technologies include development of effective materials made from recycled components, improved energy efficiency devices and systems, new methods to reduce air and water pollution, elimination of toxic materials in buildings, advances in structural building materials

7) Improve the knowledge base on the service life of buildings

Developing ways to lengthen the service life of buildings is a very effect sustainability approach. New innovations and applications in this area would produce high returns.

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Figure 1: View of the completed Clarke Corporation structure in Milford, MA

Figure 2: View of concrete floor in the Walter Reed Community Center

Figure 3: Central Place is illustrated here with its principal features of two tower structures that will be the tallest buildings in Virginia and the Washington DC area.

Figure 4: Illustration of the view from the two-level observation deck on the 28th and 29th floors of the Office tower

Figure 5: Landscaped park between the two towers that will be approximately 18,400

Figure 6: St. Anthony's Hospital in Oklahoma City following completion of their new surgical center

Figure 7: Headquarters building for the Finnish subsidiary of Pfizer Inc.