LEEDing the Way?

Integrated design approach key in rasing the bar in energy efficiency

BY PETER C. D'ANTONIO, P.E.

The United States Energy Information Administration estimates that energy bills for the approximately 67 billion square feet (ft^2) of existing U.S. commercial space total $82 billion annually. The Leadership in Energy and Environmental Design (LEED) program is one energy-efficiency and environmental initiative that targets the energy use of commercial buildings and promotes energy efficiency. According to the U.S. Department of Energy (DOE), commercial new construction can achieve reductions in energy use of 50% or more, if whole-building design and energy-saving strategies are carefully implemented.

LEED is a voluntary, points-based, national standard for developing high-performance buildings. It is a framework for informed, educated design as well as a quality control mechanism.

Since its pilot in 2000, roughly 3-5% (153 million ft^2) of all new commercial construction projects in the United States have registered for LEED certification. Of the approximately 1200 projects registered to-date, approximately 100 of these projects have completed the certification process. The low level of certification reflects a number of factors, including the age of the program and the average length of time to complete certification process (several years according to LEED). The cost of certification may have caused some building owners to register but not pursue certification. The current system (LEED-NC) evaluates new construction and major renovation projects. LEED-EB, for existing buildings, is currently in the pilot phase and will be available later this year.

Energy-efficiency efforts first took root in the energy crisis of the early 1970s. Before LEED-NC and other energy and environmental initiatives, energy efficiency in buildings was primarily driven by interested building stakeholders and building energy codes, namely the model energy code first published in 1983 and its successor, the International Energy Conservation Code (IECC), which debuted in 1998. The energy codes were based on ASHRAE's 90.1 *Energy Standards for Buildings Except Low-Rise Residential Buildings,* initially developed in the 1970s. The Energy Policy Act of 1992 required all states to certify that they have adopted energy codes that are at least as stringent as Standard 90.1-1999, such as

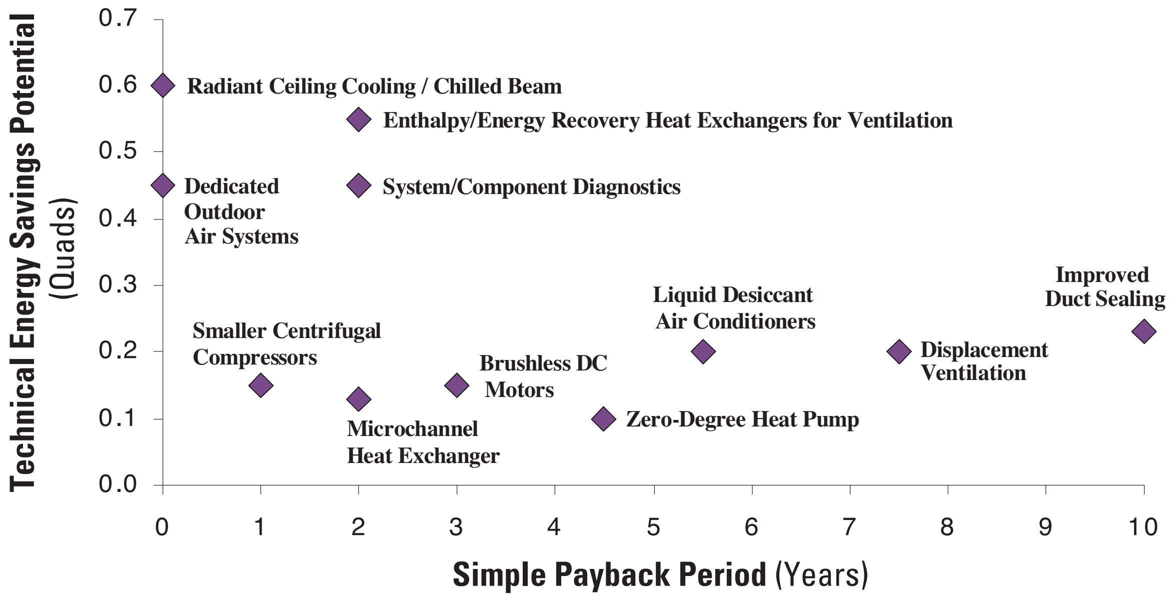
CREDIT TRENDS – CERTIFIED PROJECT CREDIT ACHIEVEMENT

Energy & Atmosphere		Points	% Earned
		17 Total Pts.	AVG 5.3 Pts.
Prereq 1	Fundamental Building Systems Commissioning	Required	
Prereq 2	Minimum Energy Performance	Required	
Prereq 3	CFC Reduction in HVAC&R Equipment	Required	
Credit 1.1	Optimize Energy Performance, 15% New, 5% Existing	1	81%
Credit 1.1	Optimize Energy Performance, 20% New, 10% Existing	1	74%
Credit 1.1	Optimize Energy Performance, 25% New, 15% Existing	1	64%
Credit 1.1	Optimize Energy Performance, 30% New, 20% Existing	1	51%
Credit 1.1	Optimize Energy Performance, 35% New, 25% Existing	1	37%
Credit 1.1	Optimize Energy Performance, 40% New, 30% Existing	1	23%
Credit 1.1	Optimize Energy Performance, 45% New, 35% Existing	1	14%
Credit 1.1	Optimize Energy Performance, 50% New, 40% Existing	1	7%
Credit 1.1	Optimize Energy Performance, 55% New, 45% Existing	1	5%
Credit 1.1	Optimize Energy Performance, 60% New, 50% Existing	1	2%
Credit 2.1	Renewable Energy, 5%	1	9%
Credit 2.2	Renewable Energy, 10%	1	7%
Credit 2.3	Renewable Energy, 20%	1	7%
Credit 3	Additional Commissioning	1	40%
Credit 4	Ozone Depletion	1	44%
Credit 5	Measurement & Verification	1	40%
Credit 6	Green Power	1	26%
Indoor Environmental Quality		**Points**	**% Earned**
		15 Total Pts.	AVG 9.0 Pts.
Prereq 1	Minimum IAQ Performance	Required	
Prereq 2	Environmental Tobacco Smoke (ETS) Control	Required	
Credit 1	Carbon Dioxide (CO_2) Monitoring	1	72%
Credit 2	Ventilation Effectiveness	1	30%
Credit 3.1	Construction IAQ Management Plan, During Construction	1	60%
Credit 3.2	Construction IAQ Management Plan, Before Occupancy	1	70%
Credit 4.1	Low-Emitting Materials, Adhesives & Sealants	1	86%
Credit 4.2	Low-Emitting Materials, Paints	1	79%
Credit 4.3	Low-Emitting Materials, Carpet	1	93%
Credit 4.4	Low-Emitting Materials, Composite Wood & Agrifiber	1	42%
Credit 5	Indoor Chemical & Pollutant Source Control	1	72%
Credit 6.1	Controllability of Systems, Perimeter	1	28%
Credit 6.2	Controllability of Systems, Non-Perimeter	1	19%
Credit 7.1	Thermal Comfort, Comply with ASHRAE 55-1992	1	72%
Credit 7.2	Thermal Comfort, Permanent Monitoring System	1	56%
Credit 8.1	Daylight & Views, Daylight 75% of Spaces	1	40%
Credit 8.2	Daylight & Views, Views for 90% of Spaces	1	77%

** Note: Percentages in first two columns represent energy cost reduction as compared to ASHRAE 90.1-1999 Energy Cost Budget*
Credits in green are directly related to energy performance

Table 1. LEED scoring demonstrates that some technologies and strategies are adopted by very high percentages of building owners; some, unfortunately can be found in less than 10% of LEED-certified buildings.

LEEDing the Way



Some high-potential energy savings techniques have very short simple paybacks.

the IECC, or justify why they can not comply by July 15, 2004.

Energy Efficiency in LEED

Energy efficiency points in LEED-NC are primarily awarded in the environmental category Energy and Atmosphere and to a lesser extent the category Indoor Environmental Quality. Of the 17 points achievable in the Energy and Atmosphere category, 15 are directly related to optimizing building energy performance. Seven of the 15 possible points in Indoor Environmental Quality are directly related to energy efficiency in buildings.

LEED-NC is a standards-based rating system, much like our present building energy codes; compliance is no guarantee of an energy-efficient building. LEED-NC evaluates energy efficiency on apparent efficiency designed into a facility (LEED-EB for existing buildings is addressing this issue to include performance-based energy-efficiency ranking).

Energy-efficiency points are based on compliance with ASHRAE 90.1-1999 or the local building code, whichever is more stringent. Energy-efficiency points in LEED are earned by reducing energy cost.

LEED requires energy modeling through use of an energy simulation program as part of its energy optimization requirements. Energy modeling, which is done using an advanced computer model of an existing or proposed building, helps architects and engineers find the best combination of materials and systems. The model is a prospecting tool that, in the hands of a dedicated user, can indicate which combination of building strategies is most likely to produce a building that is energy efficient, has the desired thermal performance, and provides a comfortable and healthy environment. Furthermore, current industry-standard, energy-modeling programs such as DOE2 and Trace 700 have limitations in accurately modeling some of the energy-efficient systems, for example displacement ventilation, radiant, and renewable energy systems.

Does LEED Succeed?

Table 1 illustrates the activity in energy efficiency and indoor environmental quality for the first 53 LEED certified buildings. In the Energy and Atmosphere category, there is a less than desirable 5.3 out of 17 possible points being achieved, or 31%. This is the lowest percent achieved in any of the five LEED categories (sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality). As evidenced from the table, the majority of facilities achieving LEED certification are designing to no more than 30% better than the ASHRAE 90.1-1999 guidelines. Renewable energy points are achieved in less than 10% of buildings, the same level of participation that is evidenced in overall energy reductions of 50% or more compared to ASHRAE 90.1-1999. With respect to efficiency-related credits under the Indoor Environmental Quality category, the achievements are equally mediocre. Increases in ventilation effectiveness and controllability of systems are achieved in less than a third of LEED-certified buildings. LEED-certified buildings do perform better in areas such as thermal comfort, carbon dioxide monitoring, and daylighting.

Identifying the Opportunities

So why aren't more LEED projects pushing the envelope on energy? Some builders and developers attack LEED, effectively shooting the messenger. LEED, however, cannot be blamed for this lack of innovation for three reasons. First, annual energy expenditures equate to only about 1% of total expenditures for a medium-sized office building, with HVAC expenses on the order of 0.5%. Second, many designers opt to play it safe by designing systems that worked for them in the past. Third, Arthur D. Little (now Tiax) found that new technologies do not achieve market penetration unless the technology has a simple payback of less than two years. The same study indicates that it may take 10-20 years to achieve any significant market penetration after the technology is introduced into the market.

LEED has analyzed why certain Energy and Atmosphere (EA) and Indoor Environmental Quality (EQ) credits are not being pursued or awarded. The high cost of technology seems to impede results in the EA2, EA3, EA5, and EA6 categories. Time-consuming required reduces compliance in EQ2 and other categories, and the increase in design costs impedes achievement of the EQ6 and EQ8 goals. LEED suggests lack of system integration is to blame for poor performance in EA1.

Identifying cost-effective systems requires identifying key considerations when planning a high-performance building, including aspects of mechanical systems. With energy efficiency having such little importance in the overall decision making process, the challenge becomes identifying the driver of energy-efficient systems. Most businesses identify labor as the greatest expense. Any technologies and designs that improve worker productivity by even 1-2% will have an enormous financial impact and be attractive investments to businesses. Of course not all productivity measures will save energy.

The LEED 2.0 Reference Guide lists three fundamental strategies to increase energy performance: reduce demand, harvest site energy, and maximize efficiency. Demand reduction strategies include reducing the overall building footprint, relaxing temperature design criteria, and utilizing occupancy sensors. Harvesting site energy includes using daylighting, outdoor air for cooling, geothermal exchange, and solar thermal technologies. State-of-the-art lighting, HVAC, and energy management equipment, reducing system losses, and proper insulation increase efficiency.

The guide lists some specific HVAC systems and strategies, but does not adequately cover the current trends in energy efficiency. Rather it makes some general statements regarding mechanical system energy efficiency.

Key Considerations

Arthur D. Little estimates that the roughly 59 billion ft^2 of commercial floor space in the U.S. consumed 14.7 quads of energy in 1995. HVAC systems consumed a total of 4.5 quads of the total, representing the largest percentage of energy end-use. In July 2002 the U.S. Department of Energy published a report entitled *Energy Con-*

Information Sources

- *ASHRAE GreenGuide*. www.ashrae.org. The book addresses architectural design impacts, conceptual engineering design, space thermal/comfort delivery systems, energy distribution systems, energy conservation systems, energy/water sources, lighting systems, plumbing, and fire protection systems and controls.
- The United States Green Building Council (www.usgbc.org) provides information and resources to its members and to the public to help transform the market.
- Energy Star (www.energystar.gov) is a government-backed program helping businesses and individuals protect the environment through superior energy efficiency.
- *Greening Federal Facilities* highlights current green strategies and follow-up resources for federal facilities from heating and cooling systems to operations and maintenance strategies. (www.eren.doe.gov/ femp)
- Rocky Mountain Institute (www.rmi.org) provides consulting activities, compiles case studies and researches new policies, technologies, and techniques for improving the performance of buildings.
- U.S. DOE Office of Energy Efficiency and Renewable Energy (www.eere.energy.gov/buildings/highperformance/) provides design approaches, a designers toolbox and technologies. The site also contains the High Performance Buildings Database. *eun*

Technology Options	Status	Technical Energy Savings Potential (quads)
Adaptive/Fuzzy Logic Controls	New	0.23
Dedicated Outdoor Air Systems	Current	0.45
Displacement Ventilation	Current	0.20
Electronically Commutated Permanent Magnet Motors	Current	0.15
Enthalpy/Energy Recovery Heat Exchangers for Ventilation	Current	0.55
Heat Pumps for Cold Climates (Zero-Degree Heat Pump)	Advanced	0.1
Improved Duct Sealing	Current/New	0.23
Liquid Desiccant Air Conditioners	Advanced	0.2 / 0.06
Microenvironments/ Occupancy-Based Control	Current	0.07
Microchannel Heat Exchanger	New	0.11
Novel Cool Storage	Current	0.2 / 0.03
Radiant Ceiling Cooling/Chilled Beam	Current	0.6
Smaller Centrifugal Compressors	Advanced	0.15
System/Component Diagnostics	New	0.45
Variable Refrigerant Volume/Flow	Current	0.3

Table 2. Potential energy savings

sumption Characteristics of Commercial Building HVAC Systems: Volume III Energy Savings Potential. This report analyzed 55 of the most promising technologies for energy savings potential. Of these 55, the 15 most attractive were analyzed further (see table 2).

The figure shows the simple payback of each of the 15 most promising technologies. Two of these, radiant cooling and dedicated outdoor air systems, have instantaneous payback, requiring no additional capital outlays.

Cogeneration is conspicuously absent from the DOE's Top 15 and so are waste-heat utilization opportunities, building envelope technologies that reduce building heating/ cooling loads, renewable energy, and natural cooling/ventilation technologies. These technologies are often present in the very-high performing buildings, but according to the DOE including these in the study would have compromised its intended focus on HVAC energy savings opportunities.

ASHRAE's recently published *GreenGuide* addresses some of the technologies absent from the DOE study. It is a reference that explores the basics of sustainable HVAC&R design, the design process, and post-design process. It presents 29 practical, efficiency opportunities called Greentips as a starting point when designing an efficient building.

Unfortunately, the high-performance innovation of the United States lags international efforts. Mechanical systems innovators internationally are splitting the HVAC system into separate systems, with many large corporate owners and developers trying different approaches to accomplishing

> LEED compliance is no guarantee of an energy-efficient building.

this split in their buildings. These systems increase the quality of the space, improve IAQ, and improve thermal control.

In the U.S., the trend in high-performance building is also away from the large fan systems and variable air volume (VAV) systems in favor of smaller, split fan systems. The split fan system approach (also called dedicated or de-coupled outside air system) separates the handling of the heating and cooling services (no outdoor air) and IAQ services. Other systems gaining favor include underfloor air distribution and low-temperature primary air systems.

Preliminary analysis from the Oak Ridge National Laboratory indicates that the energy intensity of a building will be 20-30 thousand British thermal units per square foot higher (on a source energy basis) if a building has a VAV system. This number could change as the analysis is verified and refined. Also the likelihood of VAV systems actually providing required IAQ is not very good, due to very nature of the location of mixing chambers and the varied conditions under which the systems operate. The problems associated with traditional VAV systems are poor air distribution, poor humidity control, poor acoustical qualities, and poor use of plenum and mechanical shaft space.

These shortcomings—and others—can be obviated in high-performance, energy-efficient buildings by:

- Orienting the building on the site to harvest free energy sources, including renewable energy and natural cooling/ventilation.
- Improving the building envelope to reduce mechanical conditioning requirements and right-size the equipment.
- Reducing internal loads by daylighting integration and reducing miscellaneous loads through use of Energy Star-labeled equipment.

HVAC, thermal comfort, and IAQ should be emphasized by taking the following steps:

- Separate treatment of ventilation and internal loads and use enthalpy or heat recovery in the ventilation system. Minimize fan power requirements by using smaller, local systems, preferably in a single zone.
- Employ free cooling and heating options such as economizers, evaporative cooling, and heat recovery.
- Improve zoning and delivery of space conditioning.
- Reduce system losses.
- Maximize equipment efficiency by selecting equipment with improved part-load performance.
- Provide occupancy-based control of heating and cooling systems.
- Incorporate application of improved control technologies.

The Cost of Energy Efficiency

The main stumbling blocks to informed design are often budget and first cost. Fortunately, owners pursuing LEED are generally better educated with regard to higher-quality first-purchase decisions, life-cycling costing, and return-on-investment. Furthermore higher-performing designs may not cost any additional overall project dollars, with data generally indicating added cost of 0-15% more than typical systems. Construction accounts for a mere 15% of the life cycle costs of a building, so a 15% increase in first cost for energy-efficiency equates to only about 2% of total life cycle cost.

High-efficiency lighting systems generally cost more, but their high ROI makes them an attractive investment. Mechanical systems may cost more, especially with more elaborate controls and higher equipment efficiencies. Savvy owners have indicated that the reduced energy, operational, and churn costs far outweigh this premium. High performing mechanical systems also may cost less compared to a typical building with typical building systems, primarily when the building has been tuned in such a way to reduce the loads.

LEED provides the framework and enthusiasm to raise the bar in energy and environmental efficiency. Several stumbling blocks must be overcome before the benefits of integrated, whole-building design will be realized on a widespread basis. Stimulating demand for increased energy efficiency and indoor environmental quality in commercial construction requires a commitment from all sectors, a well-documented economic case, financial incentives, investments in research and development, and code revisions. Enhancements to existing design tools and modeling software and development of new tools that support the collaborative design effort will also be needed. *eun*

About the author: **Peter C. D'Antonio** is the founding president of PCD Engineering Services, Inc. headquartered in Longmont, CO. PCD Engineering Services, Inc. is a leading provider of mechanical/ electrical sustainable design, energy management, and integrated building system solutions. D'Antonio has been an innovator in energy and environmentally efficient design and construction since 1989. He can be reached at peter@pcdengineering.com or (303) 678-1108