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In recent years, the lodging industry worldwide has witnessed a trend toward environmentally responsive facilities, called ecohotels. These structures carry the environmental theme throughout, from the positioning of buildings to maximize the natural assets of a site to the careful selection of construction materials. The hallmark of eco-hotels is the integration of all components, which allows for a sustainable design at little or no additional cost compared with conventional approaches. This is not easy, however. According to one major rating agency, applications for certification have doubled each of the past several years, with 90 percent of the applicants failing to meet the rigorous ecological standards.

In that regard, engineering solutions are critical, with the design engineer expected to contribute more than he is in the conventional design process. Key to that contribution is a proactive stance regarding a number of environmental design parameters. **Table 1** identifies basic environmental considerations and ways to address them. Much of what is involved is similar to that for a conventional project; however, far more investigation and design is required.

In addition to higher levels of cooperation between all members of the design team, engineering for ecohotels requires additional considerations regarding the traditional mechanical systems.

Environmentally responsive hotels can be luxurious. *Photograph courtesy of Lehr Associates.*

Table 1 : Environmental considerations for an eco-hotel requiring integrated solutions and engineering input.

Design Element	Consideration	Engineering Actions
Building siting	Solar loads	Minimize building load. Maximize solar-collector potential.
	Shading	Maximize summer shading. Avoid reflected radiation.
	Wind effects	Minimize wind velocity against building.
	Access to natural energy sources	Site near geothermal, water, wind, and utility resources.
Building envelope	Thermal performance	Computer model for peak efficiency and performance.
	Fenestration	Model for optimum

		performance and life-cycle selection.
	Minimize infiltration	Control all air into and out of the building.
Building-interior environment	Acoustical environment	Use quiet equipment. Avoid high on/off differential-noise levels.
	Visual environment	Avoid eye strain and discomfort.
	Thermal-comfort environment	Allow individual temperature control to the maximum extent. Control humidity, air quality, and air movement.
Recyclable materials	Use components with much recycled content	Seek out products that use recycled materials.
	Use components that are recyclable	Find suppliers of products with recyclable components.
	Avoid materials that deplete natural resources	Favor products made with renewable resources.
Global environmental consideration	Global warming and ozone depletion	Use zero-ozone-depletion refrigerants. Use zero-global-warming-potential materials.
	Renewable energy sources	Favor renewable energy sources (wind, solar, hydro, and tidal power).
	Transport impact	Use local products to reduce transport energy impact.
Building operations	Environmental awareness	Train all staff to be aware of the environment and what impacts it.
	Education	Train all staff in the proper operation of equipment and the environmentally friendly maintenance of it.
	Monitoring	Continually monitor the installation for

conformance to design intent.

Plumbing systems

Water conservation is a critical part of any environmentally responsive hotel, with every effort taken to reduce total water utilization in each of the three primary water-using areas: the hotel proper, which includes the guestrooms and public and “back-ofthe- house” areas; the food-service facilities; and the laundry installation. To that end, low-flow fixtures and fittings are used throughout the building.Internal water-conservation programs, through which guests can elect not to have bed linen and bath towels changed every day, are standard in environmentally responsive hotels. In addition to conserving water, these programs reduce the use of cleaning chemicals, as well as the fuel needed to produce hot-water for laundering.

Because these programs are voluntary, participation varies significantly by property, depending on the hotel’s type, its location, and, most importantly, the effectiveness of its efforts to convey the importance of conservation and the manner of participation. On the low end, 5-percent participation has been reported at some properties, with participation in more successful programs exceeding 40 percent. Water-conservation efforts are enhanced by minimizing the amount of wastage associated with hot-water distribution. Key to this is the maintenance of hot-waterpipe temperature throughout the distribution system. While extending hot-water circulating piping to reduce the lengths of uncirculated dead-end sections is helpful, the most popular approach is using self-regulating electric heat cable. Self-regulating electric tracer cabling can maintain temperature to almost the very end of every branch.

The use of grey water is another significant water saver. For hotels, depending on the details of the greywater installation, total fresh-water consumption can be cut almost in half, with associated reductions in both water and sewer charges. Grey water uses either mechanicaltreatment units or, if the building is in an appropriate location, natural-treatment facilities, such as “constructed wetlands” or “living-machine” technology. The earliest successful hotel grey-water systems have been in continuous operation for almost 35 years, and their value has been proven economically and practically. In addition to its use for the flushing of water closets and urinals, grey water also is widely utilized for irrigation and washdown. Another primary use of grey water is cooling-tower makeup.

Grey water is directly usable in cooling towers, provided that attention is paid to the proper use and rotation of biocides to control algal slime and growths.

Where a hotel requires extensive irrigation, water conservation also can be achieved by collecting and storing roof storm water.

Water quality is another environmental consideration. Recent history has indicated that the overall quality and safety of the nation's water supplies is increasingly being compromised and cannot be assured. That means that designs must both provide levels of treatment beyond the minimal levels currently embraced and fully assess potential threats. Water quality also has an impact on the proper operation of water-conserving fittings such as shower heads, in which scaling from hard water can reduce flow.

For both safety and energy conservation, distribution temperatures should be kept low (110 F). Unfortunately, this temperature is insufficient to assure the elimination of the Legionella organism. Resolving this conflict most often involves the use of a storage tank with internal temperatures great enough to prevent Legionella growth and outlet tempering to minimize distribution temperatures. Water conservation in laundries concerns the use of equipment, the installation of devices that permit partial reuse of laundry-waste discharge (for example, the final rinse being used for the subsequent initial wash cycle), and consideration of the use of low-temperature washing, which both uses environmentally friendly washing chemicals and significantly reduces heating energy. Kitchen equipment also can be used in water-conservation efforts; however, much of the conservation gain in work areas of kitchens comes through the education of workers as to the benefits of conservation and their role in attaining reductions. Gas conservation also is attainable through the education of staff.

The front entrance of Orchid Hotel, Bombay. *Photograph courtesy of Orchid Hotel.*

HVAC Systems

Proper HVAC design is crucial to achieving an environmentally responsive sustainable design. Not only do HVAC systems offer great potential for energy conservation, they help ensure that the indoor environment is healthy and safe.The surest way to achieve good indoor air quality is to control the materials used in the finished construction, which is part of the HVAC engineer's expanded proactive role, and to improve filtration in every component of the system. That includes the filtration of outside air for the guestroom primary air system, all of the public- and back-of-thehouse- area units, and, especially, the guestroom units. Source control of contaminants is vital and a joint-team effort. The use of low-volatile-organic-compound materials, the avoidance of formaldehydes, and the reduction of the off-gassing of trace contaminants from interior-finish materials immediately improves indoor air quality, lessening the burden on the mechanical systems.

Filtration : Traditionally, filtration in hotels has been minimal, especially in guestrooms, where filters generally are coarse throwaway units. These have proven to be less than satisfactory in arresting many of the smaller particles found in the guestroom return-air stream. Ineffective filters cause clogging of coils and drain pans and contribute to the development of biological growths. Improving filtration with mini-pleat filters in guestrooms and high-efficiency filters in other airhandling units begins the process of improved air quality; however, this can be effective only if the filters are inspected, maintained, and changed on a regular basis. Here again, the human component proves critical to maintaining the environmentally responsive hotel and reinforces the need to train and involve the entire staff.

Air temperature : In traditional hotel HVAC design, the primary emphasis is on air quality and temperature control. Eco-hotels take a far wider view of the important requirements: A healthful environment is one in which humidity is carefully controlled, attention is paid to air motion and velocities, and the entire conditioned environment is delivered with low acoustical impact.While considered in conventional hotel design, these elements, especially acoustics, take on added importance in environmentally responsive designs. Many low-end hotel rooms utilize noisy packaged or unitary air conditioning units that can have a significant negative impact on a healthful environment. To that end, control packages that keep the unit at low speed for as long as possible and variable-speed fancoil units are popular.

Humidity : Humidity. Humidity control is especially important because it not only is critical to guest comfort, it prevents mold problems that destroy fabrics, carpets, and wall

coverings in many tropical environments. Humidity is especially difficult to control during part-load periods, when cooling coils cycle off and lose their ability to remove moisture from the air flow. The guestroom-ventilation scheme must account for moisture control at all times, especially when cooling coils are off and ventilation air continues to be introduced. The most common solution involves introducing treated and dehumidified primary air continuously to each room. Desiccant equipment sometimes is used in very humid areas.

Controls : Controls are an important component of environmentally responsive hotels. Not only are they at the heart of maintaining comfort, they are fundamental to energy-conservation efforts. Conditioning a space to a desired comfort level is important when the space is occupied. When it is unoccupied, allowing the comfort conditions to drift produces tangible energy savings. A number of manufacturers offer control packages that confirm occupancy and permit conservation.

Energy : Energy conservation is not limited to controls. Operators of environmentally responsive hotels seek every opportunity to develop systems that take advantage of renewable energy resources. One such system, which will become more popular in the near future, is the geothermal water-source heat pump. Water heat pumps have been available for some time and have become a standard component in many guestroom designs. The current trend is toward the development of low-temperature geothermal units, especially ones that use environmentally friendly refrigerants. Vertical high-rise units using R-410a are in development and expected to be in operation later. Units using R-407c will follow soon after.

Passive energy sources also are popular and very effective. For example, routing outside air through underground tunnels (or piping) tempers the air, cooling it during the summer and heating it during the winter. Although altering the temperature of air by a few degrees may not seem significant, the energyconservation potential over the life of a hotel is enormous. In a similar manner, there are numerous ways to use the building as a “free” solar collector. One popular technique is mounting a dark curtain wall skin several inches from a solid facade on a sunny wall and simply drawing outside air behind the skin. This can effectively add several degrees of heating during the winter.

Solar energy is another renewable energy that grows more viable daily, as collector efficiencies improve and costs decrease. In environmentally responsive buildings, the use of batteries to store photovoltaic energy is problematic, as it introduces environmentally

unfriendly lead and acid to the site. There is a need to develop real-time uses of solar energy, avoiding the cost and complexity of storage altogether.

Table 2 examines several strategies for improving the environmental quality of hotels.

Table 2 : Strategies for an improved hotel environment.

Environmental Objective	Strategy	Comment
Improved air quality	Ducted primary air in lieu of infiltration or operable windows	Add thermal/latent recovery units between toilet exhaust and outside air.
	Improved unit air filtration	Use mini-pleats in lieu of cleanable/throwaway filters.
	Control source content	Avoid use of materials with VOCs and contaminants.
Energy conservation	Improved controls	Allow setbacks and drift in unoccupied rooms.
	Geothermal systems	Consider when resource is available.
	Energy recovery	Use on all air systems. Capture waste heat from laundries and process equipment.
	Passive energy systems	Naturally temper outside air.
	Natural energy sources	Investigate wind, solar, and water power.
Water conservation	Low-water-flow fixtures and fittings	Provide automatic operation when possible.
	Recycled grey water for non-potable uses	Use environmentally responsive treatment processes.
	Use HWAT in lieu of hot-water circulation	Minimize lengths of uncirculated hot-water pipe.
	Store/reuse rain water	Do if storage space is available.
Environmental conditions	Individual thermal control	Provide as many zones as possible.
	Humidity control	Provide close tolerance

	summer and winter control.
Acoustical environment	Select quiet equipment. Control duct / air / pipe /water noise. Use controls to permit “low-speed” operation.
Air motion	Avoid drafts and “dead” spots.

Niche Hotels

Many environmentally responsive hotels are niche properties, hotels at unique environmental sites that carry that environmental theme through every detail of the architecture and engineering.

For example, the Cuisinart Resort on the semi-desert Caribbean island of Anguilla features a hydroponic farm, as well as restaurants and foodpreparation facilities dedicated to healthful dining as a component of healthful living.The development of niche properties is continuing at an everincreasing pace, with new special interests being targeted. In his bestselling book “Boom, Bust, and Echo,” Dr. David K. Foot examines the impact of demographic shifts on the hospitality industry, predicting a boom in tourism. In one section, he attributes the mercurial rise in the popularity of bird watching to the aging of the population and details the vast sums expended in pursuing this hobby. One should hardly be surprised to see a chain of hotels for bird watchers in the future and to find many unique design features to support both the activity and the environmental consciousness of its devotees.

There is no question that the number of niche hotels will continue to grow rapidly.

Mainstream Hotels

Eco-hotels are not just small ecotourism facilities in remote locations — they are becoming more mainstream, as large international hotel chains are showing that they are very comfortable with the concept. Presently, all of Hilton International’s properties in Japan are in the process of receiving full certification.

Hotels such as The Benjamin in New York City and The Orchid in Bombay are other examples of large, luxurious city hotels that have become green. These properties feature intensive staff training, including weekly update sessions; extensive signage in staff areas

reinforcing the need for conservation; the mandatory use of water-conserving plumbing fittings and energy-conserving lighting; the extensive use of recycled materials; and a comprehensive solid-waste separating and recycling program.

As the move to full appreciation of environmentally responsive design accelerates, the engineering community will become as familiar with the basic tenets of sustainable design as it is with local building codes. That familiarity will greatly improve the environment and the world.

Eco-Hotel Rating and Certifying Several groups are rating environmentally responsive sustainable-design hotels and awarding them certification on the basis of objective criteria. Those criteria are under constant review, with the aim of making them more stringent in an effort to raise the performance bar.

Eco-rating and certifying has a number of benefits. First, it sets criteria that become the design brief and marching orders for the designer. Second, attaining certification involves activities on a number of fronts, including staff education, recycling, the use of recycled/recyclable products, and energy and water conservation. Working toward certification shows in the clearest and strongest way the interrelation of many components of an environmentally responsive design and the critical balances and compromises that need to be struck to achieve success.

Attaining certification demonstrates that environmentally conscious design and operation, which often are claimed by hotel operators with little regard for fact, has indeed been achieved. More than anything else, that explains the recent explosion in interest in the various certification programs.

Table 3 lists several eco-rating programs geared toward the hospitality industry. Of these, ECOTEL Certification has the most comprehensive and demanding engineering requirements.

Table 3 : Eco-rating programs for the hotel industry.

Program	Administered By	Contact
ECOTEL Certification	HVS International	Christopher Balfe, 516-248-8828, Ext. 238; www.hvsinternational.com/ecocert.htm.
Green Globe	Green Globe Americas	Kelly Robinson, 787-725-9139; www.greenglobe21.com.
Green Suites International Affiliate Program	Green Suites International	Dan Bornholdt, 909-920-1277; dbornholdt@aol.com.

Green Leaf Eco-Rating Program for Lodging Facilities	Hotel Assoc. of Canada and TerraChoice Environmental Services	613-247-1900; www.terrachoice.ca.
Green Hotels Assoc.	Green Hotels Assoc.	Patricia Griffin, 713-789-8889; www.greenhotels.com.
Green Hotels in the Green Mountain State	Vermont Dept. of Tourism	Tina LaPerle, 802-241-3471; www.vtgreenhotels.org.

Additional Information

Long checklists of environmental actions can be both helpful and dangerous. Their benefit lies in providing suggestions that can trigger a brilliant idea and lead to a truly innovative solution. Used blindly, however, they may appear trite and inappropriate to the sophisticated owner or operator, thus undermining the perceived value of the environmentally sustainable design effort.

The sidebar on this page contains information sources that can be of value.

For More Information
The following are sources of information on environmentally responsive sustainable design:

- Air Infiltration and Ventilation Center
  www.aivc.org
- American Hotel & Motel Assoc.
  www.ahma.com
- American Indoor Air Quality Council
  www.iaqcouncil.org
- American Solar Energy Society
  www.ases.org
- American Wind Energy Assoc.
  www.awea.org
- Center for Resourceful Building Technology
  www.crbt.org
- CMHC-SCHL Healthy Housing
  www.cmhc-schl.gc.ca/rd-dr/en/hh-lms/hh_frame.html
- Dept. of Energy
  www.doe.gov

- Environmental Building News
  www.buildinggreen.com
- Environmental Defense Fund
  www.edf.org
- Environmental Health Center
  www.nsc.org/ehc.htm
- Environmental Health Clearing house
  infoventures.com
- EPA—Indoor Air Quality Page
  www.epa.gov/iaq
- Florida Solar Energy Center
  www.fsec.ucf.edu
- Geothermal Heat Pumps
  doegeothermal.inel.gov/heatpumps.html
- Green Building Information Council
  greenbuilding.ca
- Guiding Principles of Sustainable Design
  www.nps.gov/dsc/dsgncnstr/gpsd
- HPAC Engineering
  www.hpac.com
- MCS Housing Resources
  www.thegarden.net/mcs
- MCS Survivors
  www.mcsurvivors.com
- Minnesota Sustainable Design Guide
  www.sustainabledesignguide.umn.edu
- Rocky Mountain Institute
  www.rmi.org
- Sick Building Discussion Group
  www.egroups.com/subscribe.cgi/sickbuildings
- Solstice
  solstice.crest.org
- U.S. Green Building Council
  www.usgbc.org

The Environmental Solution

Demonstrating the value of an environmentally responsive sustainable-design installation is easy for some classes of occupancy. For example, in an office building, the value of a 1 percent increase in office productivity (about 4.8 min per day) can be valued at some $4 per sq ft per year, an amount that often exceeds the total cost of all heating/cooling/power

for the same building. Further, several studies, both completed and under way, suggest that productivity increases in green-building spaces are significantly greater than 1 percent.

Several organizations are active in evaluating the relationship between environmental quality and productivity, with the work done by Steelcase Corp. in association with Carnegie-Mellon University cited most often.

For office environments, increased productivity easily justifies the growing interest in environmentally responsive design and any increased costs that may be incurred to achieve it. That type of cost-benefit analysis is more difficult to apply to the lodging industry. Certainly, getting more production out of staff is worthwhile, but the primary goal—increased value to guests—though real, is hard to quantify. That notwithstanding, the business guest who consistently gets a more restful night's sleep because of little noise, good air quality, and good thermal/ humidity control; who is productive in the evening because the lighting has not tired him further by causing eye strain; and who appreciates that his stay is minimally invasive to the environment is more likely to come back, and that is the essence of a successful hotel. Hotels that have embraced the environmental solution report exactly that kind of repeat business.