Published on *Building Design + Construction* (http://www.bdcnetwork.com)

Zero Energy Buildings: When Do They Pay Off in a Hot and Humid Climate?

Issue Relation:
February 2011 [1]

Deck:

Major Findings of the 'Hot and Humid' ZEB Study

1. Designing buildings for zero energy use in hot and humid climates like that of the Gulf Coast of Texas can be a good investment in the context of a 25-year lifetime of the building.

2. Investing in energy-efficiency measures, even extreme energy-efficiency measures required to make a building "net-zero energy ready," can become profitable within 9-13 years for a broad selection of building types, making this a potentially attractive investment for a wide range of building owners and developers.

3. The net present value (NPV) for larger buildings at 25 years was significantly higher than for smaller ones. Large buildings apparently benefit from economies of scale in the purchase of solar panels and less commonly specified HVAC system components.

4. The greater upfront investment required for larger buildings also tends to result in much higher rates of return than for smaller buildings.

Abstract:

There's lots of talk about zero energy as the next big milestone in green building. Realistically, how close are we to this ambitious goal? At this point, the strategies required to get to zero energy are relatively expensive. Only a few buildings, most of them 6,000 sf or less, mostly located in California and similar moderate climates, have hit the mark. What about larger buildings, commercial buildings, more problematic climates? Given the constraints of current technology and the comfort demands of building users, is zero energy a worthwhile investment for buildings in, for example, a warm, humid climate?

Byline:
By Julie Hendricks, AIA, LEED AP, and Kapil Upadhyaya, LEED AP

Publication Date:
Thu, 2011-02-10 10:20

Article Image:

Base Case building for study 08.jpg [2]

CAPTION: Houston office tower used as the baseline case for the mid-rise office tower in the energy simulation study. PHOTO: Courtesy Kirksey

Slideshow Image:

ZEB.png [3]

Slideshow Description:

There's lots of talk about zero energy as the next big milestone in green building. Realistically, how close are we to this ambitious goal?

There's lots of talk about zero energy as the next big milestone in green building. Realistically, how close are we to this ambitious goal? At this point, the strategies required to get to zero energy are relatively expensive. Only a few buildings, most of them 6,000 sf or less, mostly located in California and similar moderate climates, have hit the mark. What about larger buildings, commercial buildings, more problematic climates? Given the constraints of current technology and the comfort demands of building users, is zero energy a worthwhile investment for buildings in, for example, a warm, humid climate?

To answer these questions, we undertook an energy simulation study of actual buildings designed to achieve green certification in the Texas Gulf Coast. The study included a range of building types and sizes. For each building, we determined the cost and payback of strategies required to bring the buildings to zero energy use. We then calculated their net present value (NPV) to judge the value of the financial investment required to reach the target. NPV is a way of comparing the value of today's dollar with the value of money in the future: a dollar that can be invested today is worth more (in theoretical terms) because inflation reduces the buying power of future dollars.

The study took in a variety of building types, based on real projects in the Gulf Coast region of Texas. See "Six Buildings" PDF at the bottom of this page.

Our NPV analysis shows how much an investment in zero energy buildings is worth in today's dollars over 10 years and 25 years. We assumed 10 years to be a reasonable period over which certain types of building owners and investors—including school districts, colleges and universities, owner-occupied office buildings, and government buildings—would want to recover a profit. We assumed a 25-year life for the buildings, even though we recognize that individual buildings can vary greatly in their actual longevity. In general, a positive NPV is a profitable investment; a negative NPV is a losing investment.

The six buildings studied were all real projects: a mid-rise spec office building (LEED Silver), a low-rise owner-occupied office building and an elementary school (both completed and awaiting a LEED Silver rating), a university residence hall (under construction, seeking LEED Silver), a park pavilion (designed for the Living Building Challenge), and a warehouse (LEED Gold). The latter had 50% warehouse space, 50% office space; in our model, we modified the space allocation to 90% warehouse, 10% office.

To achieve zero energy, we first reduced the building energy use to the lowest possible level. We gave each building an "extreme" energy-efficiency makeover, reducing energy use another 30-60% over their actual LEED or Living Building Challenge performance. To this we added grid-tied on-site solar energy to generate any additional energy needed to get to zero.

The study showed that the payback period for applying extreme energy efficiency measures ranged from just under nine years (for the park pavilion) to just under 13 years (for the warehouse). Payback for zero energy was considerably longer, from under 15 years for the mid-rise office building to more than 29 years for the pavilion. See "Extreme Energy" PDF at the bottom of this page.

We studied only commercially available strategies and systems that have been used occasionally if not commonly in our climate, and that have been shown to be effective here. Some of the approaches we looked at may seem controversial: there's no doubt that achieving zero energy will require some openness to emerging technologies

All six building types (with the exception of the pavilion) show a positive NPV at the 25-year mark. (The park pavilion was designed to meet the Living Building Challenge; in this case additional ZEB enhancements did not improve the building's net present value). See "Payback Period" PDF at the bottom of this page.

MID-RISE SPEC OFFICE BUILDING: PASSIVE STRATEGIES NEED NOT APPLY

The 10-story LEED building used as a basis for this study was a typical speculative office building with a 25,000-sf rectangular floor plate and a central core. The first thing to note about this building is that, although it achieved LEED Silver, its configuration is not well suited to passive energy-saving strategies, including effective daylighting and natural ventilation. The floor plate has a depth of 43 feet from the windows to the core, when a depth of 20 feet (or at most 25 feet) would be more appropriate for one-sided daylighting. The central core and 110-foot depth on the short side of the building eliminate the possibility of effective cross-ventilation regardless of the season; therefore, natural ventilation was not considered.

The payback on zero energy for this building is not as good as it would have been given a more advantageous floor plate. Unfortunately, this configuration is extremely common for office buildings in this part of the country, and is likely to be a major problem in the future as building owners look to retrofit buildings for the greatest possible energy efficiency and for passive survivability in the event of natural disasters that knock out the power grid.

One of the more effective energy-saving techniques for this building, given the limitations of function and configuration, was an active chilled beam HVAC system, including a single dedicated outdoor air-handling unit with energy recovery. The dedicated outdoor air-handling unit conditions outside air separately from return air, effectively separating temperature and humidity control. Conditioned outdoor air is delivered via ductwork to the chilled beam, which induces room air across the chilled coils; the space undergoes convective cooling. Inside the occupied space, warm air rises and is cooled by the chilled beam; once it's cooled, the air falls back to the floor, where the cycle starts over.

Chilled beams save energy by minimizing fan use; it is about 10 times more efficient to pump water than to blow air. To avoid condensation problems with this system, it is absolutely critical to control humidity inside the building: therefore, the building must be as airtight as possible. As a result, chilled beams are incompatible with natural ventilation in humid climates.

Another strategy with a decent payback on this mid-rise office building is triple-glazed windows. Traditionally, triple-glazed windows are most effective in cold climates where you have a wide temperature differential between outside air and inside air. In a warm, humid climate, the temperature differential is relatively small, so the energy savings from specifying triple-pane glazing over double-pane usually don't justify the investment.

However, office buildings like the one under study are an exception. Because of its high window-to-wall area ratio (43%)—a popular feature with many architects, developers, and real estate brokers here in the Gulf region of Texas—it pays in this case to invest in the most highly insulating windows.

Another effective strategy for this building is the use of a geothermal, or ground source, heat pump. This is a central heating and cooling system that pumps heat to or from the ground, using the earth as a heat sink in the summer or a heat source in the winter. This design takes advantage of the moderate temperatures in the ground (70°F at five feet below the surface in Houston) to boost efficiency and reduce operational costs. In this building, the use of the geothermal system resulted in near-zero use of heating energy in the winter months. Geothermal systems are often classified with renewable energy sources and, like them, are a relatively expensive technology with long paybacks when considered in isolation from other strategies.

LOW-RISE OWNER-OCCUPIED OFFICE BUILDING: WHERE NATURAL VENTILATION PAYS OFF

This study was based on a two-story building with an 80X205-foot rectangular floor plate, oriented with the long sides facing north and south.

Windows on the north and south facades, along with shading devices, allow the spaces to be substantially daylit. Using triple glazing for these windows yielded a 4.7% overall energy savings for the buildings. Daylight accessibility is increased further by open plan workstations, which take up much of the floor area. Adding daylight harvesting controls in this environment yielded a respectable 7.0% savings over the original design of the building.

It's an understatement to say that using natural ventilation is controversial in a warm, humid climate. Most engineers in these parts will tell you to forget about it, that building occupants in hot climates demand, and have even become "addicted" to, static thermal conditions. Of course, 50 years ago, natural ventilation was common here. Buildings were designed with high ceilings and tall windows to generate higher air speeds. People dressed appropriately for the season, and they adapted to somewhat higher temperatures in the workplace. All of these strategies are still possible for us, even with the availability of air-conditioning.

For the applicable buildings in this study, we looked at seasonal natural ventilation. We assumed that windows would be open whenever outside conditions were in the comfort range, which we defined as a value between the standard ASHRAE 55-2005 PMV (Predicted Mean Vote), in which 7% of hours are in the comfort zone in Houston, and the ASHRAE 55-2004 Adaptive Comfort Model (see Psychrometric Chart, page 35), in which 29% of hours are in a wider comfort range (65.2°F to 84.3°F) for buildings with natural ventilation and where it is presumed that occupants would wear clothing suitable for the season. To be on the conservative side, we chose a value slightly below the mean of the two standards and assumed that 16% of hours were in the comfort range.

Because of the narrow and relatively open floor plan of this building, cross-ventilation proved to be quite effective, saving 5.7% of overall building energy. Of course, occupants in buildings using natural ventilation would certainly need a period of adjustment to acclimatize to the new conditions. It remains to be seen whether building owners would attempt such a strategy and whether occupants or tenants would be willing to accommodate to this change.

COLLEGE RESIDENCE HALL: RIDING THE UNUSUAL OCCUPANCY SCHEDULE

The study is based on a four-story, 384-bed residence hall with two students per bedroom. Residence halls have an unusual occupancy schedule. They are most heavily occupied at night when it is relatively cool and are much less occupied in the hottest part of the day. Compared to other building types in our climate, therefore, heating load is an important consideration in residence halls. The actual residence hall under study had a relatively low equipment and lighting heat load and was dominated by its envelope load. Given these parameters, triple glazing yielded an overall energy savings of 3.1%.

The original HVAC system design for this building was a central chilled and hot water plant serving individual room fan-coil units. Adding air-to-air heat recovery by enthalpy to this design resulted in 12.6% additional overall energy savings.

University residence halls also use a lot of hot water and a commensurate amount of energy to heat that water. This makes solar hot water heating a good choice. We found significant energy savings through the use of a 6,500-gallon solar hot water system.

CONDITIONED WAREHOUSE: OPENING UP TO DAYLIGHT

We studied a conditioned warehouse of 60,000 sf, consisting of eight 7,500-sf structural modules, one of which contains office space. The warehouse itself has very low human occupancy—only 1,000 sf/person for six hours per workday—and a 16.5% window-to-wall area. The original design of this building was already quite efficient; because of this and the near-zero occupancy of the building, we were limited in our ability achieve significantly greater energy efficiency toward the goal of net-zero energy.

One good avenue for energy savings in this building type is daylighting. We added double-domed diffused skylights for 2.5% of the roof area, plus stepped daylight controls. This highly effective strategy resulted in 13.6% energy savings over the original design, with savings from both lighting energy efficiency and the resulting reduced cooling loads.

To condition the building, we looked at water-source heat pumps. These are small, high-efficiency self-contained units, each of which would serve a single module of the building.

The difference between a heat pump and a traditional air-conditioner is that, while both use the same basic refrigeration cycle, a heat pump can be used to provide either heating or cooling. Water-source heat pumps save energy by using water, which is a more efficient energy-exchange medium than air and requires less work in pumping. The water-source heat pumps used in our calculations use a cooling tower to reject heat and are supplemented with a boiler for heating. Using a ground source or surface water source would have doubled the efficiency of these units, although such a strategy would have resulted in a much higher first cost.

ELEMENTARY SCHOOL: SAVING ENERGY, IMPROVING IAQ

This study was based on a two-story, pre-K to grade 5 school, with an L-shaped floor plate.

Our cooling strategy for this building employed thermal displacement ventilation, in which cool air is supplied to spaces at a low level (where the occupants are) and rises due to natural buoyancy as it heats up. Depending on the floor plan, this strategy can be achieved either with underfloor air distribution or with low-level supply grilles located in walls or against columns.

Displacement ventilation works well in single-owner buildings such as schools, where frequent wall location changes are unlikely. Delivering ventilation air at a low level saves energy because the air can be delivered at a higher temperature, since it isn't being blown down from the ceiling. Since the air is stratified, polluted air is quickly exhausted, thus improving indoor air quality. IAQ is especially important in school buildings, because high levels of indoor pollutants are believed to have a particularly potent effect on the long-term health of children, especially young children.

A couple of notes of caution here. First, displacement ventilation requires specialized knowledge to analyze and avoid potential problems related to thermal decay, leakage, and thermal comfort. Second, DOE2 commercial energy simulation software products (including eQuest, which was used to conduct this study) do not fully support displacement ventilation system calculations.

PARK PAVILION: LOW ENERGY LOAD

This park building consists of a large conference room with kitchen and restroom facilities, shaded by a very large overhanging green roof of 3,120 sf. It is the only structure in this study to have been originally designed for zero energy. This very small building is occupied only intermittently, so its energy loads are quite modest.

The building envelope was designed to be as efficient as possible, with a large roof overhang to protect the window glazing from heating loads, structural insulated panels used for the walls, and an insulating vegetative green roof.

The space was designed to be daylit; skylights in the large conference space are designed to provide all daytime lighting.

The conference space was also designed to be naturally ventilated, with operable windows on three sides of the building to allow seasonal cross-ventilation. An efficient SEER 14 air-cooled heat pump provides a cost-effective solution for the minimal conditioning needs of the building.

Ironically, small buildings like this are the most likely to seek net-zero energy status, although it is not a particularly good investment, even over 25 years. This is likely due to smaller upfront costs as compared to larger buildings.

WHAT WE LEARNED FROM OUR STUDY

New buildings in the Gulf Coast can—and, in our estimation, should—be designed to be “zero energy ready” for owners willing to accept a nine- to 13-year payback for their investment in energy efficiency. In time, as the efficiency of solar photovoltaics increases and other renewables become more available and affordable, these buildings could be more readily converted to zero energy. Building owners who want to invest in zero energy today, however, should be prepared to wait a couple of decades for their investment to start generating a positive cash flow.

Federal, state, and local governments can have a huge impact on the pace at which net-zero energy buildings could be adopted in the marketplace, since incentives can significantly reduce the payback period for these investments. For example, if the federal commercial building tax deduction ($1.80/sf per the Energy Policy Act of 2005) for highly efficient buildings was changed into a tax credit, every building in this study would have had a payback period of less than 10 years for extreme energy-efficiency measures, such as natural ventilation and geothermal heat pumps.

Of course, ZEB implementation depends not only on the building type but also on the motivation of the owner. At one extreme, for example, real estate developers looking to flip a building in a few years likely would be unimpressed with a 10-year payback period. But clients seeking to fulfill educational, philanthropic, environmental, or social missions should be heartened to know that net-zero energy may prove to be a worthwhile investment over the lifetime of their buildings. **BD+C**

Other ZEB Technologies That Merit Consideration

Although they were not included in this study, several other technologies show promise for hot and humid climates like that of the Texas Gulf Coast region. Successful installations of these strategies in the near future could further reduce the payback for net-zero energy buildings.

DX rooftop units with evaporative condensers. Traditional evaporative cooling works only in dry climates, because the system adds moisture directly to supply air in order to cool it. In the case of direct-expansion (DX) rooftop unit with evaporative condensers, the refrigerant is cooled with an evaporative heat exchanger similar to cooling towers. The supply-air side of the DX unit remains unaffected by the moisture in the evaporative heat exchange.

DX rooftop units with evaporative condensers look very promising for hot and humid climates. In our studies, they yielded significant energy savings: 12-16% overall building energy savings compared to typical DX rooftop units. Another advantage of DX rooftop systems in hot climates and humid like the Gulf Coast is that their efficiency increases with higher temperatures.

This type of evaporative unit is relatively new, and even though several manufacturers are offering them, there are not many installations in our region. And a word of caution: A system of this type does require considerably more maintenance over a typical DX-only system in locations where the municipal water supply is salt-laden. Maintenance personnel must be trained to clean the units as required by the manufacturer.

Wind power. Small-scale wind turbines could potentially reduce payback times from 20-plus years for zero energy to a 10-year range because of much lower first cost. But because annual average wind speeds in most of the country’s hot/humid zone—Florida, Louisiana, and Texas—are less than 11 mph, payback times for wind turbines would be comparable to that of

PVs in this region.

Small-scale wind might be suitable for select pockets of the hot/humid zone where average wind speed exceeds 16 mph: for example, Brownsville, Corpus Christi, Laredo, and the Texas panhandle. Other coastal regions with average wind speeds between 11 and 16 mph, like Galveston, may have success with some of the newer wind turbines designed for low-speed startup.

But don't get caught up in the romance of wind power. Building sites suitable for small-scale wind turbines must have unobstructed access to the turbine for a minimum 250 feet in the direction of the prevailing winds. Unfortunately, mounting turbines on roofs to achieve this clearance has proven not to be an effective option. Moreover, small-scale wind turbines vary significantly in performance; building owners should ask for evidence of measured performance of such turbines in their area before making this investment.

Geothermal for small buildings. Geothermal systems can be an economical investment in small offices and school buildings in the Gulf Coast, according to reports in the media. While we did include geothermal in modeling the mid-size office building, we did not consider it for small office and school buildings for lack of accurate cost comparisons between geothermal systems and rooftop units.

—Julie Hendricks and Kapil Upadhyaya

Coming in the March issue:

ZEB White Paper

"Zero and Net-Zero Energy Buildings + Homes: The Dream, the Reality, and the Business Case" is the eighth in a series of White Papers on the Green Building Movement published by *Building Design+ Construction*. (To access the previous reports, go to: www.BDCnetwork.com/whitepapers [4].)

Zero (or net-zero) energy buildings are seen by their advocates as a key component of the effort to reduce greenhouse gas emissions and America's reliance on carbon-based fuels. But how feasible is it to expect new buildings to reach zero emissions and net-zero energy use? What are the technical, social, political, and economic challenges to reaching that goal?

And what about the millions of existing buildings and homes, which account for 40% of the nation's energy use? How much of our nation's resources should we devote to renewable energy to achieve zero or net-zero energy buildings? What are the prospects for technological breakthroughs that could make zero energy buildings more feasible?

These are among the many questions the editors of *BD+C* will address in this White Paper, which will conclude with a detailed set of recommendations—an "Action Plan"—to take the U.S. construction industry to the next stage of energy conservation.

The White Paper is sponsored by Johnson Controls, Lafarge, NAIMA, Sto Corp., the U.S. Department of Energy, and the U.S. General Services Administration.

Look for it in the March issue of *BD+C*.

Channel Most Popular:

Channel Most Popular - OFF
Channel Top Rated:
Channel Top Rated - OFF
File Attachment:

- Six Buildings.pdf [5]
- Extreme Energy.pdf [6]
- Payback Period.pdf [7]

Architects/Architect-Engineers Report Architects/Architecture Building Technology Contractor / Construction Management Energy / Environment Products & Systems Energy-Efficient Design Engineers Engineers/Engineer-Architects Report Green Building / Sustainability Products & Systems Sustainability Sustainability Design and Construction Sustainable Design and Construction

Source URL: http://www.bdcnetwork.com/article/zero-energy-buildings-when-do-they-pay-hot-and-humid-climate

Links:
[1] http://www.bdcnetwork.com/issue/2011/02/february-2011
[2] http://www.bdcnetwork.com/sites/default/files/Base Case building for study 08.jpg
[3] http://www.bdcnetwork.com/sites/default/files/slideshow-images/ZEB.png
[4] http://www.BDCnetwork.com/whitepapers
[5] http://www.bdcnetwork.com/sites/default/files/Six Buildings.pdf
[6] http://www.bdcnetwork.com/sites/default/files/Extreme Energy_0.pdf
[7] http://www.bdcnetwork.com/sites/default/files/Payback Period_0.pdf