

## **Retro-Active Master of Architecture Degree On-Line Course**

**School of Architecture  
Montana State University**

### **ARCH 589 Graduate Consultation**

Following are a series of three articles that comprise the course readings for the 1-credit on-line course ARCH 589. Each article focuses upon issues of stewardship and the architectural profession. Once you have read each of these articles you can take the on-line test to complete the requirements for this course.

- The first reading is titled: *Design for a Carbon-Free Life: The Pursuit of “Net Zero Energy*. Questions 1-10 in the on-line test refer to this reading.
- The second reading is titled: *The Zero Effect*. Questions 11-20 in the on-line test refer to this reading.
- The third reading is titled: *Getting Aggressive About Passive Design*. Questions 21-30 in the on-line test refer to this reading.

The link for the on-line test is located on the School of Architecture website under Retro-Active Masters, [www.arch.montana.edu/](http://www.arch.montana.edu/)

# Section A: Questions 1-10

## Design for a Carbon-Free Life: The Pursuit of "Net" Zero Energy

### A Growing Number of Projects Focus Attention On An Elusive Goal.

October 2007

Molly Miller



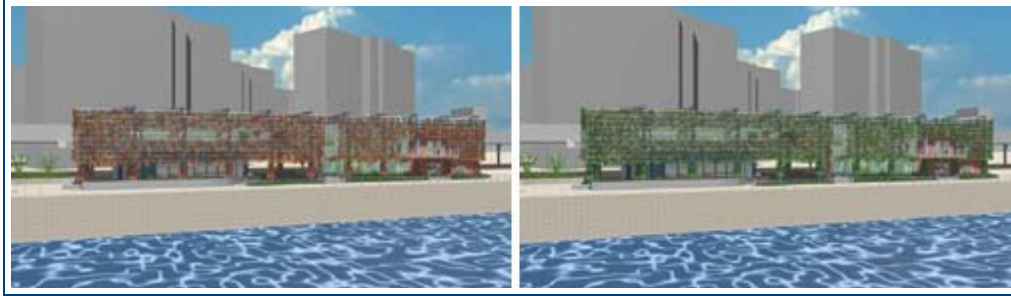
Continuing Education

**Learning Objectives** - After reading this article, you will be able to:

1. Understand the terms zero carbon and zero energy.
2. Describe strategies for designing carbon-neutral buildings.
3. Identify on-site energy generation strategies.

Buildings are responsible for nearly half of the country's greenhouse gas emissions and consume more than 70 percent of the electricity generated by U.S. power plants, according to the Energy Information Administration. These numbers have become more and more widely cited in the press and are the mantra of Santa Fe-based architect Edward Mazria, who has long spoken out on the link between buildings and global warming. In 2002, Mazria founded Architecture 2030, a non-profit organization with the mission of dramatically reducing the building sector's greenhouse gas emissions. In late 2005, the group issued the 2030 Challenge, calling for an immediate 50 percent reduction in fossil fuel use in new buildings and for climate-neutral buildings by 2030.

Mazria's challenge quickly gained legitimacy in the architecture profession when it was embraced by the American Institute of Architects (AIA) in December 2005 and subsequently by the U.S. Conference of Mayors. This past spring, the American Society of Heating, Refrigerating and Air-Conditioning Engineers, the Illuminating Engineering Society of North America, and the U.S. Green Building Council (USGBC) joined the AIA to endorse the goal and agree on a baseline and a set of metrics. Although the involvement of these professional organizations has encouraged architects, engineers, contractors, and other individuals to sign on to the 2030 goal, the effects of the initiative on the construction industry have so far been slight. But a growing number of ambitious projects suggest what could be accomplished.



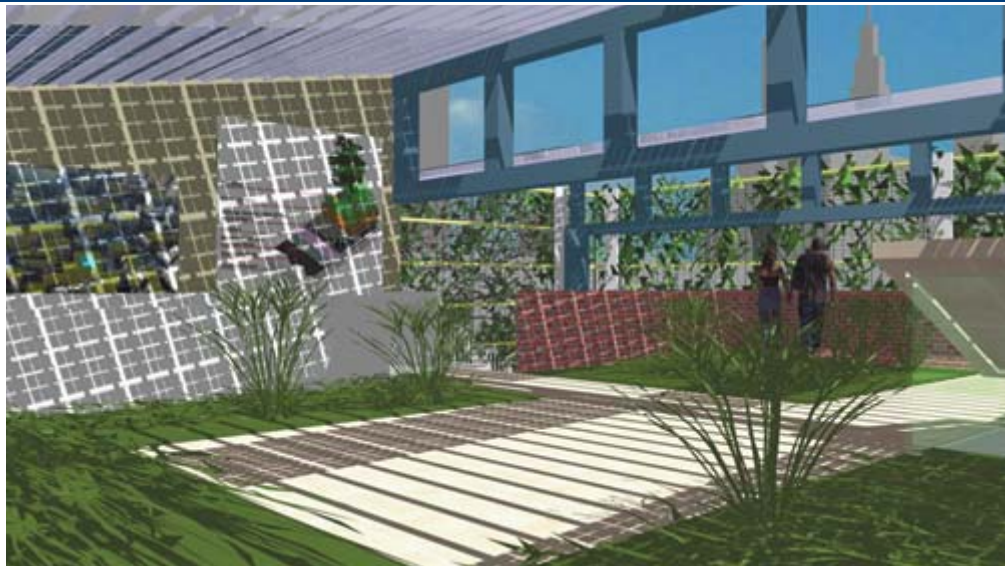
So what do designers actually mean when they refer to carbon-neutral buildings? Europeans tend to use the phrase “zero carbon,” and typically are referring to “net” zero, meaning that a building’s carbon emissions are offset by the generation of energy through non-carbon-emitting means. The phrase commonly used in the U. S. is zero-energy building (ZEB)—one that consumes no non-renewable energy, or produces more renewable energy on site on an annual basis than any non-renewable energy it consumes. Since carbon emissions are a direct result of fossil-fuel use, a zero-carbon building is necessarily a zero-fossil-fuel energy building.

Molly Miller is a Denver-based environmental journalist. She previously worked as a writer and editor at the National Renewable Energy Laboratory and is the former senior editor of Mother Earth News magazine.

While many organizations achieve carbon neutrality by purchasing carbon offsets—credits sold on an open market that finance renewable energy projects—this article focuses on projects that seek the net-zero goal solely through energy-efficient design strategies and on-site power generation. And it should be acknowledged that these featured projects don’t consider embedded carbon, or the energy required to produce and transport building materials, as part of their overall zero-energy calculation.

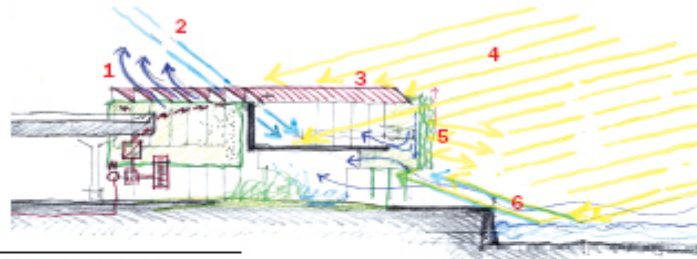
Creating buildings that meet such criteria may seem like pie in the sky, but many designers say the goals of 2030 are within reach. Bill Dunster, whose Surrey, U.K.-based architecture firm, ZEDfactory, has created several mixed-use developments in England that are about as close as anyone has come to carbon neutral. He expresses optimism about the prospects for the built environment in the U.S. and elsewhere. “Once American industrial muscle and technology engage these issues, we could move away from the fossil-fuel economy within ten years,” he predicts.





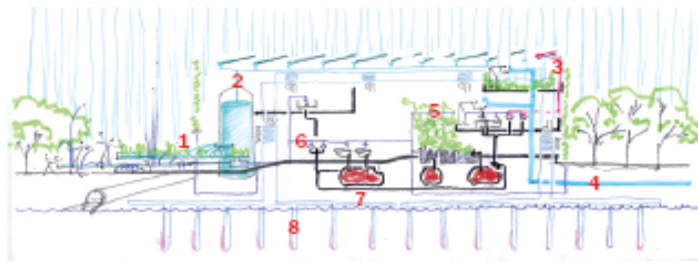
## DAYLIGHT, VENTILATION, AND POWER

- 1 Passive exhaust
- 2 Indirect daylight
- 3 Photovoltaic array
- 4 Daylight from south
- 5 Foliage screen
- 6 River breezes and reflected light



## WATER AND WASTEWATER TREATMENT SYSTEM

- 1 Wetland display
- 2 Rainwater collector
- 3 Solar thermal system
- 4 Drinking water
- 5 Living machine
- 6 Treated water supply
- 7 Composting
- 8 Geothermal wells



Wastewater treatment strategies, passive and active solar technologies, and foliage for seasonal shading, are employed by Solar 2, an environmental learning center planned for a waterfront site in New York City.

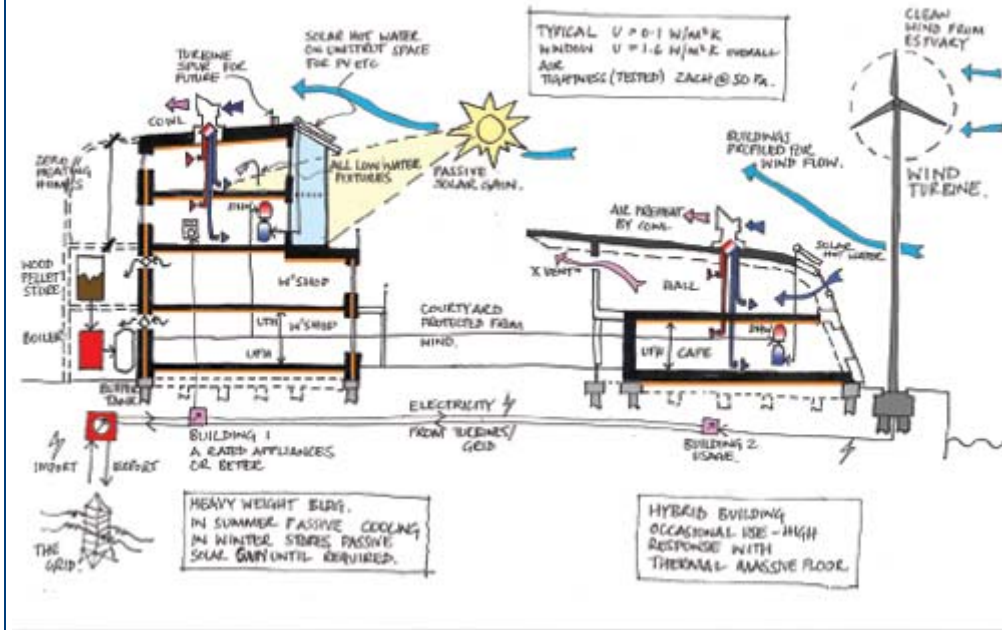
## **Breaking Ground on Zero Carbon**

One project that could become a model for future development is Solar 2, an 8,000-square-foot net-zero environmental learning center designed by the Brooklyn-based architects Kiss + Cathcart for the East River waterfront in New York City. The \$12.5 million building, slated to open in 2009, will operate under the sponsorship of the Community Environmental Center (CEC), a not-for-profit energy-efficiency contractor.

By using the planned LEED Platinum building as a teaching tool, and through classes, lectures, exhibitions, and other public events, the CEC will educate New York City residents about renewable power and energy efficiency. For example, an “eco-apartment” will demonstrate energy-saving technologies appropriate for residential construction, such as dense pack insulation, compact fluorescent lighting, high-performance windows, and Energy Star appliances.

Because it is a learning model and a showcase, the architects will incorporate a variety of materials into the building envelope for demonstration purposes. While cautioning that Solar 2 is still in the schematic design phase, project architect Clare Mifflin shared their plans. The structure will be steel with a high percentage of recycled content. One wall may be brick-clad, like a typical Manhattan apartment building, but with recycled newspaper as insulation. Another wall may be made with fiber-cement panels, with yet another in recycled aluminum. These sort of sustainable gestures are only the beginning of the project’s comprehensive strategy for achieving zero-energy status.

## Jubilee Wharf



Designed to optimize passive heating and cooling, Jubilee Wharf, in Penryn, U.K., incorporates large south-facing overhangs and a thermally efficient building envelope. Most of the electrical demand is met by four wind turbines, while space heating and domestic hot water needs are satisfied by a biomass-fueled boiler. Provisions are in place for the addition of PVs and more turbines.

Image credit: Kiss + Cathcart

## Reaching for Zero

Architects and engineers say that reaching a zero-energy goal necessarily requires a much more integrated design process than is typical for a conventional building. “When energy use is not important, you engineer to meet the codes,” says Fiona Cousins PE, a principal at Arup, Kiss + Cathcart’s mechanical consultant on Solar 2. However, the interrelationship between systems and building envelope, for example, requires close collaboration among the various design disciplines. “If you set a low-energy goal, design has to be a team effort,” she says.

The approach Arup developed for Solar 2, as well as for other low-energy projects, focuses on three main areas: load reduction, the thermal efficiency of the building envelope, and the power source. “The first thing we ask is how to reduce the loads,” Cousins says. Arup runs whole-building simulations to analyze the potential for energy savings through incorporating lower-energy lamps, reducing the number of light fixtures, and specifying energy-efficient building systems. Low wattage fixtures will be installed throughout Solar 2 and the building’s elevator will be 50 percent more efficient than conventional models. Some spaces will have carbon

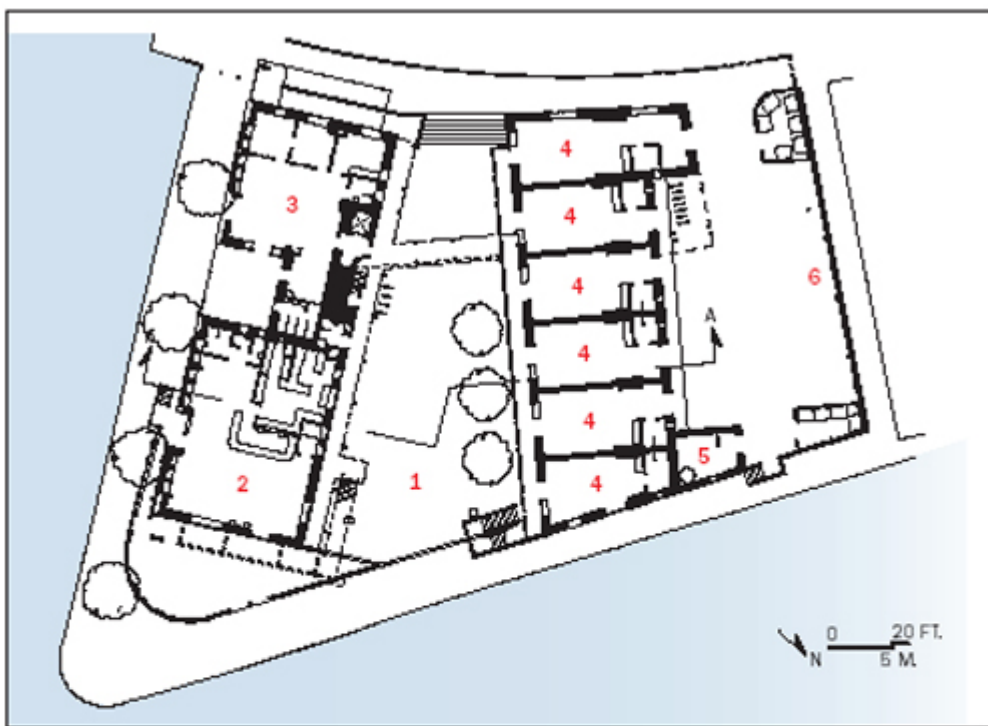
dioxide (CO<sub>2</sub>) monitors so that when there are fewer people in the building, the mechanical system will respond and decrease the intake of fresh air and thus reduce the amount of supply air that needs to be cooled or heated.

Daylighting, passive solar design, glazing, shading, and insulation are directly related to the need for electrical lighting and affect heating and cooling loads. According to current plans for Solar 2, a north-facing skylight system and copious glazing will provide enough daylight so that use of electric lights will not be required for roughly 80 percent of peak operational hours. The orientation of the skylight and a vegetated screen wall will help limit solar heat gain.

Once the demand for power is reduced as much as possible without compromising the building's performance or the health and comfort of its occupants, the focus of the design process turns to the building's energy sources. Solar 2's energy needs will be fully met by on-site supplied solar energy. However, other on-site generation strategies, such as combined heat and power (CHP), which allows capture of the energy that is normally lost in conversion and transmission from a utility, should also be considered when striving to meet a low-energy goal, says Cousins. CHP, also known as co-generation, produces both heat and electricity from a single source. Plants relying on this strategy are more efficient than separate-source plants and produce fewer emissions.







## GROUND FLOOR PLAN

- 1 Courtyard
- 2 Cafe
- 3 Community hall
- 4 Workshop
- 5 Boiler room
- 6 Parking

The mixed-use complex consists of two structures defining an outdoor court. The buildings house six residential units, workspaces, and a cafe.  
Photography: © Joe Aker/Aker-Zvonkovic

Architects and engineers say that reaching a zero-energy goal necessarily requires a much more integrated design process than is typical for a conventional building.

Combining biomass-fueled co-generation with wind or solar power can produce a very energy-efficient building that consumes little fossil energy, says Cousins. Integrating active solar systems into the building envelope early in the design stage is both more cost-effective and typically yields better performance than adding them on later, she adds. Such systems include photovoltaics (PV), solar hot-water collectors, and transpired solar collectors, which preheat ventilation air as it enters the building in winter, and help shield the envelope from heat gain during the summer.

For Solar 2, the engineers propose a PV array that can generate up to 92,716 kWh per year, or about 108 percent of the building's projected demand. Four unitary ground source heat pump units will provide heating and air conditioning. A building management system will help operations reach optimal energy efficiency, as well as control electrically actuated windows. To aid individualized zoning control, the building will be equipped with four separate air-handling units.

### **The ZED Model**

Arup cut its teeth providing engineering services toward a zero-energy goal by working with ZEDfactory's Dunster on what is often cited as one of the first zero-energy prototypes at a neighborhood scale, the Beddington Zero Energy Development (BedZED). Completed in 2002, BedZED consists of 82 residential units, a daycare center, and commercial space, on a 3.5-acre former brownfield site in south London. The buildings are configured to maximize daylighting. They incorporate both active and passive solar strategies and rely on natural ventilation—perhaps the most significant source of energy savings to make a zero-energy project possible.

A key component of the project is an on-site CHP plant fueled by urban tree waste that would otherwise be discarded in landfills. However, the plant has proved temperamental and is still not functioning properly. Replacement, underway now, should allow BedZed to operate at zero carbon by spring of 2008, says Dunster.



At NREL's Boulder, Colorado, new Science and Technology Facility, strategies such as daylighting and sun control, automated lighting systems, and underfloor air distribution reduce energy consumption by 40 percent when compared to similar new federal buildings. Patrick Corkery/Nrel (Top); Smithgroup (Bottom Left); Bill Timmerman/Nrel (Bottom Right)

Building on the BedZED model, Jubilee Wharf, the most recent low-energy development from ZEDfactory, opened in 2006. The mixed-use complex, located on a river-front site in Penryn, U.K., includes a nursery, cafe, offices, 12 rental workspaces, six residential units, and facilities for the boaters who dock along the quay. The project includes a number of basic sustainable strategies, such as large south-facing overhangs to lessen the impact of summer sun. The

envelope includes 12-inch rockwool cavity insulation and low-e glazing. Low-energy lighting and appliances reduce electrical demand.

Zedfactory relied on computational fluid dynamics to create a roofline shape that would help shelter the buildings' court and optimize natural ventilation through wind cowls. Heat exchange units recover 70 percent of the mechanical system's waste heat. Sunspaces have high- and low-level windows or vents so cool air can be drawn in and hot air exhausted. ZEDfactory plans a phased approach to reaching zero energy in this development and Dunster says the building is so far performing well.

The complex was planned to achieve an 80 percent CO<sub>2</sub> reduction as built, moving toward 100 percent over time as renewable energy components are added to the rooftop. Currently, four 6 kW wind turbines meet the majority of the buildings' electrical demand, while a 75 kW wood pellet boiler provides domestic hot water and under-floor heating, relying on evacuated hot water tubes on the roof to preheat water throughout the year. Provisions are in place for the addition of PV panels and more wind turbines to enable Jubilee Wharf to eventually become carbon neutral. This approach can make an ambitious project work within a tight budget, installing technology over time to increase generating capacity, while bringing fossil fuel use and carbon emissions down.

One U.S. project, the Adam Joseph Lewis Center at Oberlin College in Ohio recently achieved carbon-negative status using this phased approach. The 13,600-square-foot facility, designed by Charlottesville, Virginia-based William McDonough + Partners and completed in early 2001, houses the college's environmental studies department. It incorporates such features as a highly efficient building envelope, passive solar strategies, a Living Machine to process wastewater for reuse, and a 59 kW rooftop PV array. This solar system produced enough electricity to meet over half of the center's energy demand, according the National Renewable Energy Laboratory (NREL), which monitored its performance.

A goal of the project when it was first conceived in the mid-1990s was for the building to serve as a net energy exporter as available technology improved. Toward that end, a 100 kW PV array designed by Harvard, Massachusetts-based Solar Design Associates, was installed on top of an adjacent parking pavilion in 2005. The combined arrays generate all of the building's power plus a 20- to 30-percent surplus, which Oberlin sells to the municipal utility, according to David Orr, environmental studies department director.

### **Ramping Up the Scale**

Arup is now working with the city of London to plan and develop Gallions Park, a 200-unit zero-carbon housing development. The firm is also providing a range of services, including urban design, sustainable energy management, and infrastructure planning for China's Dongtan Eco-City. Situated at the mouth of the Yangtze River, just north of Shanghai, it will produce its own energy from wind and solar power, biofuel, and recycled waste. The 33-square-mile site will be a city of three villages, with a demonstration phase for up to 10,000 people slated for completion in 2010.

Efforts to create a carbon-neutral built environment at an urban or neighborhood scale are not limited to Europe and China. For example, the Los Angeles Community College District (LACCD) has adopted a plan to take all of its nine campuses, comprising 5 million square feet, off the grid by 2010. One current LACCD project is the design of a 1.2 mW PV system for its East Los Angeles College campus in Monterey Park, expected to generate enough power to meet daytime energy needs.



Planned by Arup, China's Dongtan Eco-City will be located on a 33-square-mile site at the mouth of the Yangtze River. It will meet its energy requirements with wind and solar power, biofuel, and recycled waste. A demonstration phase for up to 10,000 residents is slated for completion in 2010.

Photography: © Arup

At the level of individual buildings in the U.S., low-energy facilities are proliferating. The Department of Energy has broken ground for a 210,000-square-foot research support facility on its NREL campus in Golden, Colorado. Expected to achieve a LEED Platinum rating, the building will serve as a proving ground for the latest renewable energy and energy-efficiency technologies in areas such as daylighting, energy recovery, mechanical systems, and photovoltaics. The NREL campus already has one LEED Platinum building—the 71,000-square-foot Science and Technology Facility (S&TF) designed by the Phoenix office of SmithGroup. Energy costs for operating the S&TF are projected to be 41 percent lower than those of a comparable facility. And across the country, in New York City, the 2-million-square-foot headquarters for the Bank of America is expected to be the first LEED Platinum-certified skyscraper once construction is completed in 2008.

Lewis Center



Such features as an efficient building envelope, passive and active solar strategies, and a Living Machine contribute to sustainable measures at the Adam Joseph Lewis Center at Oberlin College.



In 2005, Oberlin installed a 100 kW PV array over a parking lot adjacent to the Lewis Center. Together with the original 59 kW array on the center's rooftop, the PVs generate enough power to satisfy all of the building's power demand and a 20 to 30 percent surplus. Photography: © Robb Williamson/nrel

Many more ambitious projects are planned throughout the country. However, due to relatively low-energy costs, zero-energy design remains on the fringe even in the sustainable design world. In February, the USGBC and Architecture 2030 hosted the 2010 Imperative, a global “teach-in” web-cast that sought to raise awareness of the need to reduce the carbon footprint of new and existing buildings. At the event, Chris Luebke, the director of Arup's global foresight and innovation initiative, spoke about the firm's work at Dongtan, summing up many of the difficulties of achieving the goals of 2030. “Green design is not more expensive,” Luebke said. “It's just more challenging.”

Originally published in the October 2007 issue of GreenSource.

# Section B: Questions 11-20

## The Zero Effect

**The future of sustainable design increasingly means eliminating carbon dioxide emissions, the most prevalent greenhouse gas. But what does that do to architecture?**

March 2007

Russell Fortmeyer



Continuing Education

**Learning Objectives** - After reading this article, you will be able to:

1. Define what contributes to carbon emissions.
2. Explain the differences between the types of net zero concepts.
3. Discuss the status of the zero-energy home market.

Today you've exhaled, on average, 2.2 pounds of carbon dioxide (CO<sub>2</sub>), the greenhouse gas poster child for our current fascination with global warming. Just by breathing, you've entered a cycle of carbon emission and sequestration, an environmental chess game with consequences that are well documented, if little understood. Americans will emit roughly 44,000 pounds of CO<sub>2</sub> per capita this year, an amount over three times the per capita average for the world. And if you're thinking of planting a forest to offset your last trip to Las Vegas, keep in mind the U.S. Department of Agriculture estimates a healthy tree can consume roughly 13 pounds of CO<sub>2</sub> in a year.

Truth be told, human breathing contributes nothing to global warming. We each eat plenty of plants, which act as carbon sinks since they absorb carbon dioxide from the atmosphere, and thus by eating we remove a great deal of carbon dioxide from the environment on a daily basis. If anything, we can breath easier knowing respiration qualifies as a carbon-neutral activity. Such calculated explanations underscore the complications of accounting for carbon emissions across the broad spectrum of our lives—the food we eat, the places we go, the energy we consume, and increasingly, the buildings and cities we create.

Bert Gregory, FAIA, thinks about these kinds of things a lot. As president and C.E.O. of Seattle-based Mithun, an architecture and planning office with a sustainable design specialty, Gregory has literally gone back to nature. In his work on Mithun's Lloyd Crossing Sustainable Urban Design Plan and Catalyst Project, a 2004 master plan for a downtrodden section of downtown Portland, Oregon, Gregory and his team began its work by conceptually recreating the native ecosystem of the site's 54 acres to determine exactly how much CO<sub>2</sub> would be absorbed and emitted annually if no human development had ever occurred. The redevelopment plan would



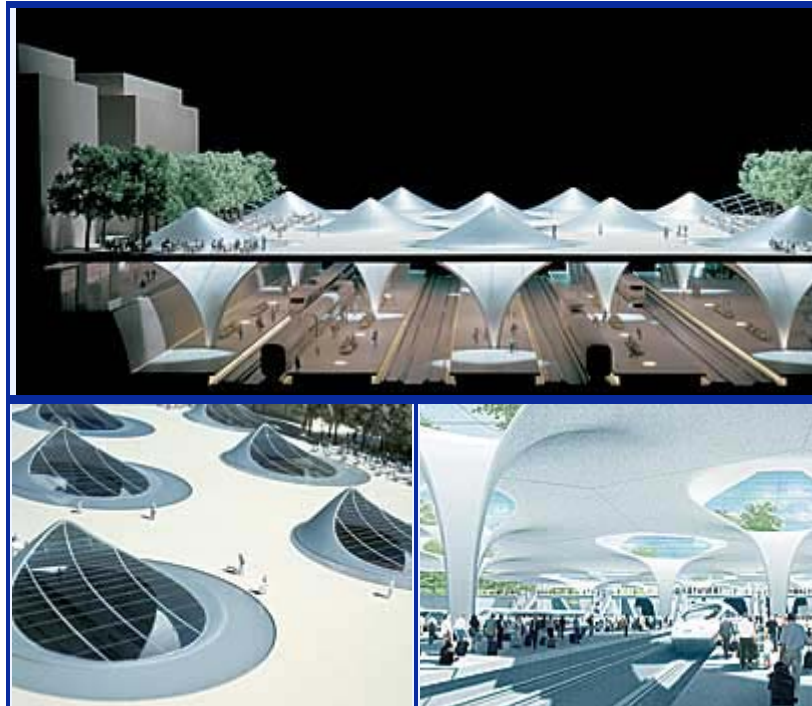
then have to match, if not beat, this carbon footprint. “We couldn’t analyze everything because the project resources weren’t there, so we focused on high-level things,” Gregory says, referring to the plan’s key issues of energy and water.



When setting up its predevelopment metrics, Mithun’s team found that the yearly baseline of the native Northwest conifer forest landscape would have produced 32 million gallons of groundwater recharge out of 64 million gallons of total precipitation. Calculating that 8 million kilowatt hours (kwh) of solar energy contributed to photosynthesis per year, the team determined that 153 million kwh remained as reflected, absorbed, or re-radiated energy. For the site’s carbon balance, the team found that annually the forest consumed 681 tons of CO<sub>2</sub>, released 495 tons of oxygen, and fixed 186 tons of carbon as biomass (such as new tree growth). The team now faced the question of how over the four decades of the plan’s premise you develop an existing infrastructure into an economically viable district that would be a forest in function, if not appearance.

The plan, which won an AIA Honor Award in 2006 and is available on the firm’s Web site ([www.mithun.com](http://www.mithun.com)), represents an attempt to define carbon-neutral design. While the term “zero carbon” gets bandied about, most designers mean “net” zero, where absorption of carbon is equal to or greater than emission, hence the neutrality argument. And when talk turns to carbon, more often than not the discussion concerns energy and its parent, fossil fuels. The Department of Energy (DOE) attributes 98 percent of America’s carbon dioxide emissions to the combustion of fossil fuels. It’s pretty straightforward to determine a building’s energy use, to trace it to its source (probably a coal or natural gas-fired power plant), and to make a rough estimate of how much CO<sub>2</sub> finds its way into the atmosphere every year when you turn on your lights or tweak your thermostat (see the EPA’s quick calculator based on kilowatt-hours usage at [www.epa.gov/cleanrgy/powerprofiler.htm](http://www.epa.gov/cleanrgy/powerprofiler.htm)). Past utility bills or electricity-demand-consumption predictions by electrical engineers, environmental consultants, and utility

companies—all of which are likely based on previously known consumption patterns—form the baseline for any discussion of a building’s energy reduction or generation. But what do we mean when we set out to make a building “zero energy”?



Main Station, Stuttgart, Germany  
Ingenhoven Architekten, of Dusseldorf, Germany, designed a zero-energy train station for the heart of Stuttgart. The building relies on passive ventilation through the train tunnels. The “light eye” scoops (right) transport daylight into the subterranean train platforms below (above) while also serving the additional duties of providing exhaust air louvers and smoke removal in case of fire. The eyes were digitally modeled to optimize their efficiency in directing light as well as funneling air out of the station. The project, now under construction, will be completed in 2013.  
Images: Courtesy Ingenhoven Architekten

### **Zero-sum games**

The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) provided one of the more concise statements on zero-energy buildings in “Understanding Zero-Energy Buildings,” which appeared in its September 2006 journal ([www.ashrae.org](http://www.ashrae.org)). The authors, Paul Torcellini, an engineer at the National Renewable Energy Laboratory (NREL), and

Drury Crawley, with the DOE's Office of Building Technologies, subclassify the concept for buildings in four schemes: net zero source energy, net zero site energy, net zero energy cost, and net zero energy emissions.

Net zero source energy compares the building's energy consumption and production to that of the utility source. Since utilities rely on multiple generation plants and transmission systems, this concept generally proves too difficult to quantify and is therefore rarely used in architecture. The net zero site energy concept measures energy consumption within the boundaries of the building's site, ignoring whether the utility source is coal or wind. This applies more generally to what architects try to achieve, since even so-called "off-the-grid" buildings loaded with photovoltaics (PV) and wind turbines still typically connect to utility transmission lines for backup power. Skidmore, Owings & Merrill's design for Pearl River Tower [record, December 2006, page 172], in Guangzhou, China, exemplifies this approach. The third element, net zero energy cost, relies on volatile energy rates—a notoriously difficult metric—to reach a balance between the energy generated on-site and sold to the utility versus the energy supplied by the utility. Finally, the concept of net zero energy emissions only measures the emissions produced by the generation of power to meet the building's total energy needs, which can also prove difficult with a utility company dependent on multiple sources at any given time.

Architects approach this topic in multiple ways, but the ASHRAE article stresses the need to define the project's goal from the beginning to guide the design team in its decisions. The Dusseldorf, Germany-based firm Ingenhoven Architekten established a net zero site energy constraint on its competition-winning scheme for the Stuttgart Main Station, an expansion and upgrade to the city's train station. The design of the building, for completion in 2013, essentially amounts to a roof to cover below-grade train tracks, a public park, and some interior circulation space. Christoph Ingenhoven, the firm's principal, describes the design as a 21st-century response to a 19th-century problem. "It's very difficult to get a zero-energy building," he says, noting that although his own house is nearly zero energy, he still purchases some power from a renewably sourced utility company.

With the program of the train station, Ingenhoven's firm focused on passive strategies—a popular tactic of energy reduction first, followed by an investigation of on-site generation to make up the difference. The design includes 28 so-called "light eyes," which serve multiple purposes: daylighting the underground station, relieving exhaust air, and passively removing smoke in the case of an emergency. (Ingenhoven observes that architectural systems serving more than one purpose are a hallmark of sustainable design.) Computational fluid dynamic modeling, as well as conventional wind tunnel tests, proved that a natural ventilation scheme would work since the station's tracks slope nearly 16 feet across its length and trains push air in and out. And since Germany has a relatively temperate climate, expected interior temperatures range from 46 degrees Fahrenheit in the winter to 78 degrees in the summer—not uncomfortable temperatures for passengers seasonably dressed. PVs and renewable power purchase agreements make up the station's only electricity needs for elevators and lighting.

## Public, private, power

It's conventional wisdom that public institutions have been in the forefront of adopting most design and technology supporting sustainable goals. City train stations, built to last decades, must meet higher operational standards and can afford to take a longer view than the classic developer model building that requires a payback in a handful of years. At least, developers have conditioned architects to expect this.



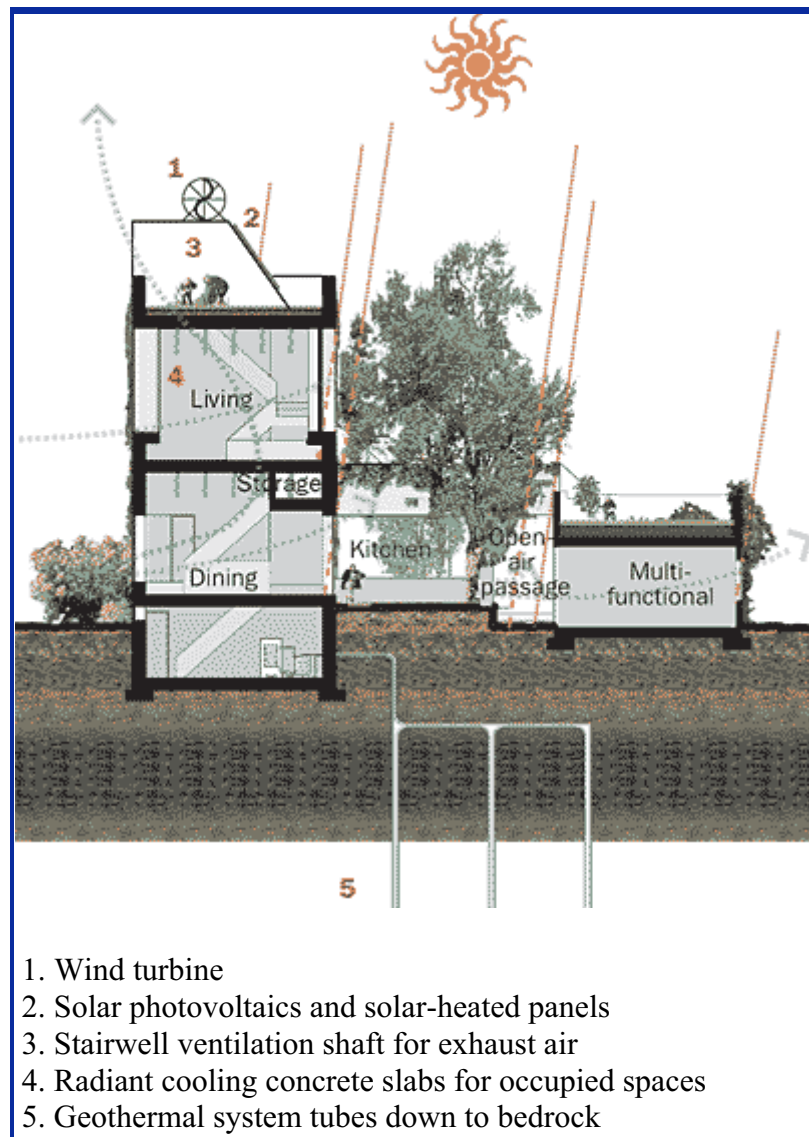
### Zero-energy house, Chicago

Zoka Zola, AIA, has designed a site-sensitive single-family home for an inner-city lot that takes advantage of passive heating and cooling strategies. The house, which goes into construction this spring, will eventually support a rooftop PV system.

Renderings: Courtesy Zoka Zola

The Los Angeles Community College District (LACCD) has adopted an ambitious plan to transform its nine campuses with a net zero site energy policy. With an existing building base of 5 million square feet and plans to add 3 million more, the LACCD worried it wouldn't have money for increased energy costs for new building. Larry Eisenberg, executive director of LACCD's facilities planning and development department, says the district decided to just eliminate its \$9 million annual energy bill. "A comprehensive strategy is key," Eisenberg says.

For the nine campuses to reach zero energy, the LACCD has implemented a three-part plan: improve, reduce, and generate. First, the district intends to convert each of its campuses to a central plant model, an improvement that allows systems to operate more efficiently with fewer maintenance costs. Second, the district has enlisted a third-party contractor to perform an efficiency study of its campuses and to install energy-saving technology, such as occupancy sensors, low-E glass, and better insulation. The district pays for this service out of the money the technology saves on its annual energy bill. These two preliminary strategies ensure the success of the third: the generation of power through a 9-megawatt (mw) photovoltaic installation (or 1 mw per campus).



What's more, the district will subcontract out the system cost and installation to a contractor/supplier (requests for proposals are due back this spring). That third party supplier could then reap federal and state tax credits to eliminate an immediate 20 percent of the PV installation cost. Further, in tax parlance, rapid depreciation of the PV system will pay for another 20 to 25 percent. Green tags—renewable energy credits—can sell on the open market to generate another 5 to 10 percent of the cost. Adding it up, Eisenberg estimates the 9 mw system will cost between 10 to 20 cents on the dollar. With these incentives, Eisenberg projects 1 mw of PVs costs between \$1 million and \$2 million, which translates to a one to two year payback for a campus with a \$1 million annual energy bill. Eventually, the LACCD will buy the system back from the contractor. To skeptics who point to the erratic performance of PVs, which need good sunlight exposure, Eisenberg says the district is exploring a few promising options in energy storage technology, such as hydrogen-powered fuel cells.

### **Decarbonated living**

Large-scale projects garner attention and offset the most CO2 emissions in a single gesture, but zero-energy single-family homes represent a growing market in nearly every corner of the country. A February 2006 report for the NREL prepared by the National Association of Home Builders (available at <http://www.toolbase.org/pdf/casestudies/zehpotentialimpact.pdf>) found that the concept of zero-energy homes would be part of the mainstream residential building market by 2012, and by 2050 could result in reducing by 17 percent the electricity demand for the entire U.S. single-family-home sector. Many of the homes referred to in the study, however, appear business-as-usual, incorporating PVs with higher-performance building materials in a conventionally designed tract home on a cookie-cutter subdivision site. As any sustainable-building consultant will tell you, 90 percent of your opportunities for designing a zero-energy home begin with site orientation.



Zero-carbon beach resort, Nungwi, Zanzibar  
Richard Hywel Evans Architecture and Design have planned to use photovoltaics and wind turbines to power a beach resort for ecoconscious tourists (left). The resort will offset the carbon emissions associated with guest travel.  
Rendering: Courtesy Richard Hywel Evans Architects

Zoka Zola, AIA, who practices in Chicago, says unless an architect can decide where to place windows and how to take advantage of natural ventilation on a site, reaching a zero-energy goal through passive strategies becomes difficult, if not impossible. “The discussion should be how to make the building as efficient as possible through its general configuration,” Zola says. With her design for a zero-energy house in Chicago, she included south-facing windows, specified 25-percent-fly-ash concrete to provide thermal mass, and devised a layout with courtyard gardens to combat heat island effects. She also helped the client pare his space needs, avoiding the desire to build out the maximum allowable square footage for the inner-city site. Zola planned infrastructure for the eventual installation of PVs on the roof, but advised her client to wait until PV efficiency reached a higher level to bring the house to full zero-energy status.

### **May contain hazardous materials**

Embedded energy or carbon, which takes into account the energy used to manufacture a construction material or product, constitutes an altogether trickier component of the zero-sum game. Zola did not consider the embodied energy in the house, simply because the material information and tools to quantify such things are sketchy at best. For the Lloyd Crossing plan, Mithun did not consider the occupants or the furnishings of a building and only encouraged the use of construction materials with low embodied energy levels. Mithun’s Gregory says any master plan undertaken today should consider occupant and operational factors for individual buildings. “This is an emerging issue,” he says, noting that most clients interested today are college campuses and other tightly focused building constituencies.



Hull Architecture Centre, Hull, England Níall McLaughlin Architects created a zero-energy temporary structure to raise design awareness in Hull. Wind turbines and photovoltaics mounted in a plaza supply the building’s energy and feed back into the city’s grid.  
Photography: © Nick Kane

Ingenhoven began the design process for the Stuttgart station with simple models to test structural solutions. “We wanted to minimize the amount of concrete used, so we needed to find a purely pressure-loaded structure,” Ingenhoven says. With Frei Otto and Buro Happold as

consultants, as well as a team of German university researchers, Ingenhoven used experience to shape the structure with the models prior to building a digital model that could optimize it. The work paid off in a slim, 14-inch, reinforced-concrete slab across the tracks (compared to Toyo Ito's 7.8-inch slab roof for the Kakamigahara Crematorium, on page 166). Saving concrete cuts down on cement plant production, a notorious source of CO<sub>2</sub> emissions.

Although accounting for embodied energy in our buildings represents a challenge (see the related story RECORD, March 2007, at the top of page 170), raising awareness of architecture's effects on carbon emissions has reached a fever pitch. The U.S. Green Building Council announced in November that it would require all buildings going for commercial certification to achieve a 50 percent CO<sub>2</sub> reduction over current levels [RECORD, January 2007, page 127] through stricter enforcement of the energy and optimization points in the LEED rating system. As exhaustively noted in the February 12 issue of Engineering News-Record, there is no shortage of CO<sub>2</sub> emissions news—such as the January call from an unlikely industry coalition, including Alcoa, General Electric, and Dupont, for instituting national-emissions limits or the release of the Intergovernmental Panel on Climate Change's Climate Change 2007 report—helping architects wade through the competing claims, various options, and unwieldy concepts remains a daunting challenge. Mithun's Gregory stresses the combined wisdom of multidisciplinary teams as the short-term solution. On the Lloyd Crossing project, the Mithun team included architects, energy engineers, civil engineers, economists, landscape architects, and even a branding company to help the team communicate its ideas to the community. While meaningful change will take time, Gregory notes, "There aren't enough carbon offsets for the entire world."



# Section C: Questions 21-30

## Getting Aggressive About Passive Design

**Architects cannot approach the final frontier in low-energy, zero-carbon design without addressing that old energy hog - and beloved American friend - air-conditioning**

May 2007

Russell Fortmeyer



Continuing Education

**Learning Objectives** - After reading this article, you will be able to:

1. Discuss how some passive ventilation systems work.
2. Explain the energy savings from passive ventilation systems.
3. Explain the advantages of mixed-mode ventilation systems.

How sad that air-conditioning, perhaps the definitive building technology of the 20th century—responsible for the appearance of more architecture than all of the “isms,” genius practitioners, and political dictators put together—has increasingly become a dirty word among some architects. And how ironic that the more energy-hogging air-conditioning systems we build, the hotter the planet becomes.

In his 1969 book *The Architecture of the Well-tempered Environment*, Reyner Banham considered the air-conditioning unit a “portent in the history of architecture.” But might we be on the cusp of a decline in its dominance? Although basic, time-honored design strategies such as exterior shading, interior thermal mass, operable windows, and careful site orientation have reemerged in the past decade under the guise of green architecture, passive or natural ventilation remain exceptions.

According to McGraw-Hill Construction’s 2006 Construction Outlook, America built more than 150 million square feet of office space in 2005 alone, with the largest portion in Phoenix. We can safely assume that all of this space—and that in Phoenix in particular—came equipped with air-conditioning. This overwhelming evidence of our addiction to what Willis Carrier, the father of modern air-conditioning, called “man-made weather,” has not prevented an adventurous set of architects and engineers from aggressively pushing for more passive design strategies.

## They call it the “Windy City”

Devon Patterson, AIA, a principal with Solomon Cordwell Buenz (SCB) in Chicago, calls the implementation of passive ventilation strategies—basically, anything to reduce dependence on air-conditioning—a “forward-thinking” consideration. In the firm’s design for the 69,000-square-foot Information Commons and Digital Library at Chicago’s Loyola University, scheduled to open in November 2007, the need for energy efficiency that wouldn’t sacrifice the building’s transparency led the architects to knock on Matthias Schuler’s door. Schuler, a mechanical engineer who runs the Stuttgart-based climate engineering firm Transsolar, assisted SCB in developing a double-skinned glass curtain wall as part of an integrated system of radiant slabs, underfloor ventilation, and operable windows that would result in smaller overall mechanical systems. Patterson says Chicago’s extreme weather conditions—hot summers, cold winters—prevented an entirely natural scheme, but that so-called “mixed-mode” systems that combine conventional heating, ventilation, and air-conditioning (HVAC) with various levels of natural ventilation represent the best attempt to combat air-conditioning’s prevalence.



A library at Chicago’s Loyola University uses a double-skinned glass curtain wall.

Photography: Courtesy Solomon Cordwell Buenz Architects

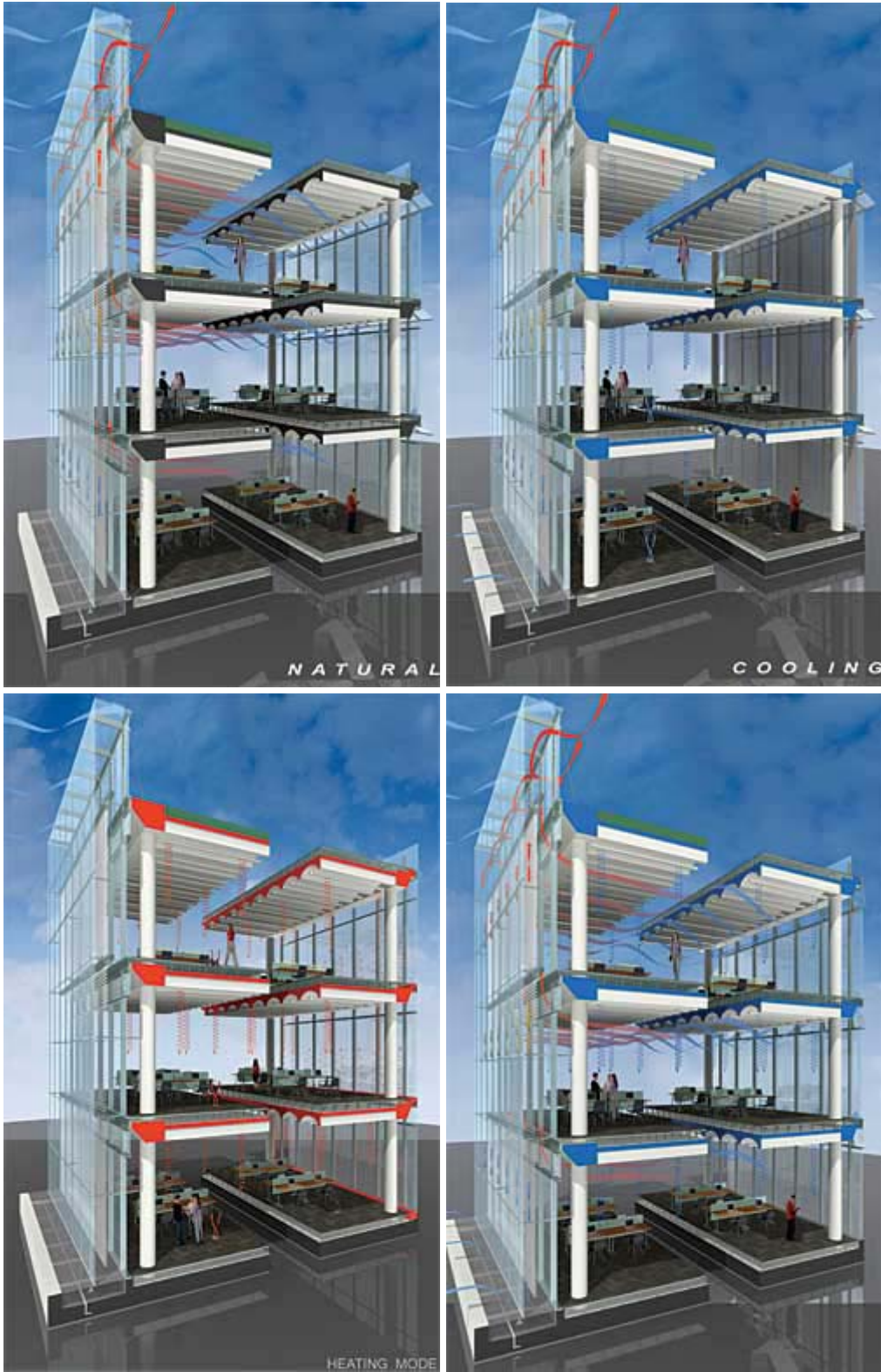
“We were initially going to install some sunshades, but we found this was a better way to mitigate heat gain,” Patterson says. Air enters the building off of Lake Michigan from the east through automatically operated clerestory windows on the glass curtain wall. It then moves across the interior to louvers at the top of the west wall, where it enters the 3-foot-wide cavity of

the double-skinned curtain wall, a design-build point-supported glass system. This warmed air then exhausts via a natural stack effect through a large vent on the top of the building. There are basically two kinds of natural ventilation—the stack effect and wind. Loyola represents a combination of the two.

Loyola is a simple enough solution—a tunable glass box wrapped around a concrete structure—but complexity resides in its details. For one, the east wall includes interior low-E shades that form a mini-double-skinned facade when early morning sunlight might otherwise overheat the space. (Europeans often place these shades on the exterior, Patterson says.) Two systems sandwich the air of the interior, which consists mostly of open space for computer workstations. A raised-floor displacement ventilation system provides conditioned air designed to handle the first 8 feet of vertical space, as opposed to conditioning the entire 12 feet to the ceiling. By locating the air supply in the floor, the architects could install in the exposed poured-concrete, barrel-vaulted ceiling the plastic tubing needed for radiant cooling and heating. Vaulting not only contributed more surface area for the radiant system, it also optimized reflection for the efficient T5 fluorescent indirect lighting system.

Of course, chilled slabs lead to worries of condensation and indoor rain showers, but Transsolar's modeling showed that with a minimum of 67 degrees Fahrenheit for the slabs, there would be only 10 days each year where the slabs would be colder than the dewpoint. The building's conventional HVAC system easily accommodates dehumidification for these instances. The west facade, though, remains the lynchpin in the design. Early computational fluid dynamic (CFD) modeling of this side of the building showed air would flow over the top of the extended curtain wall and create a negative pressure zone on the backside that would pull air out of the wall's cavity. The curtain wall sits atop a trench, which pulls air in to facilitate the stack effect. In winter months, with the trench closed, warm air builds up in the wall cavity to help heat the building.

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Solomon Cordwell Buenz architects developed four cooling and heating strategies for a digital library at Loyola University in Chicago (above). The natural ventilation scheme takes advantage of wind off of Lake Michigan on

the east side of the building to pull air across the space and up through a double-skinned glass curtain wall on the west side. The other schemes show how mechanical systems operate in concert with passive and natural strategies.

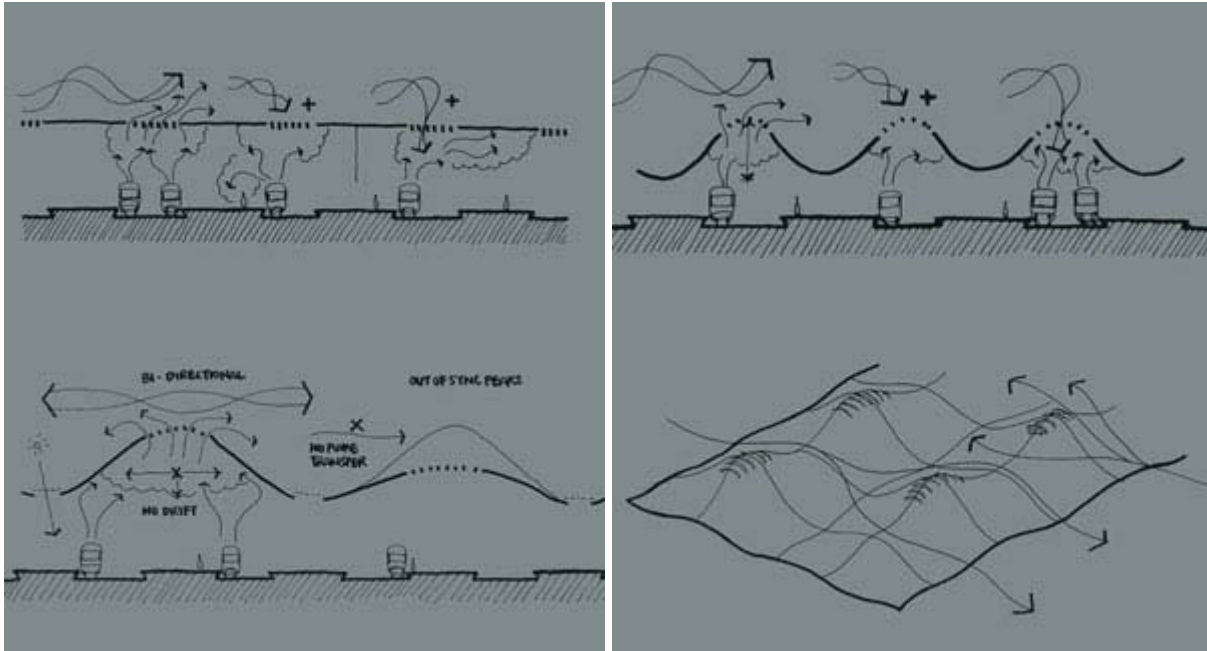
Images: Courtesy Solomon Cordwell Buenz Architects

In 2004, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) revised its bible of air-conditioning—Standard 55, Thermal Environmental Conditions for Human Occupancy—to account for studies that proved that when people have more control over their environment, they typically accept a wider range of temperature conditions. In 2000, one influential study led by Gail Brager at the University of California at Berkeley’s Center for the Built Environment showed that traditional research in human comfort expectations neglected to adequately consider three modes of adaptation: physiological, behavioral, and psychological. While Brager did not find that physiological adaptation, or how a body adjusts to a climate over a long duration, could account for much, she did find that behavior—removing clothing, turning up fan velocities—could significantly alter environmental perceptions with occupants. Brager also found that psychologically, occupants of naturally ventilated buildings grow accustomed to less consistency in temperature, eventually coming to expect interior conditions that more closely hew to outdoor weather.

These shifts in perception undoubtedly encouraged SCB’s architects to take advantage of Chicago’s more temperate weather periods for natural ventilation. “A weather vane on the roof can open the facades and induce ventilation when outdoor temperatures fall within a range of 55 to 65 degrees,” Patterson says, noting that the building’s fullest potential lies in spring and fall. Still, he estimates that’s enough time averaged across the year for the building to beat ASHRAE’s 90.1 Energy Standard by 50 percent.

### **Green for open, red for closed**

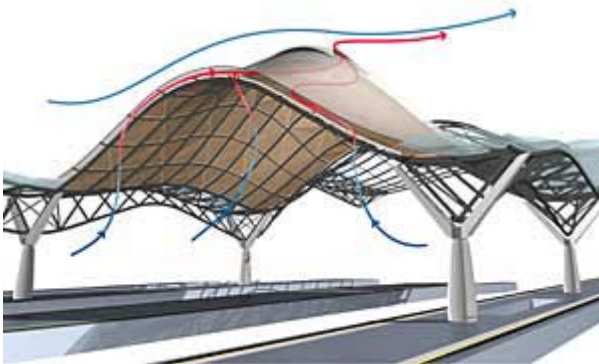
For architects and engineers, this sort of mixed-mode design probably represents the future direction of passive ventilation schemes. For risk-adverse developers, mixed-mode designs offer flexibility—tenants who prefer air-conditioning can choose to ignore the windows—as well as a buttress against the unrelenting onslaught of humidity. At NBBJ’s new offices in Seattle [record, January 2007, page 110], Allan Montpellier, a mechanical engineer with the local office of Flack+Kurtz, developed a mixed-mode approach for an underfloor HVAC system that depends on occupants to operate windows when the air-conditioning is off. Green and red indicator lights, tied to the building’s HVAC control system, alert staff to when they can open windows. The approach can also backfire. “If you put a desk up against a window, that person will then ‘own’ that window,” Montpellier says. “You really need space between desks and windows—you have to think psychologically about the space.”



Grimshaw Architects’ design for the Southern Cross Station in Melbourne, Australia, takes advantage of crosswinds to induce the stack effect in a double-skinned domed roof. The architects and engineers relied on 19th-century train-station designs to inspire the completely naturally ventilated station, since computational fluid dynamic modeling could not be undertaken until design had progressed significantly. The station, open since 2006, has been considered a success.

Images: Courtesy Grimshaw architects

But before Montpellier could get to this point, he undertook a comprehensive review of what he terms a “typical meteorological year” in Seattle. He developed a chart for NBBJ that showed the number of hours in a year when the temperature would stay in a specific range; even the jargonists, many engineers call this “binning up” temperatures. For example, the chart indicated 432 hours annually for a bin of 60 to 62 degrees, but Montpellier mainly focuses on the values above 80 degrees. “You really start to get uncomfortable around 80 to 85 degrees, even with a ceiling fan,” Montpellier says. “Above that, people will complain.” He found there were only 64 working hours per year where the temperature exceeded 80 degrees, which helped convince NBBJ to go with the mixed-mode design, though he notes each client tolerates different environmental conditions.



Grimshaw Architects' design for the Southern Cross Station in Melbourne, Australia, takes advantage of crosswinds to induce the stack effect in a double-skinned domed roof. The architects and engineers relied on 19th-century train-station designs to inspire the completely naturally ventilated station, since computational fluid dynamic modeling could not be undertaken until design had progressed significantly. The station, open since 2006, has been considered a success.

Image: Courtesy Grimshaw architects; © Shannon Mcgrath (top left); Courtesy Southern Cross Station Authority (right)

Having established a case for natural ventilation, Montpellier then had to determine if he could secure enough openings in exterior walls to get the minimum amounts of air the scheme would require. The International Mechanical Code requires that for every square foot of floor area, you need 4 percent of the wall area for operable windows. Montpellier says he designs closer to 10 percent, as the code suggests a minimum that doesn't adequately address occupant comfort issues. At this point, Flack+Kurtz developed a CFD model of the building to gauge airflow patterns around and through the structure to ensure a natural ventilation scheme could accommodate the interior recesses of the building. Relatively standard design tactics—shallow, open floor plates no wider than 50 feet and a central atrium—facilitated air movement.

Engineers often refer to CFD modeling as definitive—a design tool producing results as good as the built thing. Paul Linden, chair of the department of mechanical and aerospace engineering at the University of California at San Diego, says CFD modeling can generate skewed results since

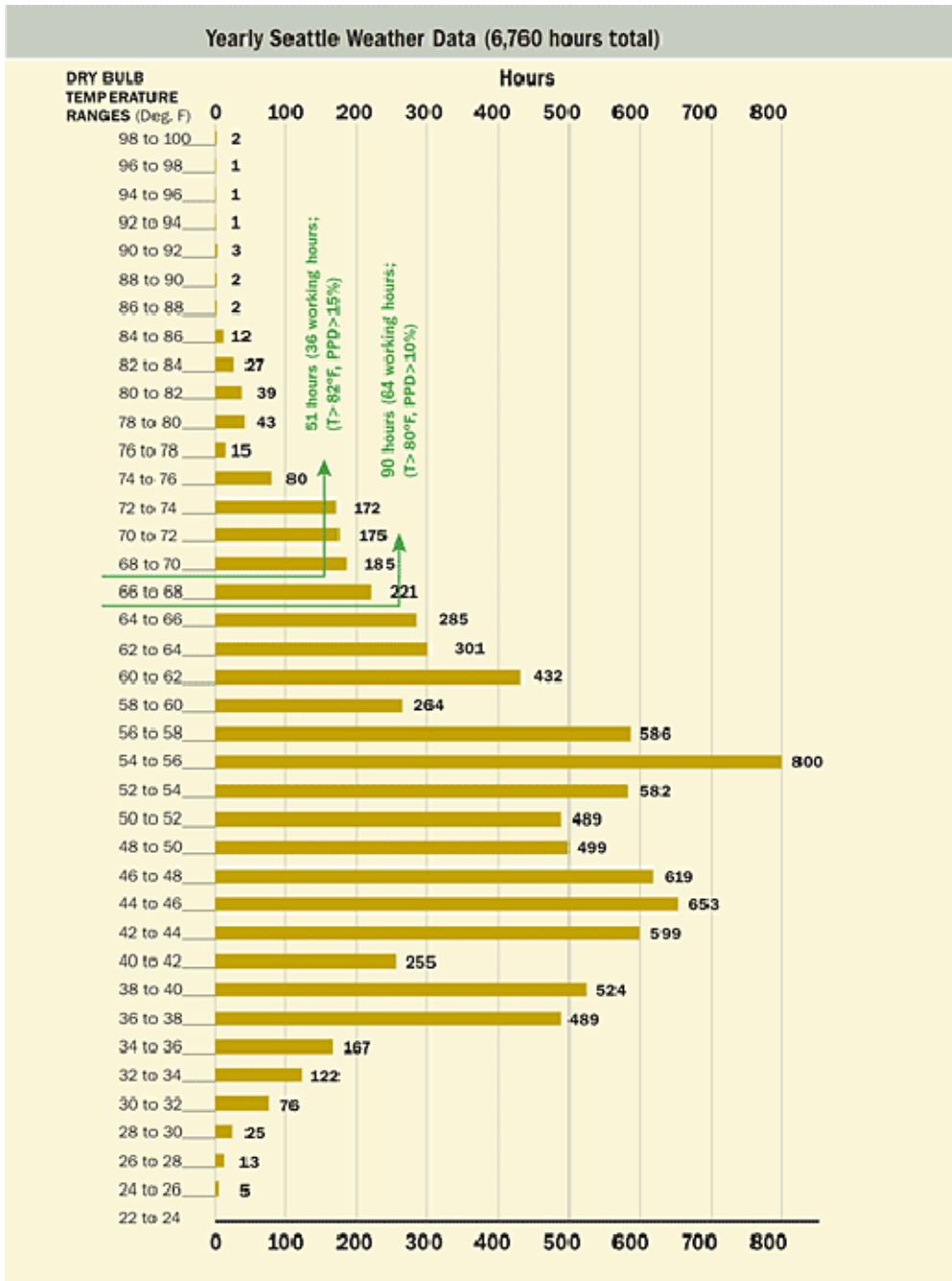
most existing software, such as the widely used EnergyPlus from the Department of Energy, contains programming code that doesn't take into account internal heat gains. "EnergyPlus in its traditional form is for sealed, air-conditioned buildings," he says.

Linden, whose research has focused on airflow modeling, says updating EnergyPlus to consider natural ventilation schemes, transient environmental conditions, more complicated geometries, and estimates of comfort levels for spaces will be key to the software's usefulness in design. Still, he says he worries that many consultants don't know how to read CFD analysis results, and even worse, hardly anyone monitors buildings post-occupancy to determine the accuracy of CFD predictions. "CFD models produce nice pictures," Linden says, "but who's to say what's right or wrong."

### **Model behavior**

William McDonough + Partners developed a similar scheme as that at NBBJ for a mixed-use office project in Barcelona, with manually operable windows that allow cool air to filter into a central atrium and then exhaust through the roof. The architects produced a user's manual for the building, now under construction, explaining the role each occupant would play in how the building functions. John Easter, a director at McDonough, says the busy Barcelona streets surrounding the project certainly produce problems with indoor air quality and noise—two of the chief complaints of natural ventilation—but the city's commitment to reducing pollution should help in the long run. "There are times with heavy traffic where they will need to close up the building, but it's a system the tenants monitor and will have to adapt to," he says



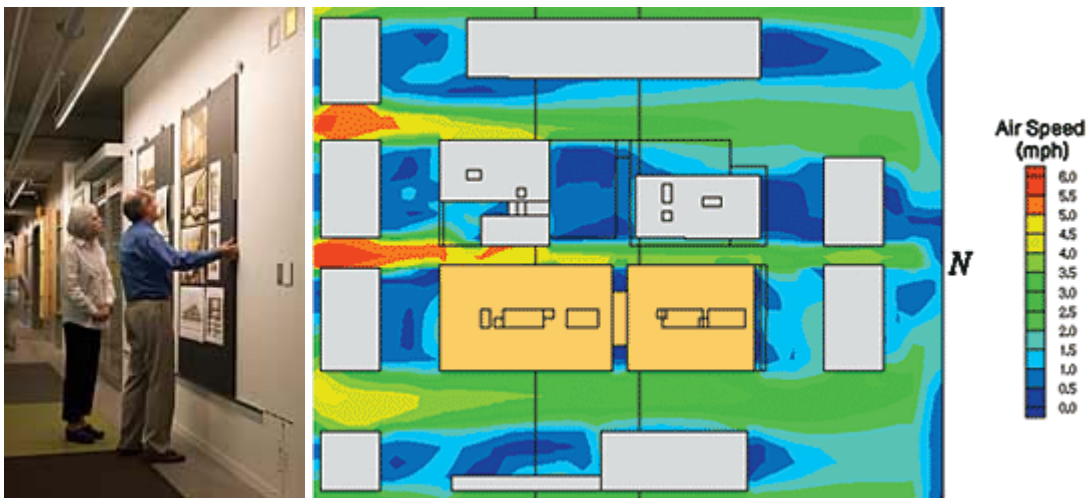


Flack+Kurtz prepared a typical meteorological year chart for the design of the offices for NBBJ architects (far left). The chart indicates how many hours out of each year the outdoor temperature will fall into specific ranges.

Graph: Courtesy Flack+Kurtz

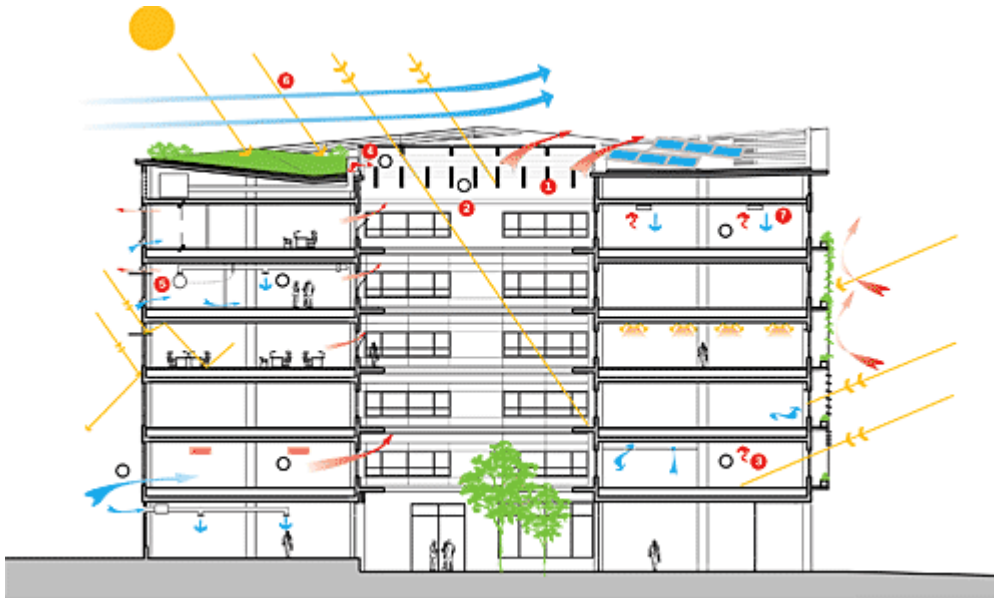
The term “risk” pops up frequently in discussions of natural ventilation and unconventional building systems. Matt Herman, an energy-modeling consultant with Buro Happold’s New York office, worked on the McDonough project. He says the emergence of better performance-based

analysis tools has instilled engineers with more confidence. After typical building energy modeling, or thermal analysis, is complete, Herman usually embarks on creating an airflow network. This relatively simple analysis, which he performs using the IES Virtual Environment software, models bulk air transfer around and through a building across an entire year. An airflow network primarily yields graphs that compare indoor to outdoor air temperatures throughout a year. It takes into account materials, solar obstructions, internal heat loads, and occupancy. Although it takes time to set up, running the program can take a few minutes to a few hours. A CFD model, on the other hand, can take days to calculate and, while it produces a high level of information about airflow, its data accounts for only one specific instance in time, usually a worst-case situation.



Temperatures above 80 degrees Fahrenheit are typically too uncomfortable to take advantage of natural ventilation. A CFD analysis of a typical office floor (above right) indicates the air velocity across the floor plate on a particular day. Open offices facilitate airflow across the entire floor, helped in part by a central atrium that draws air to exhaust through the roof. Architects at NBBJ (above left) open and close windows based on green and red indicator lights installed throughout the offices.

Photography: © Benjamin Benschneider (above left); Graph: Courtesy Flack+Kurtz

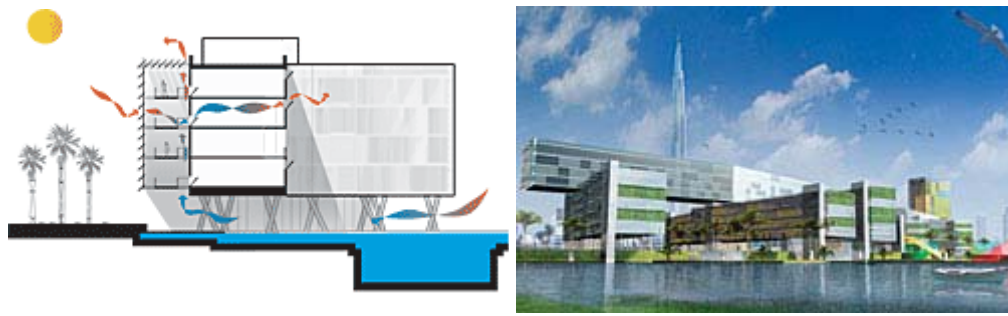


Ecurban 22@, Barcelona, Spain, by William McDonough + Partners

1. Baffles to minimize solar heat gain and increase stack effect.
2. Air stratifies above this “neutral pressure level.”
3. Exposed building thermal mass lessens temperature swings from day to night.
4. Louvers induce the stack effect, providing return air to the mechanical room.
5. CO2 sensors reduce mechanical ventilation during unoccupied times.
6. Northwest winds assist ventilation with southeast facing openings.
7. Fan-coil units supply mechanical ventilation.

Diagram: Courtesy William McDonough + Partners

Although software tools have helped justify designs to risk-averse clients, some architects have returned to the pre-air-conditioning era for inspiration. Architects and engineers must discard a lot of cultural baggage to implement natural ventilation schemes. Modern air-conditioning, arguably first installed in Brooklyn in 1902 by Carrier, took decades to become what Philip Johnson would call a crutch—an easy solution allowing architects to block out the real world, hermetically sealing our daily lives in a cocoon of ignorant bliss. Not until movie theaters widely adopted the technology in the 1920s did the public begin to demand it. ASHRAE first institutionalized occupant comfort levels with a chart for engineers in 1924. That became Standard 55 in 1974, which for years has supported the case for air-conditioning for nearly every building in America.



FXFowle Architects designed this residential project for Dubai to take advantage of man-made lakes for natural cooling during the night. A screen on one side of the building filters sunlight to lessen heat gain on each apartment.

Images: Courtesy FXFowle Architects

Grimshaw Architects looked at 19th-century European rail stations to find design tactics for the Southern Cross Station, completed in Melbourne, Australia, in 2006. Victorian stations typically had high barrel vaults that would help force a plume of smoke up away from travelers, with linear clerestory vents along the top of the arch for exhaust. Grimshaw implemented a more high-tech version of this with a domed, double-skinned roof that would absorb heat and contaminants into an open, gridlike inner layer, which would then exhaust through a 16-inch cavity out of “moguls” at each peak. CFD modeling showed that wind sweeping across the top of the roof would engender a pressure differential, or stack effect, at the mogul openings, naturally pulling the heat out of the cavity. Engineers considered a variety of airborne contaminants—sulfur dioxide, nitrous dioxide, and carbon monoxide—to ensure the system would work under every condition. Keith Brewis, a director in Grimshaw’s Melbourne office, says a 1-foot opening along the ground plane of each wall’s facade supplies the station’s air for the system to work. “During the competition phase, we hadn’t done the CFD analysis, so we made a provision in the plan and cost to put a fan in the apex of the domes,” Brewis says. “But we’ve been open and there hasn’t been a concern.”

Although Brewis says Grimshaw seeks to implement natural ventilation schemes on every project, he feels governments should lead the call to action since leasing agents can thwart a developer from even considering unconventional design approaches. While enlightened clients help, in nearly every case discussed in this article designers stressed the need to educate clients. SCB’s Patterson says Loyola approached the topic unenthusiastically until the architects took the university’s key players to visit similarly ventilated buildings Schuler had designed in Germany. Scott Frank, a mechanical engineer with Jaros Baum & Bolles in New York, says it can be a tough sell since owners view the components that make mixed-mode systems function as adding directly to cost and maintenance. “In the end, facades of buildings are going to have to be a more active component of design,” Frank says, suggesting perhaps the integration of radiant systems into facade components as one potential solution. Although eliminating air-conditioning sounds radical in 2007, the possibilities for an architecture unburdened by its demands clearly remain open to discussion.