centerline

Newsletter of the Center for the Built Environment at the University of California, Berkeley

Summer 2008

Getting to zero-energy buildings

Director's Note

Contents

Dear Industry Partners,

In this edition of *Centerline* we report on some of the exciting zero-energy projects that our Industry Partners are involved with. As developers start working towards new zero-energy goals, our partners offer a wealth of experience that will help them to compete and succeed in this arena. We think these goals are positive developments that are improving the entire building industry, however meeting the goals is going to require a lot of new design techniques, tools, and products. We hope to support your work in this area through our research and development efforts.

We are also happy to report on recent progress from our core and developing research areas, including design guidance for radiant systems, new occupant survey modules, and new UFAD field studies. We are also excited to tell you about the continued success of Adura Technologies, a growing clean-technology firm that was established based on CBE's research. Seeing our work being implemented in practice is a real reward, and we look forward to more collaborations with you on research projects that will be beneficial to you and the building industry at large.

Sincerely,
Edward Arens

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Getting to Zero

How CBE Industry Partners are meeting net-zero energy goals

Along a typical commercial strip in San Jose, California, an unassuming office building is gaining notoriety for its ambitious sustainability goals. The new offices for Integrated Design Associates (IDeAs) were designed to meet the goals of net-zero energy and net-zero carbon emissions, new benchmarks for buildings that far exceed current sustainable building practices. Using readily available technologies, the project team endeavored to meet challenging new energy conservation and on-site generation goals that are predicted to be adopted industry-wide within the next two decades. Mark Fisher, principal for IDeAs, thinks that zero-energy goals are already within reach for many projects. "We didn't do anything that other people can't do, we just decided to do now what many people will be doing ten years from now," he explains.

> "We didn't do anything that other people can't do, we just decided to do now what many people will be doing ten years from now."

The drive towards net-zero energy buildings is the latest phase in the ongoing process of raising the bar on sustainably designed buildings. Since the 1990's the LEED rating system has increased the adoption of green building technologies and spurred competition to reach sustainable building goals. However many LEED-certified buildings did not improve energy efficiency beyond code allowances (though recent updates to LEED, and additional proposed revisions have more rigorous energy requirements.) Now a number of project teams are striving for the ambitious goal of creating zero-energy buildings that fully offset their energy consumption and carbon emissions by generating electricity and/or heat on-site using renewable resources.

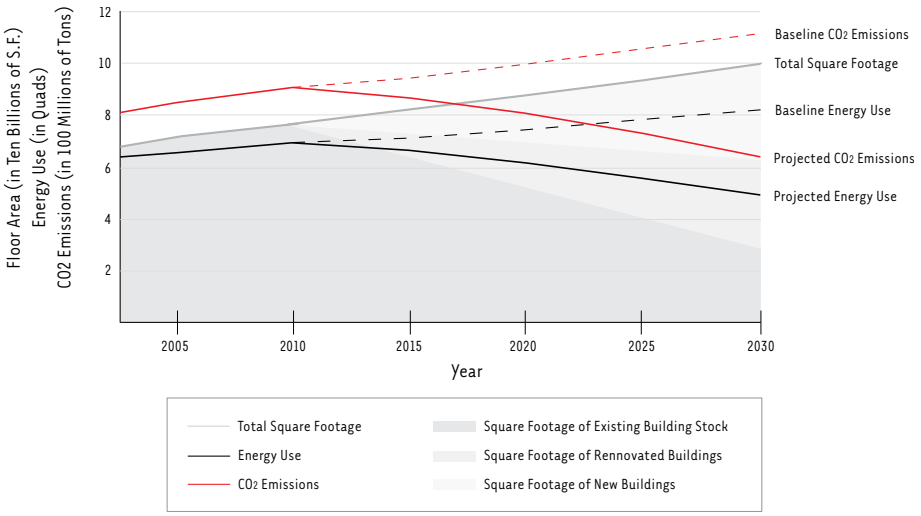
A number of societal factors are converging to drive this trend. With the devastation wrought by hurricane Katrina, scientific evidence of the rapidly melting polar ice cap, and the attention gained by Al Gore's documentary *An Inconvenient Truth*, concern about global climate change has reached a tipping point. In a recent speech, Gore told a conference of energy policy makers that the U.S. should transform its electrical grid to rely solely on renewable energy sources within a decade. He likened this goal to JFK's challenge of putting a man on the moon by the end of the 1960s, and that to meet this challenge that U.S. should transform its tax policies to encourage investment in renewable power. In Gore's words, the government should "tax what we burn, not what we earn."

New policy directions

Numerous organizations have adopted emission reduction policies for buildings with far-reaching implications. In 2006 the non-profit group Architecture 2030 proposed the 2030 Challenge, advocating that new buildings and major renovations be carbon neutral – using no energy from greenhouse gas (GHG) emitting sources – by the year 2030. The plan advocates an immediate energy reduction target of 50 percent of the national average for each building type, based on the existing building stock. The plan will then increase the reduction by 10 percent every

five years, reaching a 100 percent reduction by 2030. These ambitions goals have been adopted by many influential industry organizations including the American Institute of Architects (AIA), the U.S. Green Building Council (USGBC), the Environmental Protection Agency (EPA), and the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE).

Several energy policy actions have been initiated at state and federal levels with zero-energy phase-in plans similar to those in the 2030 Challenge. The U.S. Energy Independence and Security Act of 2007 (EISA 2007) was signed into law in December of 2007, and will have broad implications for energy efficiency of public buildings. The new law authorizes a Zero-Net-Energy Commercial Buildings Initiative within the U.S. Department of Energy (DOE) to support the goal of net-zero energy for all new commercial buildings by 2030. The law also creates an Office of Federal High-Performance Green Buildings within the U.S. General Services Administration (GSA), and puts new and renovated federal buildings on an energy reduction plan that reaches carbon neutrality by 2030. The law also specifies a zero-energy target for 50 percent of the U.S.'s commercial buildings by 2040, and for all U.S. commercial buildings by 2050.



Potential effect of 2030 Challenge targets on the U.S. commercial building sector
Source: U.S. Commercial Building Stock Model, Lawrence Berkeley National Laboratory

A number of zero-energy policies have also been adopted at the state level. In March of 2008 Massachusetts Governor Deval Patrick announced the formation of a green building task force to develop specifications for the first state-owned net-zero energy building by 2010. The state's plan will encourage universal adoption of net-zero energy targets for all new construction by 2030.

EISA 2007 specifies a zero-energy target for 50 percent of the U.S.'s commercial buildings by 2040, and for all U.S. commercial buildings by 2050.

In California a broad series of policy actions were set in motion after Governor Schwarzenegger signed the Global Warming Solutions Act of 2006 (AB32). This law requires California to reduce GHG emissions to 1990 levels by 2020, with later reductions of 80 percent by 2050. Both the California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) have adopted policies for all new residential construction in California to meet zero energy by 2020, and for all new commercial construction by 2030. These policies will drive funding for incentives for net-zero buildings, and will provide the basis for future revisions to California's Title 24 energy code. Panama Bartholomy, Advisor to CEC Commissioner Karen Douglas, says that incentive programs are critical for preparing the market to adopt zero-energy goals. "We have the authority to continue to ramp up efficiency requirements of Title 24, but we can't do it all with standards."

In July the Pacific Gas and Electric Company filed a proposal with CPUC that would double PG&E's budget for energy efficiency programs, including some $60 million to promote adoption of zero-energy buildings. Nick Rajkovich, Senior Program Engineer with PG&E, is helping the utility

to structure a series of pilot projects, incentives, and development tools for zero-energy homes and commercial buildings. He explains that "subsidies alone will not change the market," and that design methods and tools will be necessary. PG&E has already been approached by a number of developers interested in doing zero-energy pilots as a way to differentiate themselves in the marketplace. Nick believes that universities, non-profits, and owner-occupied projects pose the best candidates for early adoption. The new incentives for zero-energy buildings are expected to be available in 2009.

If the 2030 Challenge goals are met, the commercial building sector could be a major contributor towards meeting the new GHG reduction goals. Using models of the U.S. commercial building stock created by the Lawrence Berkeley National Laboratory, and assuming current rates for new construction, renovation, and retirement of buildings, we can estimate the collective impact of 2030 goals (see chart p. 4). The model shows that although the total commercial square footage is expected to increase close to 40%, the resulting CO_2 emissions could be reduced by approximately 25%. (The reduction is not greater due to the low rates at which existing buildings are retired, only 0.8% per year.)

Complexities of definitions

Determining if a building is truly zero-energy can be a complex task. A study by Paul Torcellini, Shanti Pless and Michael Deru with the National Renewable Energy Laboratory (NREL), and Drury Crawley of DOE, illustrates that our definitions of net-zero energy can influence project design, and how we measure success for these projects [1].

The authors describe four primary definitions for net-zero buildings – those that are net zero in terms of site energy, source energy, energy costs, or emissions (see inset box below). All four definitions assume that grid connectivity is available so that buildings can export excess electricity, and measure energy use and on-site production on an annual basis. Net-zero site energy buildings (site ZEBs) produce as much energy at the site as they consume. For net-zero source energy buildings (source ZEBs) one must calculate energy losses from generation and transmission, however for buildings that use natural gas and generate excess electricity on site, this becomes an easier goal than a site ZEB. The authors suggest that buildings should first reduce energy use overall, and produce electricity within the building footprint. Buildings that import renewable supplies to the site (for example biodiesel, wood pellets, or biomass) or purchase off-site renewable energy, are considered less optimal, as these options provide less of an incentive to reduce building energy loads.

Many practitioners have opted to meet the site ZEB goal, as with this approach there is no need to adjust for grid generation and transmission losses, utility emission rates, or utility cost structures. As these values can vary greatly by location, the site ZEB goal simplifies energy calculations and provides a more level playing field.

Net-Zero Site Energy:	Producing at least as much energy as used in a year, when accounted for at the site.
Net-Zero Source Energy:	Producing at least as much energy as used in a year when accounted for at the source, referring to the primary energy used. Uses site-to source conversion factors.
Net-Zero Energy Costs:	Money paid by the utility to the building owner for energy exported to the grid is at least equal to the amount the owner pays the utility over a year.
Net-Zero Energy Emissions:	Producing at least as much emissions-free renewable energy as used from emissions-producing energy sources.

Definitions based on "Zero Energy Buildings: A Critical Look at the Definition, Preprint," P. Torcellini, S. Pless, M. Deru, and D. Crawley, NREL Conference Paper, August 2006

Feasibility of zero energy

Although many new policies encourage gradual and universal adoption of zero-energy buildings, few feasibility studies of these policies are available. A study by a team of NREL and DOE researchers provides an optimistic outlook and suggests that zero-energy goals are achievable for significant portions of the U.S. commercial building stock [2]. Using models based on the 2003 Commercial Buildings Energy Consumption Survey

(CBECS), the researchers predicted the potential for zero-energy buildings based on several possible scenarios. The scenarios included a base case with today's standard buildings with rooftop photovoltaics (PVs), a scenario with currently available low-energy solutions, and scenarios that assume that building energy technologies will improve by 2025.

The simulations show that with an aggressive package of current technologies and practices, 22 percent of U.S. commercial buildings have the potential for reaching zero energy. If these technologies were applied to the entire U.S. building stock, site energy use by the commercial building sector would be reduced 82 percent. The most optimistic scenarios – which assume increased efficiency for lighting, HVAC, photovoltaic panels, and appliances by the year 2025 – show that 70 percent of commercial buildings could reach zero energy.

The study further shows the potential to reach net-zero goals broken down by climate and commercial building sub-sector. ASHRAE climate zones 1-3, which represent roughly the southern third of the continental U.S. and most of California, show the greatest potential for reaching zero-energy goals. Building types with the greatest potential for net-zero energy are warehouse buildings, followed by office and educational buildings. While the authors demonstrate possible outcomes based on the adoption of building technologies, the report does not consider the costs or economic feasibility of these scenarios. Obviously, reforming the market and cost structures for sustainable technologies will be crucial factors in the adoption of zero-energy solutions.

Early attempts

One of the first projects to strive for zero energy was the Adam Joseph Lewis Center for Environmental Studies at Oberlin College, completed in 2000. The project by William McDonough + Partners was widely touted as one of the first buildings to be a net-energy exporter. The project's performance was monitored and evaluated by Oberlin faculty member John Scofield, who published his findings in *ASHRAE Transactions* [3]. However Scofield's findings were criticized by McDonough's office as an unfairly poor report because Scofield included data collected before building commissioning was complete (this discussion is included in the *Transactions* paper). A more balanced assessment of the project was given in a field study by NREL and Oberlin College, which found that although the building fell short of its goal to be an energy exporter, its rooftop PV system provides 57 percent of the building's annual energy demand [4]. In 2006, six years after the completion of the project, an additional 100 kWp (kilowatt peak) PV array was installed as a canopy for an adjacent parking lot, and the building is now believed to be operating as a net-zero energy building.

The Beddington Zero Energy Development, another early adopter, was intended to be the first carbon-neutral community. The project, known as BedZED, designed by Bill Dunster Architects and Arup, and completed in 2002, included 99 low-energy homes in the London Borough of Sutton. The project was analyzed in a University of East London student's Master's Thesis in 2005. The study found that although the project made significant reductions in energy use, including space heating reductions of 88 percent, the project fell short of its overall goal of carbon neutrality.

Current trends in net-zero

The projects at Oberlin and Sutton show that meeting zero-energy goals in operating buildings has been an elusive challenge. Scott Shell, Principal with EHDD Architecture, thinks that energy modeling tools are not always effective for predicting actual operating energy use, and that they are primarily useful for estimating specific loads and as a baseline for compliance with energy standards. However, with ultra-low energy buildings, even minor problems with building operations can seriously affect energy budgets.

For the Chartwell School in Seaside, California, EHDD pursued the goal of net-zero purchased electricity, allowing natural gas for space heating that would not be compensated for with on-site electrical generation. Scott says that the PV system was relatively inexpensive when considered as part of the overall budget for the

> ...continuous monitoring and improvement of operations can make or break zero-energy goals...

Chartwell School in Seaside, California is operating as a net-zero electricity building. Photos by David Rose, except lower right by Clay Haskell

school. After rebates the system cost was $158,000, only 1.6 percent of the project's construction cost, and with accelerated depreciation the payback period was significantly reduced. "We routinely value engineer 10 percent of a project's cost, of course we can afford this," Scott explains, "but it requires a mental shift to have this as a key goal for a project." He says that when zero-energy is a goal, attaining a LEED Platinum rating is much easier to reach. "You get all the energy credits, the innovation points for zero-energy, and the IEQ points which are relatively easy for high-performance buildings, putting you well on your way to platinum."

When Chartwell first opened and was not meeting its net-zero electricity goal, the school asked Taylor Engineering, the mechanical engineer and energy consultant for the project, to conduct an energy audit and compare it with the energy predictions. The building had been equipped with detailed end-use metering, in part to obtain a LEED credit for energy monitoring, which greatly aided the energy audit process. Gwelen Paliaga, Senior Project Manager with Taylor Engineering, discovered that lighting loads were highest during the evening when the school was largely unoccupied. He was told that a security consultant advised that site lighting be left on all night, though this turned out to consume 20 percent of the building's annual energy budget. In addition, two large commercial refrigerators had been donated to the school, but were not included in the design-phase energy modeling, and were using seven percent of the energy budget. (They were later replaced with much more energy-efficient models.) Gwelen thinks that the building can meet its zero-electricity goal, but says that "continuous monitoring and improvement of operations can make or break zero-energy goals, and somebody at the building has to be paying attention to energy use over time." He also believes that improved energy data visualization systems, such as the building dashboards provided by Lucid Design Group, will help building operators keep track of ongoing energy use and identify operational problems.

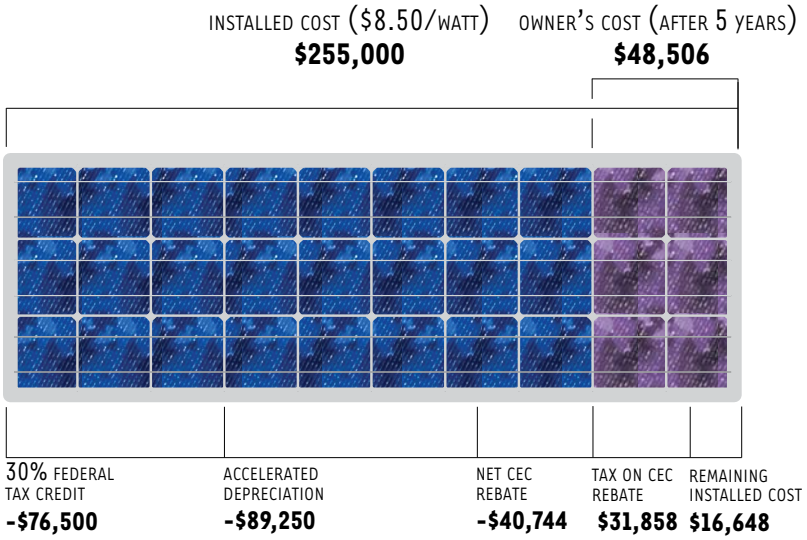
The San Jose headquarters for Integrated Design Associates (IDeAs), completed in the fall of 2007, was designed to be net-zero in terms of both energy consumption and carbon

emissions. The building is housed in a 7200 s.f. former bank building, and is expected to generate 100 percent of its energy requirements with a building-integrated photovoltaic (BIPV) system. The design team that included EHDD Architects, Rumsey Engineers and IDeAs, first designed an all-electric, low-energy building using readily available systems and technologies. Lighting loads are reduced with skylights, high-efficiency fixtures, occupancy sensors, astronomic time switches and daylight harvesting controls. Solar gain is controlled with spectrally-selective glazing, overhangs and electrochromic glazing. The designers also analyzed plug loads including printers, computers, screens, peripherals and task lighting for ways to further reduce energy consumption.

The building's mechanical system incorporates a high-efficiency geothermal heat pump with polyethylene (PEX) tubing under an adjacent landscaped area that provides the ground-source heat sink. A radiant floor system with PEX tubing is imbedded in a topping slab over the existing slab. A Metasys energy management system by Johnson Controls is designed to optimize this low-energy system by controlling flow rates and floor slab temperatures. The system evaluates the potential for floor condensation by monitoring humidity and floor surface temperatures, and is able to provide dehumidification through the dedicated outside air handler which provides ventilation air. Operable windows and sliding glass doors allow occupants to control their indoor environment.

The building was designed to use 60 percent less electricity than Title 24

IDeAs offices in San Jose, California. Shown above are main entry, building integrated photovolatic system with skylights, and PEX tubing for radiant floor during installation. Images courtesy of IDeAs



Incentives and rebates are estimated to reduce the cost of the BIPV system at the IDeAs offices by approximately 80%.

standards. The project's 30 kWp BIPV rooftop system, with additional BIPV panels on south-facing shading devices, are expected to generate 42,700 kWh per year, meeting the annual electrical demand of the building. The building owners took advantage of several financial incentive programs, including rebates from the CEC, a 30 percent federal tax credit, and 5-year accelerated depreciation. Together these incentives reduce the cost of the photovoltaic systems from the installed cost of $255,000 to an estimated cost (after 5 years) of $48,500, a reduction of over 80 percent (see chart p. 8). Energy savings are estimated at $6833 per year, resulting in a simple payback of slightly more than seven years.

The project has not been without its challenges. Obtaining the approval and equipment from PG&E for net metering took several months, and the utility would not review the application until the building inspector had verified the installation was complete. As a result, several months passed in which the system produced electricity that could not be used. (PG&E representatives say that ten days is the average turnaround time for net meters.) In addition, diodes in the project's monocrystalline BIPV panels failed and had to be replaced. Because the diodes are integral with the PV panels and the roofing system, the manufacturer had to get UL approval for the new design, causing additional delays.

Although not all of the defective panels have been replaced, the system generated an excess of 33 kWh from April through June. The building owners continue to monitor electricity purchased and generated on-site to determine whether the building meets its net-zero goals on an annual basis. Mark Fisher of IDeAs describes the project as a work in progress and a living laboratory. "It is very efficient, but may never be perfect, as soon as something new comes out we change it." He also says that the project has gotten a great deal of interest from the media, including spots on CNN and NBC, and has attracted a large number of tour groups.

Future directions for reaching zero energy

In our discussions with design professionals for this article, we learned of several net-zero energy projects currently in design and soon to be built. The Research Support Facility for NREL's Golden, Colorado campus looks to be a promising case study. The design-build RFP for the project included a number of required and desired performance goals. As a minimum, the project had to meet LEED Platinum, and had to provide natural ventilation and daylight to all workspaces. Competing design-build teams were encouraged to comply with a maximum energy budget of 25 kBtu/s.f., approximately 50 percent better than ASHRAE standards for the site's climate. Further down the list of desired performance goals was net-zero energy.

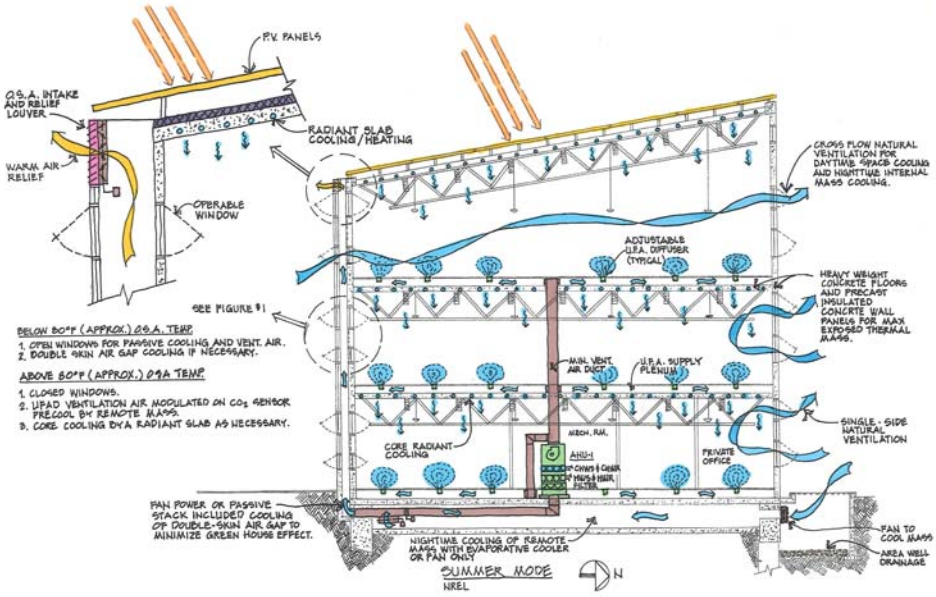
The winning team, consisting of Haselden Construction, RNL Design, and Stantec, was able to meet all four definitions for net-zero building as outlined by NREL – net-zero site energy, source energy, cost and emissions. To meet the specified budget of $64 million, the PV system will be financed through a power purchase agreement (PPA), an arrangement by which a third

Proposed design for NREL's Research Support Facility, in Golden, Colorado. Images courtesy of RNL Design

party pays all installation costs, and recovers the investment over time through monthly payments from the building owner. From the owner's perspective the payments are similar to utility payments, though rather than paying a utility they are financing a fully renewable energy source. However, Phil Macey of RNL Design points out that a key to the project's PPA is Congress' continuation of federal investment tax credits for photovoltaic systems currently pending approval in Washington. Without these tax credits it may not be possible to include the PV system as designed, jeopardizing the zero-energy goals.

John Andary, Principal with Stantec, says that reaching zero-energy goals meant that engineering solutions had to lead the design process and shape the building forms. Stantec provided early input in terms of the building's massing, facades, and wall sections, based on previous research and practice. "The key was keeping the building narrow enough for daylight to reach all areas. Once the buildings work for daylight they are easy to ventilate, and all the other aspects fall into place."

The building is configured with two 60-foot wide three- and four-story wings, with PVs integrated into the roof. A precast wall system – typically used for refrigerated buildings – includes thermal mass on the interior, a rigid insulation core, and a concrete exterior finish. Daylighting is distributed into the building with the use of light louvers from Architectural Energy Corporation, the firm that also provided the daylighting analysis. The south facades feature a double skin that will be used to preheat supply



Sketch diagram of proposed integration of systems and envelope for NREL's Research Support Facility. Image by Stantec

air in winter. The design also includes operable windows, in-slab radiant cooled ceilings, and a low-velocity displacement ventilation system integrated with a raised floor.

Due to expansive clay soil at the site, floor slabs be above grade, allowing the HVAC system to use the thermal mass of the crawl space as a "thermal labyrinth," a system that has been used successfully in England and Australia. Unlike the rock bed systems of the 1970s that were frequently plagued with mold and air quality problems, new thermal labyrinths are designed to be accessible for maintenance, with regular airflow to maintain air quality. The NREL project is scheduled for completion in 2010, and we expect the performance to be monitored and reported in detail by NREL.

A much larger zero-energy project also scheduled for completion in 2010 is the ambitious Masdar Headquarters in Abu Dhabi's master-planned city of Masdar City. The design by Chicago firms Adrian Smith + Gordon Gill Architecture, and Environmental Systems Design (ESD) will strive to create the first "large-scale, mixed-use 'positive energy' building, producing more energy than it consumes," according to a project press release. The courtyard building will be shaded by an enormous PV array and will house offices for the Masdar administration, private residences, retail, and leasable office space.

Mehdi Jalayerian, Senior Vice President and Principal for ESD's International Division, says that the initial design process was fully integrated, and the entire design team contributed to the conception of the building from the initial visioning session. "You can't look at

Proposed design for Masdar Headquarters, Abu Dhabi, United Arab Emirates. Clockwise from above: Exterior view, rooftop garden, and section. Images courtesy of Adrian Smith + Gordon Gill Architecture.

the components independently," he says. For example, the building's large canopy acts to shade the building and to provide a platform for a large array of PVs that will produce more energy than will be needed by the project. Mehdi tells us that the future design process will be facilitated through Building Information Modeling (BIM) tools such as Revit, which are becoming more effectively integrated with energy modeling tools.

The building will be one of the first to be completed in the ambitions master plan for Masdar City, a 2.3-square-mile community that will house 50,000 inhabitants. The design by Foster and Partners will create a walled city infused with new technologies that will strive to be a net-zero in terms of carbon and waste. The project's funding body recently announced plans to invest $2 billion in thin-film PV production facilities in Germany and Abu Dhabi, with an annual production capacity of 210 megawatts by 2010. It may seem surprising to see such a large investment in renewable energy technologies from an oil-rich state, but the organizers of the Masdar Initiative are clearly planning for contingencies should the income from oil subside.

As these and other zero-energy projects are completed, occupied, and monitored, we can expect to see a number useful case studies emerge the near future. By adopting net-zero energy as a goal, the building industry has raised the bar for sustainable development, and many developers and building industry professionals are eager to compete and take on these challenges. These targets are also spurring substantial investment from clean tech investors that may lead to disruptive industry breakthroughs and make these goals more achievable.

Notes

1. Zero Energy Buildings: A Critical Look at the Definition, Preprint. P. Torcellini, S. Pless, M. Deru, and D. Crawley, NREL Conference Paper August 2006. http://www.nrel.gov/docs/fy06osti/39833.pdf

2. Assessment of the Technical Potential for Achieving Zero-Energy Commercial Buildings, Preprint. B. Griffith, P. Torcellini, N. Long, D. Crawley and J. Ryan, August 2006. http://www.nrel.gov/docs/fy06osti/39830.pdf

3. Early Performance of a Green Academic Building. John H. Scofield, *ASHRAE Transactions*, June, 2002. http://www.oberlin.edu/physics/Scofield/pdf_files/ashrae-2002.pdf

4. Oberlin College Lewis Center for Environmental Studies: A Low-Energy Academic Building, Preprint. S. Pless, P. Torcellini, and J. Petersen, 2004. http://www.nrel.gov/docs/fy04osti/36273.pdf

Project Updates

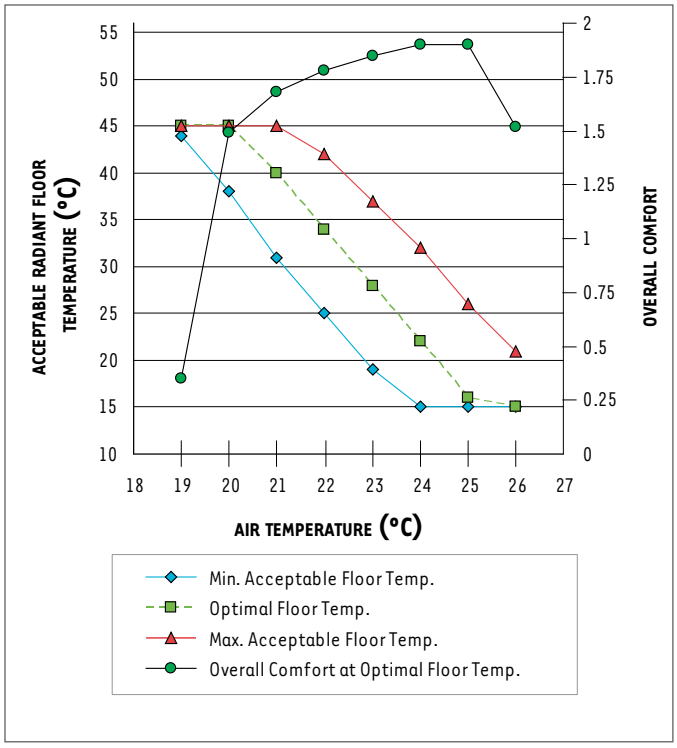
Findings from our current research

New Design and Operating Guidance for Radiant Floors and Ceilings

Researchers at CBE have conducted a series of simulations using CBE's Thermal Comfort Model to provide guidance to designers and operators of buildings with radiant systems. The simulation results show the range of acceptable floor or ceiling surface temperatures that will provide thermally comfortable conditions when applied at specific air temperatures. The results also show the surface and air temperature combinations that will provide an optimal level of comfort, and the relative overall comfort that can be achieved.

Previous research on comfort with radiant systems had been conducted in test chambers with human subjects. Due to the limitations of such tests, the studies provided information only for a limited number of temperature combinations. By using CBE's Thermal Comfort Model we were able to simulate comfort scenarios for the full range of possible operating temperatures. We also validated our model by replicating the conditions of the earlier test chamber results, and found generally good agreement between our results and the earlier studies.

This work builds on a previous CBE study on comfort with radiant ceilings distributed in a CBE Internal Report in October 2007. Our new simulation results have been documented in tabular and graphical formats, and we plan to provide a summary of these findings to CBE industry partners at our October 2008 meeting. Our findings have been submitted for peer review and publication in the journal *Buildings and Energy.*



Comfort zone for radiant floors, light office work (met 1.2, clo 0.59, RH 50%)

EPA Region 8 Headquarters was designed by CBE partners Zimmer Gunsul Frasca Architects and Syska Hennessey Group.
Photos by Robert Canfield, courtesy of ZGF

Underfloor Research Team Studies Denver EPA Building

In May CBE research specialists conducted a field study of the Environmental Protection Agency (EPA) Region 8 Headquarters in Denver, Colorado. The building provided a great opportunity for CBE to conduct research in support of two projects on underfloor air distribution (UFAD) systems – a multi-building study of UFAD systems in GSA buildings, and the development of UFAD commissioning guidelines.

For the GSA study the research team implemented the occupant IEQ survey to gather occupant feedback about the building, conducted measurements of the interior conditions, interviewed facility managers, and analyzed energy performance. The team used a mobile measurement cart similar to the one developed for the commissioning of the NY Times headquarters in 2007 (and featured in *Centerline* in 2007). The cart allowed the researchers to quickly and rapidly document room air stratification, plenum temperatures (diffuser supply air temperatures), and plenum pressures at a large number of locations in the building.

For CBE's commissioning guidelines project, funded by the California Energy Commission with additional support from EPA, the project team conducted a series of detailed plenum air leakage tests, including a GSA test protocol, and a new protocol developed at CBE described as the "multi-path" test method. CBE's multi-path method is being developed to help project teams accurately determine the amounts and types of supply plenum air leakage, based on three types of leakage that have been documented by CBE – uncontrolled airflow migrating into the room, into building cavities, and to the building exterior.

Several CBE members have involvement in the project. During the tests CBE collaborated with Charlie Johnson and Jim Blackledge of Engineered Interiors Group (EIG), one of the subcontractors for the project. The EPA headquarters was designed by CBE partners Zimmer Gunsul Frasca Architects and Syska Hennessey Group.

In August members of CBE's UFAD research team will go to Chicago to conduct a field study of GSA's Clark Street Federal Office Building.

New Occupant Survey Modules for Schools, Healthcare, and Acoustical Performance

Our survey research team has been busy this summer with a number of new projects. In April we started a new project to study acoustical satisfaction in offices and healthcare facilities. One goal of the project, which we are now conducting in collaboration with Ken Roy, PhD, of Armstrong, is to better understand occupants' expectations regarding acoustics in the spaces they occupy, and to study the distinction between hearing, intelligibility and distraction. We have already created the new acoustics survey module and plan to implement pilot surveys in one or more hospitals this fall.

As part of our effort to expand use of our occupant survey beyond office buildings, we have created new modules for post-occupancy evaluation of schools, healthcare, multi-unit residential, and laboratory facilities. We are planning a concentrated effort this fall to widely implement the schools module as part of a new study on IEQ in schools headed by Graduate Student Researcher Lindsay Baker. As part of a special promotion we will implement the survey in schools for no cost in the fall. If you know of a school that would be a good candidate for this promotion, please see our website for more information, at www.berkeley.edu/schools. Also, our multi-residential module, being developed in collaboration with Kim Fowler of Pacific Northwest National Laboratory, will be available for partners' use by October.

We are using a pilot version of the school module in our ongoing project to survey several buildings on the AIA's list of the top ten green buildings. We have implemented the pilot module at the Sidwell Friends Middle School in Washington, DC (Kieran Timberlake Associates) and will do the same this fall at the Ben Franklin Elementary School, Kirkland, WA (Mahlum Architects). We also recently surveyed the headquarters for Heifer International (Polk Stanley Rowland Curzon Porter Architects, Ltd.), on AIA's top ten list for 2007.

We have also completed a study of the survey's usefulness as a tool based on a four-year survey project with GSA. We found that over a third of the buildings (14 out of 38) that used the occupant survey more than once saw an increase in overall building satisfaction. In addition, 20 of the 38 buildings showed improvement in half or more of the IEQ categories tested. Building managers reported satisfaction with all of the survey's features but found the occupant comments and responses to detailed "branching" questions to be the most useful.

Image © De Anza College

Image © David Rose

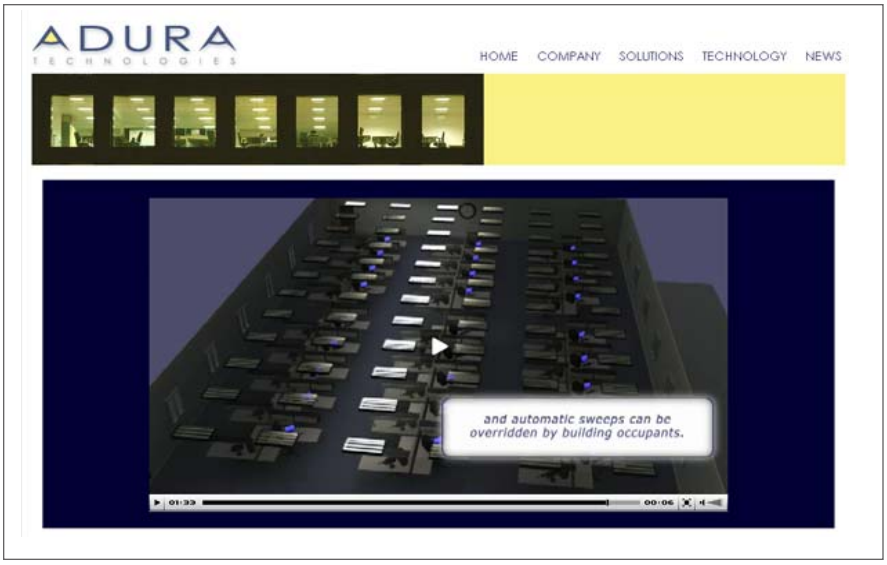
CBE plans to implement a new survey module for schools in fall of 2008. Top, Kirsch Center for Environmental Studies, De Anza College, one of the highest performing buildings in the CBE survey database. Bottom, Chartwell School, a zero-electricity school designed by EHDD Architecture.

Adura Technologies Secures Venture Funding

Adura Technologies, a provider of energy efficient lighting control solutions, recently secured venture capital investment from Claremont Creek Ventures of Oakland, California. Adura's core technology was initially developed at CBE by Research Specialist Charlie Huizenga, one of three founders of the company, who now serves as its Chief Technology Officer.

This investment is characteristic of Claremont Creek Ventures, as the company typically seeks opportunities beyond Silicon Valley, making investments at leading institutions including UC Berkeley and the National Laboratories in Livermore and Berkeley. This infusion of capital has enabled Adura to hire new staff, and the company has grown from four employees to twelve in a period of only three months. With recruiting assistance from Claremont Creek, the company has made several strategic hires of individuals having more than 20 years experience in software architecture, hardware design and marketing, and business development in the lighting industry.

This growth has helped Adura broaden its capabilities. Charlie Huizenga explains, "We are expanding our product line in terms of hardware and software, and will soon roll-out an enterprise software solution that is scalable to large facilities and campuses." Adura's next product revision, expected in January of 2009, will include integration with light level and motion sensors, new scheduling features, data visualization tools, and the ability to report lamp and ballast failures. With this release Adura expects to be well positioned to serve large institutional and commercial building owners.



An animated video illustrates the capabilities of the wireless lighting control system from Adura Technologies. Source: http://www.aduratech.com

Adura is monitoring a number of pilot installations, including two at UC Berkeley libraries, at Webcor Builders' offices in Hayward, at the California Energy Commission in Sacramento, and in a parking garage at a Silicon Valley corporate campus. Adura's project at the Alameda County Water District, a collaboration with Lawrence Berkeley National Laboratory and PG&E, is testing Adura's integrated demand response (DR) functions. When demands on the electrical grid reach certain thresholds, the system is programmed to automatically shed lighting loads by 40-60%, with minimal impact on building occupants.

The research staff at CBE is excited by Adura's continuing success. CBE Associate Director Gail Brager points out that Adura is a great example of CBE research being applied in practice. "That is what drives our work, none of us is interested in seeing our research sit on a shelf," she explains.

More info is available at:
http://www.aduratech.com
http://www.claremontvc.com

Partner News

ENR Reports on Green Building Revenues, and related partner news

Engineering News-Record (ENR) recently published lists of the top 100 design firms, and the top 50 construction firms, in terms of revenues for green projects. The lists were compiled based on surveys of industry firms, and counted green projects that were accredited by a third-party organization such as the USGBC or the Green Building Initiative.

Collectively the 100 design firms reported revenues of $1.74 billion from green design, making up just over 7% of the revenues for the group, based on figures from 2007. The strongest sector for green design is for commercial offices, making up 19.5% of the firms' green revenues. **HOK** was the top firm in the list, with green revenues of $151 million, representing 23% of the firm's total. Other CBE industry partners in the list include **ZGF Architects** (#11), **KlingStubbins** (#19) **Syska Hennessey Group** (#49) and **Stantec** (#85).

The 50 top green contractors reported green project revenues of close to $9 billion, representing 15% of their total contracting revenues, based on 2006 figures. Education was the strongest green sector, representing 20% of revenues, followed by commercial offices at 18.5%. CBE industry partner **Swinterton Inc.** was #4 in the list, with $628 million in green project revenues, representing 37% of the firm's total.

Reflecting the growing market for green building design services, **KlingStubbins** has created new positions for Director of Sustainability and Director of Practice Technology. Jonathan A. Weiss, AIA, NCARB, LEED AP, who presented at CBE's Industry Advisory Board meeting in April 2008, will take on the role of Director of Sustainability, providing expertise and information on LEED certification, sustainable design technologies, events and projects on a firm-wide basis. He will also coordinate the efforts of sustainable design leaders in each of the firm's six offices. As Director of Practice Technology, Craig A. Barbieri, AIA Associate, will be responsible for identifying and implementing best practice and cutting-edge technologies that will enhance KlingStubbins' design process.

Jonathan A. Weiss, left, and Craig A. Barbieri

CBE is pleased to announce a new partner joining in October, **Coherent Structures** of Tempe, Arizona. Coherent Structures is a specialty subcontractor that provides sales and installation of flexible, expandable plug-and-play solutions for data, power and HVAC distribution. The firm represents several building technology products including raised access floors, underfloor air, modular voice/data and power, movable walls and floor coverings. The firm is also a provider of Building Technology Platform® (BTP) and provides products from Tate Access Floors, Johnson Controls, Communications Integrators Inc (CII) and Kwik-Wall. More information will be available soon (site under development) at http://www.costruct.com.

Interview

Kirstin Weeks, Energy and Building Ecology Specialist, Arup
MS in Architecture in Building Science, UC Berkeley 2007

What were you doing before you started at Arup?
Between graduation at Berkeley and starting here in April I was working on several things. For my thesis I studied the thermal performance of green roofs on the Nueva School in Hillsborough. I found that the green roofs did perform well, staying cooler in the day, and warmer at night. I presented my findings at the National Green Roof Conference in May. While writing my thesis, I also worked at Rana Creek Living Architecture. Afterwards, I spent several months conducting retro-commissioning projects with Federspiel Controls and installing photovoltaic systems with Sun Light and Power.

Does your work at Arup involve climbing on building roofs?
So far it does not, although there is a solar volunteer group in the office. I am in the buildings group, and am doing sustainability consulting on a wide variety of projects.

Arup has a broad range of practices. How do you find working in such a large organization?
It's great to be able to work in an interdisciplinary way inside your own office. I also appreciate the international aspect, both in terms of projects and colleagues. We have an amazing intranet system that connects the entire firm of about ten thousand internationally. If I am working on an unfamiliar topic, I send a post on our skills network and get lots of useful responses. I can also search for people with specific experience on the people pages, kind of like a professional Facebook.

What types of projects have you been working on?
A whole collection. One project is a new office building for a Silicon Valley company. We're really pushing on load reduction and water recycling, with goals of net-zero energy and water use. In another project, we are providing advice on waste-to-energy technologies. We have projects improving energy performance of existing buildings, and I may also be doing some more research on green roof energy impacts. The most recent addition to my list is sustainability consulting on a feasibility study for a large resort in Las Vegas.

Can such a project be sustainable?
My opinion is that people are going to build these projects one way or another, so I see it as an opportunity, though I know that some people don't agree. Because of its size, small efficiency improvements mean significant savings. Given the climate, we are going to focus on potable water use reduction measures like using native plants and reusing gray water, and on minimizing cooling energy.

You come from a grass-roots background. How do you like working in a corporate setting?
I've been very impressed with Arup as an organization so far. There are so many resources, and they are quite well-connected. I expected to like the types of work I would get to do, but I have really appreciated the company culture and the people I work with as well. I will admit that it took me a little while to get my bearings, particularly being a non-engineer in a group of engineers, and having a lot of responsibility from the beginning. But I've settled in now, and find myself taking on more and more projects because there is so much exciting work going on. I'm also looking forward to the opportunity to explore the larger Arup world at some point on a short-term transfer to one or more of the other offices – perhaps Amsterdam, Copenhagen, London, or maybe Singapore or Tokyo. They all sound pretty good to me!

Industry Partners at the Center for the Built Environment

CBE's research is supported and guided by CBE's consortium of industry partners, a diverse group of leaders in the building industry. The Center's membership includes the following firms and organizations (as of August 2008):

Armstrong World Industries
Arup*
California Energy Commission
Charles M. Salter Associates
Coherent Structures
Cohos Evamy
CPP
EHDD Architecture
Engineered Interiors Group (EIG)
Environmental Systems Design
Flack + Kurtz
Glumac
Haworth
HOK
Johnson Controls*
KlingStubbins
Larson Binkley
Pacific Gas & Electric Company
Price Industries
RTKL Associates
Skidmore, Owings & Merrill
Stantec
Steelcase
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- Taylor Engineering
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- Guttmann & Blaevoet
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