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Counting Carbon
Understanding Carbon Footprints of Buildings

HISTORICALLY THE AMOUNT OF CO_2 in the atmosphere hovered just under 300 parts per million (ppm), but it's now approaching 400 ppm. CO_2 is not the most powerful of the greenhouse gases on a per-molecule basis—not by a long shot—but it is by far the most common and most significant of those generated by humans. Various targets have been proposed as acceptable levels of CO_2, most famously 450 ppm, above which the resultant temperature rise would likely cause extreme disruption to Earth's ecological and social systems. Many policy initiatives give lip service to this goal, but current actions are inadequate to reach it. Based on more recent scientific findings, author Bill McKibben has launched a campaign to reset that target at 350 ppm, a point we passed in 1988. That's a much more ambitious goal, but one that, if achieved, would more likely lead to a future climate that resembles our own.

Regardless of the target, there is general agreement that we have to slow the growth in carbon emissions and then shrink those emissions. As researchers seek ways to reduce human-generated carbon emissions at a cost that society will accept, buildings consistently emerge as the best opportunity. "Buildings are the biggest and lowest-hanging fruit in dealing with greenhouse gases in the atmosphere," says architect and researcher Hal Levin, who chairs the Project Committee on Carbon Emissions Tool Development of the American Society of Heating, Refrigerating, and Air-Condi-

(continued on p. 10)

Volumes representing one metric ton of three common building materials (small cubes), along with the volume of the carbon dioxide typically released to produce those materials (larger cubes). Rendering: Mithun

In This Issue

Quote of the month:

"We spent a long time figuring out the carbon associated with moving a cubic yard of soil."

– Sean Cryan of Mithun on calculating a building's carbon footprint

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From the Editors

Get Ready for Fuel Switching

In regions of the country that rely primarily on heating oil or propane for heat, including the Northeast and parts of the Upper Midwest, something pretty surprising has happened over the past six months. The cost of delivered heat from these fuels has risen above that of electricity—even when that electricity is used for electric-resistance heating in baseboard radiators. (For more on comparing fuel costs, see the BackPage Primer on page 16.) Electric-resistance heat can sometimes be cheaper than even natural gas, particularly for buildings with old furnaces and leaky, poorly insulated ducts. If a heat pump is used to double or triple the efficiency of electric heating, heating with electricity is almost always cheaper than using natural gas, oil, or propane (though purchasing and installing a heat pump is expensive).

Barring a significant price drop for heating oil or propane, and if the price of natural gas keeps rising faster than that of electricity (which is regulated), lots of buildings may be switching from their standard heating fuels to electric heat this coming winter—which could wreak havoc in the utility industry.

In recent decades, the peak demand for electricity at many utility companies has shifted from winter to summer, due largely to increases in air-conditioning. That trend could reverse in cold regions if customers switch from oil or gas heating to electricity. Small heating loads could convert to electricity very quickly as homeowners turn off their oil- or gas-fired furnaces and boilers and install portable electric heaters, electric baseboard heat, or heat pumps. Setting up a portable space heater can be very inexpensive and rarely involves an electrician—but it can overload electrical circuits. The incidence of house fires could increase dramatically this coming winter.

There is little evidence that utility companies, public utility commissions, or public officials are paying attention to this trend, but it wouldn't surprise me to see electric capacity shortages—and even brownouts or rolling blackouts—in places like northern New England this winter. As electricity demand grows, so too will the environmental impacts of power generation—especially if shortfalls are made up by power plants in the Midwest, which are predominantly coal-fired.

To head off this surge in electricity use, the utility industry should dust off its demand-side management programs and ramp them up—supporting such programs as lighting upgrades, appliance replacement, and off-peak electricity rates for water heating. Energy conservation programs should expand to address building envelope improvements, not just electrical loads. Adding insulation and high-performance storm windows will become common strategies for reducing *electricity* use. Utility companies and state energy offices should ramp up public education campaigns urging homeowners to invest in energy conservation and warning of the potential for space heaters to start house fires.

Over time, electricity prices will rise, partly reflecting the rising cost of generating power and partly responding to the laws of supply and demand. Because the utility industry is regulated, however, such price increases occur fairly slowly. It's unlikely that electricity prices can increase quickly enough to prevent widespread fuel switching.

– Alex Wilson

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Massachusetts Code Requirements for Air Barriers

There is misinformation in the article on air barriers [see *EBN* Vol. 17, No. 6]. Massachusetts has a requirement of 0.004 cfm/ft^2 @ 75 Pa for materials, not assemblies. Big difference. Massachusetts' requirements are the same as the National Building Code of Canada. Massachusetts does not have a requirement for the airtightness of assemblies or whole buildings.

The comment on Massachusetts requiring a hole in the top of elevator shafts is also wrong. National elevator codes in the U.S. require a louver to vent smoke at the top of elevator shafts. Massachusetts rectified the problem by requiring an airtight operable damper in the closed position linked to the fire-alarm system.

– Wagdy Anis, FAIA
Wiss, Janney, Elstner Associates
Cambridge, Massachusetts

I think you have an error in the article on air sealing. The article mentions "a very stringent requirement for air barrier assemblies in commercial buildings of 0.004 cfm/ft^2" in Massachusetts—and speculates as to whether somebody goofed up in the drafting. In fact the stringent requirement applies to air barrier components rather than assemblies.

So far as the assembly is concerned, the Massachusetts commercial code is reduced to adjectives—"continuous" and "air-tight," "durable or maintainable," and capable of withstanding lateral pressure "without displacement or damage." All laudable, but not measurable. The difference between a component specification and the assembly performance is fundamentally tied to how well this string of adjectives is implemented and enforcement of how they are interpreted. As John Straube and others have noted, a performance standard and a testing protocol is where we ultimately need to be.

– Bruce Coldham, AIA
Coldham & Hartman Architects
Amherst, Massachusetts

Editors' response: *Coming from the drafter of the Massachusetts code and an authority on air barriers, Wagdy Anis's clarification is much appreciated. We are not the first to point out, though, that the language can be misleading. In any case, including materials meeting 0.004 cfm/ft^2 @ 75 Pa is easy; providing continuity is tough. We second the call for a performance standard and testing protocol.*

What's Happening

Cities Mandate LEED But Not Certification

Washington, D.C., started it all in 2006 with legislation that required certain privately owned buildings to meet LEED standards. Boston quickly followed suit in early 2007, and Los Angeles and Dallas have both passed similar ordinances (see *EBN* Vol. 17, No. 6). Although the ordinances vary in scope and timeframe as well as stringency, none of them requires buildings to achieve actual LEED certification. This makes the cities responsible for examining building plans for green attributes, presenting financial and organizational challenges.

Although the U.S. Green Building Council (USGBC), the organization behind the LEED Rating System, has noted that LEED-certifiable buildings may not perform as well as LEED-certified buildings (see *EBN* Vol. 17, No. 4), for municipalities, requiring certification presents political and legal challenges. According to Krista Kline, the urban planning and design coordinator for Los Angeles, the City did not require certification because it is "expensive and time-consuming,

Photo: Lawrence Anderson

The 236-residence Luma building in Los Angeles, a project of development company South Group, achieved LEED Gold in 2008. As of May 2008, all privately owned buildings in the city with more than 50 units or over 50,000 ft^2 (4,600 m^2) must meet LEED Certified standards.

and we wanted buy-in from the development community" for the overall green goals. Projects that pursue LEED Silver certification or higher are eligible for expedited permitting that saves between one and six months in the process. Kline noted that requiring certification would make building permits or occupancy certificates contingent on the decisions of USGBC. That situation is legally untenable, explains Kline. "We didn't want to give USGBC control over our land use."

Although municipalities could incorporate green building requirements similar to LEED into their building codes, the rating system offers both recognition and choice for developers. "People like LEED as a standard," said Zaida Basora, AIA, assistant director of administration and architectural services for Dallas and a past board member for USGBC, "so we felt that it was better to go ahead and use it." Using LEED as a standard also makes it easy for developers to pursue certification for buildings if they want to do so, since many of the documentation requirements have already been met. In addition to its popularity and marketing cachet, LEED allows developers to choose which credits to pursue. "We wanted to give flexibility to the development community and didn't want to quash creativity," said Kline.

Without certification through USGBC, however, cities must find ways to verify that buildings aren't ducking requirements. In Boston, where buildings larger than 50,000 ft^2 (4,600 m^2) must meet LEED standards at the Certified level, an interagency permit-review process has evolved to encourage integrated design and ensure that large buildings are meeting green requirements. All members of a project team meet with representatives from several City agencies before a project is submitted for permit review as well as throughout the design process. The team must submit documentation to the City, approved by a LEED accredited professional (LEED-AP), that shows a project has met LEED requirements.

Coordinating several city agencies as well as project team members represents a shift from the typical permit review process and has not been simple. "There was a learning curve, and it's challenging, but it's a steadily improving thing," said Barbra Batshalom, executive director of The Green Roundtable in Boston, a nonprofit. The biggest challenge, according to Batshalom, was educating city staff about green building and the LEED checklist so that all projects could receive similar assessments. The result has been a more streamlined, uniform review process.

In Los Angeles, the City had to figure out—quickly—how to include green building review in its permit process with little added funding. For now, front-line staff members are being trained to look for a LEED-AP on the project team and the basic requirements for the LEED checklist. Higher-level staff members are being trained to read the checklist and plans more closely. "We know it's not perfect," Kline said of this limited review, "but it's what we could come up with without being punitive." To ensure green requirements are being met, every seventh project will be audited by USGBC; if the city finds a lot of projects would not have been certified, it will consider changing the ordinance. Both Los Angeles and Dallas plan to track energy and water use in the new buildings to see if the green building requirements are making a difference.

– Allyson Wendt

For More Information:

Boston Redevelopment Authority
www.cityofboston.gov/bra

Dallas Green Building Program
www.greendallas.net

Los Angeles Environmental Affairs Department
www.lacity.org/ead/environmentla/

Newsbriefs

Green Cleaning Required in LEED for Existing Buildings—The U.S. Green Building Council (USGBC) first released LEED for Existing Buildings: Operations and Maintenance (LEED-EB) in November 2007. The reference guide for the system is due out in June 2008, and, as of July 1, all projects seeking certification must register under the new version. Among the many changes are the addition of a green cleaning prerequisite and two points in a green cleaning credit requiring verification of custodial effectiveness. According to David Holly of the Ashkin Group, a green cleaning consulting firm, the prerequisite is a sign that the importance of cleaning is gaining recognition. The new points, which are awarded for achieving a certain level of cleanliness, also represent a shift away from thinking about green cleaning as a set of products towards thinking about it as a set of best practices that include making a cleaning plan, using less-toxic chemicals, and using energy-efficient equipment. To achieve the performance-based points, a building must meet standards set by APPA, which provides guidelines for educational facilities. The Ashkin Group is working with APPA and USGBC to adapt the guidelines to other types of facilities; the resulting guidance will appear in the LEED-EB reference guide.

Affordable Housing Benefits from IRS Rule Change on Solar Tax Credit—In May 2008, the Internal Revenue Service (IRS) issued a letter clarifying the rules for using the federal solar investment tax credit in conjunction with tax-exempt bond financing in affordable housing projects. The tax credit provides incentives for businesses purchasing solar arrays; it is set to expire at the end of 2008, although bills designed to extend the credit are still making their way through Congress. Before this ruling, projects using tax-exempt bond financing could apply for half the value of the solar investment tax credit; the new rule allows these projects to apply for the full credit if the project team can prove that the bond funds were not used to purchase the solar equipment. Since it will make solar arrays more affordable, this ruling opens the door for many affordable housing projects to pursue the technology. This, in turn, will help them meet the green building requirements often associated with state funding for affordable housing (see *EBN* Vol. 17, No. 4).

Nation's First LEED Platinum Affordable Housing Built in Massachusetts—On Martha's Vineyard, an island where affordable housing is in short supply, nine single-family, detached, green homes were recently developed and funded by the Island Affordable Housing Fund and sold for 25%–50% of the median home sale price on the island; one additional home in the cluster was sold at the market rate. The homes, collectively known as Jenney Way, were designed and built by South Mountain Company with green strategies, including white cedar siding certified to Forest Stewardship Council standards, high-performance windows tuned to building orientation, and tankless water heaters. Because of high insulation levels and air-sealing, heating costs for the homes are expected to be 60% below those of comparable houses built to code, allowing use of high-efficiency, direct-vent space heaters instead of central heating systems. The project team faced a choice between preserving trees on the site and providing solar access for all of the homes, and decided to preserve trees and put a 1.5-kilowatt photovoltaic array on just four homes. These four homes achieved Platinum ratings in the LEED for Homes program, the first single-family affordable housing units to do so.

Facility Operating Costs Increase Despite Drop in Energy Consumption—According to a recent report by the International Facility Management Association (IFMA), rising utility costs have led to increased overall operating costs even as energy consumption has dropped. The report, "Benchmarks V: Annual Facility Costs," pulls data from over 1,000 survey responses from IFMA members. Operating costs have risen 10% since 2004, according to the report, thanks in part to a 19% increase in utility costs since 2006 but despite a decrease in energy consumption; average electricity consumption dropped from 93 kBtu/ft^2 (1,060 MJ/m^2) in 2006 to 81 kBtu/ft^2 (920 MJ/m^2) in 2007. Natural gas consumption has remained constant at an average of 35 kBtu/ft^2 (400 MJ/m^2). According to IFMA, increases in energy costs have led to energy efficiency measures, decreasing consumption. Costs tied to some environmental initiatives have also risen: for example, the cost of recycling doubled from \$0.02/ft^2 to \$0.04/ft^2 (\$0.21/m^2 to \$0.43/m^2) since 2004. The 2008 report (which does not include 2004–2005 data for comparison) is available for \$120 at www.ifma.org/tools/research/benchmarks_v.cfm/.

Plastic Water Piping Leads to Greater Corrosion, Lead Levels—Despite the reduced use of metals in potable-water piping systems using plastic pipe such as PEX and CPVC, recent research has found that the bacterial environments in those pipes can lead to higher content of metals, including lead, than in systems using copper pipe. A paper published in *Environmental Science & Technology* examined interactions among several variables: pipes of various kinds, water treated with chloramine (commonly used by water utilities as an alternative to chlorine), pH, phosphates (often added to water as an anti-corrosive), and nitrifying bacteria. While most water-test protocols involve flushing pipes before collecting a sample, the researchers studied stagnant "first draw" water that had been sitting in pipes. They found that the greater inertness of plastic pipe allows nitrifying bacteria to create more acidic conditions, which in turn leach more lead, copper, and zinc from brass fittings and fixtures. That leaching created lead contamination exceeding U.S. Environmental Protection Agency standards, as well as potentially causing premature failure of fittings. Copper pipe inhibits those same

Four of the 1,200-ft^2 (110-m^2), two-bedroom homes at Jenney Way on Martha's Vineyard have earned LEED Platinum, the first single-family affordable houses to do so. Photo: Randi Baird bacteria, resulting in less leaching. While the findings might be a reason to avoid plastic piping, or at least run the water before using it, the researchers declined to make firm recommendations.

LEED Exam Required of ASU Real Estate Students—Students entering the Master of Real Estate Development (MRED) program at Arizona State University in the 2008–2009 academic year will be required to study the U.S. Green Building Council's LEED Rating System and take the LEED Professional Accreditation exam. Begun in 2006, the program is one of only five in the nation to offer the master's-level degree. According to its director, R. Nicholas Loope, FAIA, the university has been incorporating environmental awareness into its curricula and physical plant. The MRED program has added more focus on sustainability each year, Loope said. About a third of the program's students volunteered to study LEED last year, and all students visited the LEED Gold Solaire building in New York City. A thorough understanding of green building provided by LEED training, Loope said, helps graduates understand how to assemble the multifaceted team needed to tackle a complex green building project.

Bike Sharing Comes to the U.S.—SmartBike, a bike-sharing program owned by Clear Channel Outdoor, has been available in Europe since its start in Rennes, France, in 1998. Having spread to ten European cities, the program is now making its U.S. debut in Washington, D.C., with 120 bicycles available in ten locations in the downtown area. The program, a partnership between the city's Department of Transportation and SmartBike, is membership based: users pay an annual fee of $40 to obtain a membership card that allows them to unlock bikes, which they can use for up to three hours at a time and return to any location. Several other U.S. cities, including San Francisco and Philadelphia, are considering similar programs. More information is available at www.smartbikedc.com

Photo: Jonathan Smith

Members of the SmartBike program in Washington can pick up a bike at a rental station like this one and use it for up to three hours.

Green Real Estate Certification Available—Promoting green building can be "extremely profitable" for real-estate professionals, according to one educational company, illustrating a trend in a market reeling from the subprime-mortage crisis. Tampa-based Green Real Estate Education, a company that hosts courses for real estate agents, house inspectors, mortgage officers, and appraisers, is now offering a three-hour green building course that fulfills continuing education requirements for real estate licensees in numerous states. The course is intended to inform participants about green building materials and techniques, global climate issues, renewable energy, air quality, and marketing of green features, among other subjects. Kerry Mitchell, Green Real Estate Education's president, acknowledges that the course cannot be comprehensive: "I don't think you can cover [the course's topics] in three days," she said. Mitchell says the goal is to provide an overview, teaching real-estate professionals "how not to greenwash, not to call a house green if [the seller has] done one or two upgrades," for example. She also hopes to train real estate agents to offer guidance on improving salability with green improvements. Those who complete the course—over 3,100 so far—may call themselves Green Certified Real Estate Professionals.

Los Angeles Limits "Mansionization"—In what may be a sign of backlash against the decades-long trend toward larger houses, the Los Angeles city council unanimously passed an ordinance in May 2008 limiting the footprints of new and renovated houses in many neighborhoods—affecting about 304,000 lots—to about half their lot size. The Neighborhood Character Ordinance, commonly known as the "mansionization ordinance," also limits the size of garages to 400 ft^2 (37 m^2), which can hold two cars. The law is intended to halt the construction of out-of-scale houses in older neighborhoods and the loss of privacy that results from residences being built up to property lines, but also has environmental benefits, such as limiting the growth of hardscape. While some homeowners, builders, and real-estate professionals predictably opposed the measure, other critics say it isn't tough enough. In fact, the City's planning department says 70% of houses built in recent years would not have been affected had the rules been in place, and many houses could still be doubled in size.

Product News & Reviews

An Affordable Heat-Pump Water-Heater Retrofit

The engineers at AirGenerate (previously Beyond Pollution) appear to have done something remarkable: create an affordable, effective, heat-pump water heater that can be retrofit onto a conventional gas or electric water heater, more than doubling the energy performance compared with a standard electric water heater. The AirTap A7 water heater has a rated output of 7,000 Btu/hour (7.4 MJ/hour), a first-hour rating of 42.5 gallons (160 l), a maximum water temperature of 135°F (57°C), an efficiency of 240% (coefficient of performance of 2.4), and an energy factor of 2.11. (Energy factor is a standardized measure of performance of water heaters; the higher the number, the better.) All this is in a unit that measures only 18" wide by 14" deep by 14" high (460 x 360 x 360 mm), weighs only 48 pounds (22 kg), and sits on top of a standard water heater. The list price is $499. The energy factor and first-hour rating of the AirTap are certified by GAMA (previously the Gas Appliance Manufacturers Association and now a broader association of appliance and equipment manufacturers).

Heat-pump water heaters have always been a good idea, but most efforts to design, build, and market them have failed. With today's high energy prices, however, consumers should be more receptive to heat-pump water heaters, according to Harvey Sachs, Ph.D., the buildings program director at the American Council for an Energy-Efficient Economy. "The economic savings potential is so much greater than before, with the run-up of energy prices," Sachs told *EBN*.

AirGenerate initially produced its AirTap A7 water-heater kit in Houston, Texas. After selling a few hundred units in late 2007, the company began sourcing the product from an offshore supplier. The outsourcing of production will allow the company to significantly ramp up production. The first of the new (offshore-manufactured) AirTap units were received in January 2008, and about 200 had been sold through May 2008. Of 400 units scheduled to arrive in June, almost all were pre-sold by the end of May, according to Sunil Sinha, chief scientist at AirGenerate.

Skyland Falls, a Tennessee developer, has installed 30 AirTap units since January 2008 in a 70-unit subdivision currently under construction. Houses in the subdivision are 2,000 ft^2 (190 m^2) each and sell for an average of $230,000. "The AirTap is doing a fantastic job," according to Skyland Falls president Gary Alexander, who told *EBN* that he also intends to use the product in a 100-unit subdivision that is in the works.

Skyland Falls is installing the AirTap units on new, 40- and 50-gallon (150 and 190 l) electric water heaters, set up so that the standard electric element provides a backup. The controls on the water heater are set so that the standard element will come on at 100°F (38°C), while the AirTap is set to heat water to 130°F (54°C). If the heat-pump module stops working for some reason, the conventional electric-resistance element will still keep the water warm, but homeowners will notice the problem and contact Skyland Falls. The company will go out and troubleshoot the problem—but it probably won't be an emergency call, since the water will remain at least warm. "Since this is a new system, we wanted a backup," Alexander told *EBN*. With some units in place for four months, Skyland Falls has yet to receive a call.

Installation is fairly easy—even feasible for skilled do-it-yourselfers. According to Alexander, one of his employees can install three AirTap units in a day. Skyland Falls installs the water heaters in utility closets with the outflow air from the AirTap heat pump vented into the adjacent garage; this setup provides some cooling to the garage, which is beneficial in the summer. Of the 30 units so far installed, only one unit has had a problem—a loose bolt that Skyland Falls easily fixed. In late spring 2008, the all-electric homes were using less than $2 per day for energy, according to Alexander, though how much of this is for water heating is not known.

Other heat-pump water heaters will be coming along soon. General Electric expects to introduce its Hybrid Electric Water Heater in late 2009. The model will sell for about $400 more than a standard, 50-gallon (190-l) electric water heater but save an average family $250 per year with electricity at 10 cents per kWh, the company claims. According to Sachs, a second major player is likely to soon announce another heat-pump water heater. Having major manufacturers enter the heat-pump

Photo: AirGenerate

Standard fittings and simple connections are used to install an AirTap heat pump unit onto a standard electric or gas-fired water heater.

water-heater market, according to Sachs, will give this sort of product legitimacy. "[AirTap] may be able to ride the wake instead of having to break through the ocean waves," he said.

In addition to the AirTap A7 model, AirGenerate is introducing a larger 12,000 Btu/hour model in August 2008, according to Sinha. This model will offer the same energy factor of 2.11 but will have a first-hour rating of 60 gallons (230 l).

– Alex Wilson

For More Information:

AirGenerate, LLC
Houston, Texas
713-574-6729
www.airgenerate.com

Forbo's Marmoleum Composition Tile is thinner and less expensive than its standard tiles, making it competitive with vinyl composition tile. Photo: Forbo Flooring

Forbo Offering Marmoleum Composition Tile

Forbo's Marmoleum sheet and tile linoleum products have been available in the U.S. for over ten years, in that time becoming popular for their attractive appearance, biobased content, low maintenance requirements, and good environmental performance (see *EBN* Vol. 7, No. 9). In some markets that are more sensitive to first costs, such as K-12 schools, however, Marmoleum has had trouble competing with the less-expensive industry standard, vinyl composition tile (VCT), which comes with concerns about PVC and pthalates as well as the chemical emissions from the repeated stripping and waxing cycles required for maintenance.

To compete in these markets, Forbo has introduced Marmoleum Composition Tile (MCT), a thinner, less-expensive version of its product that is sold in 13" by 13" (330 x 330 mm) tiles. The company has also taken the innovative step of working with its affiliated distributors to guarantee an installed price of \$2.75–\$3.45/ft^2 (\$29–\$37/m^2), compared to around \$5/ft^2 (\$54/m^2) for its standard Marmoleum tile. By comparison, average installed costs for VCT from Armstrong range from \$2–\$7/ft^2 (\$22–\$75/m^2), with the bulk of its products falling below \$2.99/ft^2. Armstrong's biobased Migrations tile is expected to cost \$2.50–\$3/ft^2 (\$27–\$32/m^2) before installation (see *EBN* Vol. 16, No. 12).

The only difference between MCT and standard Marmoleum tiles is the thickness. MCT is 2 mm (0.08 inches) thick, while the standard product is 2.5 mm (0.1 inches) thick; most VCT is 1/8" (3.2 mm) thick. Common to all of these products is their sensitivity to imperfections in the floor's substrate. The thinness of MCT may cause the product to be even more sensitive to an uneven or cracked substrate, making floor preparation important.

Both Marmoleum products consist of a linoleum tile with a polyester backing, and both use Forbo's water-based TopShield finish. Unlike most commercial VCT products, MCT and Marmoleum do not require additional finishing after installation, or continual stripping and waxing. According to Tim Cole, director of environmental initiatives and product development for Forbo, the company developed TopShield in 2005 in response to customer complaints that Marmoleum was not easy enough to maintain. The factory-applied finish is applied in two layers and the bottom one cured with UV light to be very hard. If the softer top coat is damaged, the floor can be scrubbed and a new coat of TopShield applied in the field.

In 2007, Forbo set up a pilot composting program in the Mid-Atlantic region. Product scraps from installation and manufacturing are collected and sent to regional compost facilities. The program has diverted nearly 20 tons of solid waste per month from landfills and has reduced the amount of solid waste from the distribution facility by 85%.

– Allyson Wendt

For More Information:

Forbo Flooring North America
www.forboflooringna.com

Product Briefs

Nanotech Textile Finish Gets (Mixed) Environmental Ratings— The Victor Group, a major manufacturer of interior textiles, has become the exclusive distributor of GreenShield finishing from G3 Technology Innovations, ensuring a wide market for the nanotechnology product. Instead of coating textiles with large quantities of fluorocarbons, which provide water repellency and other benefits, GreenShield uses tiny nanoparticles of fluorocarbons, giving it the same functionality with only one-eighth as much of the chemical, says the company (see *EBN* Vol. 17, No. 3). That reduction in fluorocarbons, which are associated with various health and environmental risks, has earned GreenShield several environmental ratings—all of them mixed. In 2007 GreenShield earned Indoor Advantage Gold from Scientific Certification Systems for low indoor emissions, although emissions are not among the chief concerns with fluorocarbons. More recently, Victor's Eco Intelligent Polyester fabrics with GreenShield earned a Silver rating in the Cradle to Cradle program. However, the same textile *without* the GreenShield finish (or any finish) earned a higher Gold rating, reflecting the risk of toxicity introduced to the product by GreenShield. Information on product availability is at www.victor-innovatex.com.

Soy-Based Composite Introduced in Waterless Urinal—The Waterless Company has introduced a new version of its pioneering waterless urinal, using 30% soy resin in place of a portion of the petrochemical resin typically used. Noting the potential water savings of a waterless urinal, Niki Bradley, marketing director for Waterless, said, "We wanted to develop a more sustainable, environmentally friendly way to manufacture them as well." The company emphasized that its fiberglass urinals using soy resin would appear and work no differently from its other waterless urinals, although they will cost a little more. While the move to replace petrochemicals with rapidly renewable agricultural content is, on its surface, laudable, life-cycle data on other building products using soy resins shows that the shift may not reduce overall environmental impacts, due to the effects on biodiversity and eutrophication, among other agricultural impacts. The percentage of soy resin will likely increase as the manufacturing technology evolves, according to Waterless. More information is at www.waterless.com.

Furniture Gets Multiple-Attribute Sustainability Certification—A variety of products from five furniture manufacturers have met the requirements for the Sustainable Choice certification from Scientific Certification Systems (SCS), which is now available for furniture in addition to the range of interior products previously covered. The Sustainable Choice certification and label for furniture is based on the new BIFMA Sustainability Standard, written through a consensus process by the Business and Institutional Furniture Manufacturer's Association (BIFMA). That trade group itself will not perform certifications, leaving it up to groups like SCS to decide how well products meet the standard. Systems furniture, case goods, tables, and seating from Allsteel, Gunlocke, HON, Kimball Office, and National Office Furniture have been certified. The BIFMA standard considers materials, energy use, health issues, and social responsibility, assigning products to three certification tiers: Silver, achieved by four of the companies; Gold, achieved by National Office Furniture for a case good; and the highest level, Platinum, which no products have yet achieved. A directory of certified products is at www.scscertified.com.

Thermal Energy Storage Units Come Down in Size—With thermal energy storage, buildings use cheaper and often cleaner off-peak electricity at night to chill or freeze water, then use that stored thermal energy during the day for cooling. In 2005, Ice Energy introduced its Ice Bear 50, becoming the first company to offer thermal energy storage for medium-sized commercial facilities using unitary, refrigerant-based air conditioners (see *EBN* Vol. 14, No. 10). In development since then, the Ice Bear 30 is now available from Ice Energy, while the Ice Bear 50 will no longer be offered. The Ice Bear 30 is smaller and is easier to install on medium-size commercial facilities and large homes, according to Alanna Gino, a spokesperson for the company. The Ice Bear 30 is compatible with conventional 3–10 ton rooftop and split systems and 3–5 ton mini-splits, and multiple units can be connected for larger systems. The company offers a variety of systems for new construction as well as retrofits of existing systems. More information is at www.ice-energy.com.

FSC Certification Available for All SierraPine Composites—SierraPine, a major U.S. manufacturer of composite paneling and other products, has achieved certification under the Forest Stewardship Council (FSC) standard for chain-of-custody procedures. As verified by a third party, SierraPine has the proper protocols in place to track FSC-certified forest products as they move through its manufacturing facilities. With that certification, and with its investments in FSC-certified feedstock, particularly post-consumer wood waste, SierraPine now offers the option of FSC certification on any product supplied from any of its particleboard or medium-density fiberboard (MDF) manufacturing facilities. More information is at www.sierrapine.com.

Photo: Ice Energy

Ice Energy has introduced the Ice Bear 30 for off-peak thermal storage that integrates with new or existing cooling systems.

Counting Carbon *(from page 1)*

tioning Engineers (ASHRAE). Since carbon emissions from buildings generally follow energy use, we'll go a long way simply by making buildings more energy efficient.

But energy use, whether it's measured in dollars or kilowatt-hours, in absolute terms or as a percent reduction against code, is not exactly a measure of carbon emissions. How energy is generated and distributed changes how much carbon is released in the process. And energy used in the building is not the whole picture when it comes to greenhouse gas emissions. What you count and how you count it can change both the answers you get and what you do about them.

What to Count

Emissions from energy used in building operations are the obvious place to start in measuring a building's carbon footprint, but stopping there leaves many emission sources on the table, such as emissions from transportation to and from the building, providing water to the building, and creating the building itself. These other sources grow in relative significance as the building's operations get more efficient: "The more you improve the energy performance, the more your carbon footprint is dominated by transportation," notes Christopher Pyke, Ph.D., director of climate change services at CTG Energetics, based in Irvine, California.

Which carbon sources you attribute to the building depends largely on why you are counting. Many carbon-accounting schemes are driven by efforts to regulate emissions or monetize emission reductions, so they focus on careful assignment of emissions to a variety of owners in a way that avoids double-counting. "Their fundamental interest is to take the entire economy and add up how much carbon is in it," notes Pyke. "But from the point of view of reducing greenhouse gas emissions, ownership is not that important." In its work for the U.S. Green Building Council (USGBC) on the LEED 2009 weightings tool (see *EBN* Vol. 17, No. 6), CTG's primary interest was asking, "What does the building provide in terms of opportunities for reducing emissions?" said Pyke. Hence transportation-related impacts are included in the tool, even though the building owner can't claim ownership of those emissions or cash in on reductions.

Carbon emission estimates based on energy models and other predictive tools are useful, but they aren't sufficient for carbon accounting schemes, according to Pyke. "We're going to plan based on models, but we'll regulate and manage based on data," he says. That doesn't mean that models won't play a role in regulations, however. Since the U.S. Supreme Court ruled in April 2007 that the U.S. Environmental Protection Agency (EPA) has the authority to regulate greenhouse gases as pollutants, there is a growing trend to include carbon emissions as part of the environmental impact statement that is filed for permitting and approvals, according to Sean Cryan, associate principal at Mithun Architects + Designers + Planners. These requirements, beginning in California, Massachusetts, and western Washington State, have created a demand for new tools to predict the carbon impacts of new projects and whole developments.

CO_2 has captured our attention, but it is certainly not the only air-pollutant from building-related activities. Some of the tools described below also quantify emissions of sulfur dioxide (which causes acid rain), smog-generating nitrous oxides, and other pollutants.

Operational energy use

Energy used onsite is the most direct, and typically the most significant, contributor to a building's carbon footprint. This energy usually arrives at the building in the form of electricity and natural gas or other fossil fuels, such as fuel oil or propane. Each of these fuels has a carbon footprint, so if you know the type and amount of fuel consumed, you can estimate the building's primary contribution to greenhouse gases (see sidebar, page 13).

Electricity is the most common form of energy used onsite. Power plants generate this electricity with a range of fuels, each of which emits a different amount of carbon. Unfortunately, half of the electricity in the U.S. is generated by burning coal, which is the most carbon-intensive fuel (see chart, page 14). As a result, buildings in areas of the country where electricity is generated primarily from coal have a higher carbon footprint than those in other regions, even if they are equally energy efficient.

Most tools that convert electricity

Units of Carbon

Several related metrics are used to describe greenhouse gas emissions. The most common measurement is the mass of carbon dioxide (CO_2), in pounds in the U.S. and in kilograms or metric tons internationally. Until recently, U.S. government documents tended to express these metrics using just the carbon part of carbon dioxide. The carbon atom represents only 27.3% ($^{12}/_{44}$) of the mass of a CO_2 molecule, so those measurements are significantly smaller than the total mass.

CO_2 is also used as the metric for a broader set of greenhouse gases. Methane, nitrous oxide, and many other industrial gases also contribute to global warming, in a way that is much more powerful than CO_2 on a per-molecule basis. Over a 100-year period, for example, one ton of methane is estimated to have as much impact as 25 tons of CO_2. For nitrous oxide the factor is 298, and for sulfur hexafluoride it's 22,800! The climate change impacts of these gases are reported in units of CO_2-equivalent, or CO_2e, so the impact of one metric ton of methane emissions would be documented as 25 metric tons CO_2e.

use to carbon emissions rely on EPA's Emissions & Generation Resource Integrated Database (eGRID), which is also the basis for EPA's online Power Profiler. This database provides average annual emissions of carbon and other pollutants for each power plant in the U.S. based on the mix of fuels used by that utility to generate electricity.

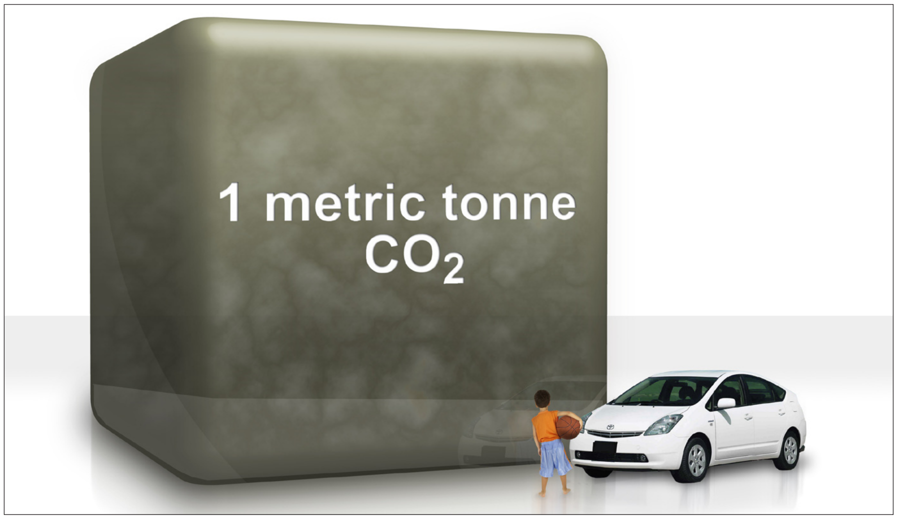
Transportation

Macroscale models of carbon emissions consider the transportation sector separately from the buildings sector. Many building-related strategies can reduce energy use and emissions from transportation, however; they range from locating buildings in pedestrian- and transit-friendly places to designing them with pedestrians and cyclists in mind (see *EBN* Vol. 16, No. 9). Automobile use is often measured in vehicle-miles traveled (VMT), and converting VMT to gallons or liters of fuel depends on the efficiency of the vehicles—the average passenger car in the U.S. achieves 22 miles per gallon (10 liters/100 km). Gasoline contributes about 19.4 pounds of CO_2 per gallon (2.3 kg/l), according to EPA. A more difficult question is whether, for carbon-accounting purposes, those miles should be pinned on where a person lives or on where she works or shops. Fortunately, we don't have to solve that riddle to encourage carbon-reducing strategies.

Water

The energy used to treat and transport potable water is substantial, especially in dry regions. Pumping water over the Tehachapi Mountains from Northern to Southern California represents an extreme case: the energy used to deliver water to Southern California homes amounts to about one-third as much as the average electricity used in each of those homes, according to a 2005 report from the Pacific Institute.

This energy can be translated to carbon emissions, but the relative importance varies widely. In USGBC's LEED 2009 credit weighting tool, water use at the typical 135,000-ft^2 (12,500-m^2)office building accounts for anywhere from 5 to 823 metric tons of carbon dioxide equivalent (CO_2e), depending on how much water the building uses—which is driven largely by the size of irrigated landscape area—and how much energy it takes to deliver that water. Compared with operating energy calculated using USGBC's median building-systems scenario, the carbon from a building's water use ranges from 0.17% to 29% of the carbon associated with operating energy.



Visualizing the volume represented by one metric ton of carbon dioxide at ambient temperature and pressure makes that quantity more real for non-scientists. Rendering: Mithun

These numbers do not account for methane released from wastewater treatment plants, which can be significant if the plant uses anaerobic digestion and doesn't capture its methane. "Some sewage facilities actually have data on how much methane is released," reports Rod Bates, environmental researcher at KieranTimberlake Associates, although in his experience they are more likely to have good data if they are capturing and reusing the methane.

Materials

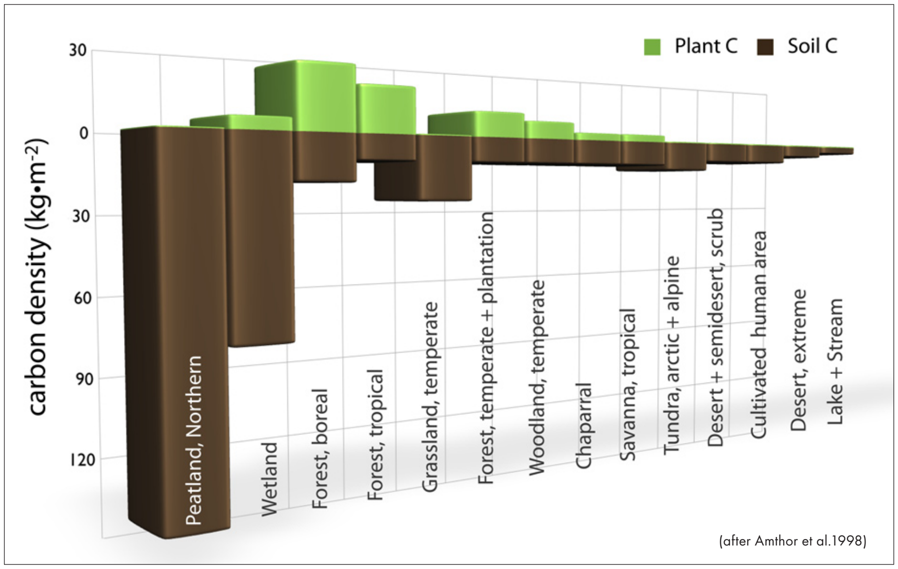
Before environmental life-cycle assessment (LCA) became widespread, the environmental impact of materials in a building was often estimated based on their *embodied energy*, meaning the energy used to make and transport those materials. LCA tools provide a more directly relevant metric in the form of "global warming impact" CO_2e. This measure adds to the energy picture by including things like carbon dioxide released from minerals as limestone is turned into portland cement, and methane released from the digestive systems of sheep as they grow wool. (Wool carpet is much worse than synthetics on a climate-change basis for this reason.)

It is also possible to estimate emission reductions that come from recycling construction waste (and from recycling by occupants). The reductions are primarily from avoiding the need to manufacture virgin materials when recycled-content materials are available instead. EPA has an online calculator and downloadable spreadsheet that can help estimate these savings. While it is not designed specifically for construction waste, it does include many of the material categories that are encountered on construction sites, including corrugated cardboard, lumber, bricks, and carpet. See www.epa.gov/climatechange/wycd/waste/calculators/Warm_home.html.

Construction

"Carbon embodied in a building typically represents 13% to 18% of the carbon emissions over the life of the building," says Cryan. This estimate includes CO_2 emitted while manufacturing and transporting materials, as described above, as well as activities on the construction site, including emissions from running construction equipment and the release of carbon that had been sequestered in the soil. "We spent a long time figuring out the carbon associated with moving a cubic yard of soil," reports Cryan.

Researchers have measured carbon sequestered in various soil types, but precise numbers are questionable when it comes to releases of sequestered carbon because so little is known about what really happens to soil-based carbon on a construction site. "Whatever they're assuming is pure guess," suggests Steven Hamburg, Ph.D., of Brown University, about efforts to include this information in a simple calculator. Nevertheless, both Hamburg and Cryan suggest the same design responses: minimizing the size of development footprints, increasing the density of neighborhoods, and protecting natural areas from development.



This graph shows the relative carbon content in soil and in vegetation for various ecosystems measured in kilograms per square meter of area. Rendering: Mithun

Construction Carbon Calculators

Build Carbon Neutral combines on-site energy use with data on the CO_2 emissions in the materials drawn from the Athena Institute's Impact Estimator for Buildings and from estimates of carbon released from soils during construction. It offers an overall score, but since it doesn't show what fraction of the carbon comes from each source, it offers limited guidance for improvements. That capability is coming with the next iteration of this free Web-based tool, now under development. *www.buildcarbonneutral.org*

The U.K. Environment Agency's carbon calculator for construction activities is a free, downloadable spreadsheet that facilitates a detailed analysis of the carbon embodied in building materials and the carbon released through the transportation of both materials and construction workers. The data are all from the U.K., but the calculator is transparent and editable, so other numbers can easily be substituted. *http://tinyurl.com/68hlkc*

The Athena Impact Estimator for Buildings is a software package that provides life-cycle data on materials with an option to enter operating energy use to calculate an integrated, whole-building total for greenhouse gases and other environmental impacts. Pricing runs from $230 to $600. *www.athenasmi.ca*

How to Count

Based on the simplified method described in the sidebar on page 13 for estimating carbon emissions from operating energy, any energy simulation can be used to predict carbon impacts. Increasingly, energy modeling tools have this capability built in, with output reports that include predicted carbon emissions alongside the predicted energy use.

Results from energy modeling tools

In June 2008 Integrated Environmental Solutions, Ltd., released VE-Ware, a free plug-in for Autodesk's Revit Architecture and Revit MEP software that generates a carbon footprint report for a modeled building. Carbon-emission reports are already built into EnergyPlus, which now has an energy simulation plug-in available for Google SketchUp and for Green Building Studio, a Web-based energy simulation service that was recently acquired by Autodesk. The translation from building information models (BIMs) created for design and construction purposes to models that can be used for energy simulations is rapidly improving, but it is not yet seamless, especially for complex buildings and detailed designs. As those connections improve, carbon footprint estimates should increasingly be available throughout the design process at the click of a button.

As a quick test of these tools, designers at KlingStubbins created a simple core-and-shell Revit model of a three-story building in Boston and generated an energy and carbon report using both Green Building Studio and VE-Ware. The results were "uncannily close," according to Jason Olsen, an associate involved in the experiment. Both systems use gbXML as the protocol for transferring data to the simulation tool, but the underlying energy simulation engines are different, and the assumptions the tools made about the breakdown between electricity and natural gas were also somewhat different. Additional testing against models generated in a more controlled way by experienced engineers would be advised, but this single test indicates that these tools may already provide useful carbon-footprint feedback, at least from early design models.

Counting the Electricity Grid

A big piece of nearly every building's carbon footprint comes from the electricity it uses, so how you translate kilowatt-hours into tons of CO_2 is important. This is not a simple translation, however. Complicating factors include the way power is shared throughout large regions, variations in emission profiles from electricity generation over time, and the difference between reporting based on historical power profiles and that based on projected future conditions.

How tightly to define the grid?

EPA's Power Profiler and many other tools estimate carbon emissions for electricity use as reported in eGRID for the electricity subregion in which the building is located. EPA divides the U.S. into 26 such subregions, and each has its own fuel mix and emissions profile. The Pacific Northwest, for example, has a lot of hydropower, so its emissions are relatively clean. The mountain states, on the other hand, rely primarily on coal, resulting in lots of carbon and other emissions. These variations make an inefficient building in Seattle look better in terms of carbon emissions than a high-performing building in Denver.

One could conclude that it's more important to build low-energy buildings in Denver than in Seattle, but that's not the whole story, according to Michael Deru, Ph.D., of the National Renewable Energy Laboratory, because power is transported throughout a much wider region to meet demand: "If you use more energy in Seattle, you're using hydro, but you're causing more coal to be burned," Deru says, noting that if hydropower were not needed in Seattle, it would be transferred to a part of the grid where it could

The Quick-and-Dirty Carbon Footprint Calculation

Some energy-modeling software now provides results in pounds of CO_2 alongside the Btus and kilowatt-hours. If you don't have those results but know your building's actual or estimated consumption of electricity and other fuels, you can plug those numbers into an online calculator to learn the CO_2 emissions from those fuels.

One such calculator is included in Target Finder, from the U.S. Environmental Protection Agency (EPA). Target Finder adds a few extra steps because it is designed to benchmark your energy use and carbon emissions against the existing building stock in the U.S. Another option is to use one of the many lifestyle footprint calculators available online. Not all of these allow you to enter quantities of fuel directly, but one that does, and has reliable data behind it, is the World Resources Institute's SafeClimate calculator (www.safeclimate.net).

If you want to take a more hands-on approach, you can estimate the carbon footprint from operational energy use yourself, though you'll still need to access online tools or downloadable spreadsheets to get the conversion factors. One approach is described below.

Step 1: Divide the building's annual electricity use, in kilowatt-hours, by twelve to get an average monthly use. Enter your project's zip code on EPA's Power Profiler website (www.epa.gov/cleanenergy/energy-and-you/how-clean.html), select your utility, and then click on "My Emissions" to enter your monthly electricity use and learn your annual carbon emissions from electricity.

Step 2: Estimate the carbon emissions from any fuels burned onsite. You can find the average carbon content of various fuels and a factor to account for the energy it takes to get the fuel to your building in the World Resources Institute's Greenhouse Gas Protocol (www.ghgprotocol.org), which defines standard methods for reporting on carbon emissions, or use the table below. To convert fuel from other units (for example, if you know your natural gas usage in therms but not cubic feet), a handy converter is available at www.eia.doe.gov/kids/energyfacts/science/energy_calculator.html.

Step 3: Sum the carbon from each source. Divide by the building's gross floor area if you want a result, like pounds of CO_2 per square foot, that's comparable from one building to another.

Sometimes it's not so simple: There are some situations that can make this tricky. If your building uses chilled water or steam from a central plant, for example, you'll want to get data from that plant on how much energy it uses per unit of chilled water or steam. And if you're working off an energy model that excludes some energy uses in the building, as directed by older versions of ASHRAE Standard 90.1, you should factor those uses back in before estimating your carbon emissions.

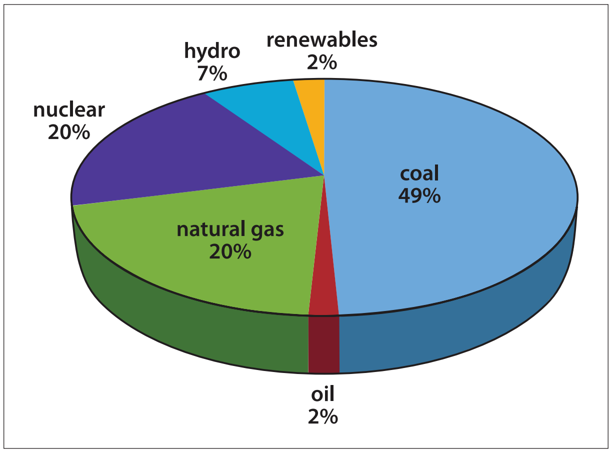
Combustion and Precombustion Emissions of Greenhouse Gases From Heating Fuels

Fuel	Quantity	Pounds CO_2e On-Site Combustion	Pound CO_2e Precombustion Processes	Total pounds CO_2e	Pounds CO_2e/ MMBtu
Coal, bituminous	1,000 lbs	2,740	189	2,819	232
Coal, lignite	1,000 lbs	2,300	137	2,437	377
Natural gas	1,000 ft^3	123	27.8	150	149
Fuel oil, residual	1000 gal	25,600	4,470	29,970	200
Fuel oil, distillate	1000 gal	22,800	4,100	26,900	194
LPG	1000 gal	13,570	2,560	15,760	173

Source: U.S. Lifecycle Inventory Database, as reported in "Source Energy and Emission Factors for Energy Use in Buildings" by M. Deru and P. Torcellini

Notes: MMBtu = million Btus higher heating value of fuel.

U.S. National Average Fuel Mix for Generating Electricity



Source: Energy Information Administration, U.S. Department of Energy, 2006 data.

offset electricity generated from fossil fuels. Deru argues that we need to minimize nonrenewable energy use nationwide, so it's better to use national average values for carbon intensity of electricity. If not national values, he suggests using values based on the large regions defined by how the nation's utility grids are interconnected. The continental U.S. has three of these interconnected regions, one each for the eastern and western halves of the country, and a third covering most of Texas.

A related issue is the question of focusing on existing generation rather than the additional (marginal) capacity that is needed to meet new demand. Some argue that it makes more sense to estimate the carbon footprint of a new building based on this marginal capacity. In the Pacific Northwest, for example, no new hydropower dams are being built, so most new loads are being met with fossil-fuel or nuclear plants. Some would argue, then, that it is not reasonable to allow new buildings to take credit for existing hydropower in their carbon footprints.

Time-of-use impacts

Even within a small region, emissions from electricity generation vary by time of day, by season, and from one year to another. Because power is in short supply during peak times (usually daytime) and is readily available at other times, incentives exist specifically to shift the demand for electricity from day to night. California's Title 24 energy code includes factors for time of use for this reason.

Ice storage is a typical example of this strategy: chillers are run at night to make ice, which is used during the day to cool a building so the chillers can sit idle. But whether these measures reduce carbon emissions depends on various factors, such as which fuels are used to generate power under which conditions. California relies heavily on natural gas for its base-load power, so the electricity it buys to meet peak loads is dirtier, notes Hal Levin. But in South Dakota, where the base load is met by coal, "they are often buying cleaner electricity for peak conditions," Levin says.

A more difficult type of variation to track and design for is the availability of hydropower, which in many places depends on snowpack in the mountains, according to Levin. That resource changes both through the year and from one year to another.

Even power from the same fossil-fuel-powered plant can vary in its emission profile based on ambient temperatures and how that plant is operated. At night, when the air is cooler and demand is low, operations can be optimized for efficiency, according to Deru. During the day, however, the need to meet constantly changing demand leads to compromises that increase emissions.

ASHRAE is working on a tool that will take into account regional and time-of-use variations in the electricity grid, and other factors, to provide more accurate carbon-footprint estimates. Because standard energy simulation software models energy use in buildings on at least an hourly basis, this tool—due out in 2009—is intended to use that hourly data to predict carbon emissions.

Upstream emissions of fuels

It takes energy to extract, refine, and deliver fuels to a building or to a power plant. These "precombustion effects" can account for anywhere from 5% to 20% of the total emissions associated with each fuel used in a building (see sidebar, page 13), according to the National Renewable Energy Laboratory's U.S. Life-Cycle Inventory Database. When it comes to fuels used at power plants to generate electricity, it is not as easy to compare precombustion carbon emissions with carbon emissions from fuel content, especially for

Greenhouse Gases By Energy Content of Power Plant Fuels

Fuel	Pounds CO_2e per MMBtu from Combustion	Pounds CO_2e per MMBtu Precombustion	Precombustion as Percent of Combustion	Pounds CO_2e per MMBtu Total
Coal, bituminous	208	18	9%	226
Natural gas	117	27	23%	144
Fuel oil residual (#6)	176	30	17%	206
Fuel oil distillate (#2)	161	30	18%	190
Uranium	0	2.5	n/a	2.5

Sources: U.S. EPA's Carbon content per Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2005 Annex 2.2; U.S. Life Cycle Inventory Database; Michael Deru, Ph.D., NREL, personal communication.

Notes: MMBtu = million Btus higher heating value of fuel. To convert to g per kWh, multiply values by 1.55.

sources such as nuclear and renewable energy, which have low or no combustion-related emissions.

Of all the fuels, precombustion CO_2e emissions are highest for natural gas, largely because of the high global warming potential of gas that leaks from pipelines. Overall emissions, including both precombustion and combustion effects for nonrenewable fuels, range from about 2 pounds of CO_2e per million Btus for nuclear energy to 225 pounds for coal (see table, page 14).

The estimates for nuclear energy are hotly debated, with some arguing that as the quality of available uranium declines, more energy will be needed to process it. Also, even where estimates of precombustion effects are available, the long-term energy and environmental cost of processing and storing waste nuclear fuel are still not taken into account.

Making It Count

With all the complexities and efforts to refine our estimates, it's easy to lose track of the fact that we can reduce carbon emissions dramatically by doing things that we already know about. Variations in the electrical grid and in fuel choices notwithstanding, reducing energy use also reduces emissions. Beyond that simple point, here are a few things to keep in mind.

Durability of reductions

If design and construction strategies that we implement today are going to help us meet carbon emission goals in 2020 or beyond, those strategies have to be robust and durable. Nothing is guaranteed, but there is a fundamental difference between, for example, orienting a building properly and sealing ducts. The former should last as long as the building; the latter, on the other hand, may have a dramatic short-term benefit, but "How tight do the ducts stay?" asks Pyke. This distinction won't show up in an energy model, but it's worth considering when evaluating which strategies to implement on a project. Rather than investing in sealing ducts, it's better to design the building so that all ducts are contained in the conditioned space, so slight leaks are not a problem.

This distinction is even more obvious when it comes to the nebulous world of carbon offsets. An owner may decide that reducing carbon emissions from operations is too complicated and might choose instead to purchase carbon offsets or renewable energy credits with a low carbon load. But even if one accepts that buying offsets is as effective as directly reducing emissions (which few experts do), that purchasing policy can easily be reversed in the future, so it isn't nearly as compelling a solution for long-term climate change concerns.

Other policy-related solutions are similarly vulnerable. Providing mass-transit passes to employees is certainly laudable and beneficial, but it reduces a building's carbon footprint only if the employees use those passes and only for as long as they are available. Structural solutions like limiting the amount of parking may be more durable over time, in that they can survive changes in management philosophy.

Historical vs. future-based predictions

Measures that shift electric power demand from peak to off-peak times may not directly reduce CO_2 emissions, but they may do that indirectly. By reducing peak loads they help prevent or delay the construction of additional power plants. If the plants are not built, the business case for investing in conservation is much stronger than if the power is readily available as excess capacity.

That factor is one of many ways in which changes to the economy and to the environment over time may change the long-term impacts of decisions we make today. Anticipating these changes is tricky, so perhaps the smartest response is to maintain some flexibility in design solutions. This kind of thinking is not new to architects, notes Levin: "We always look at that tradeoff in building design between optimization and flexibility."

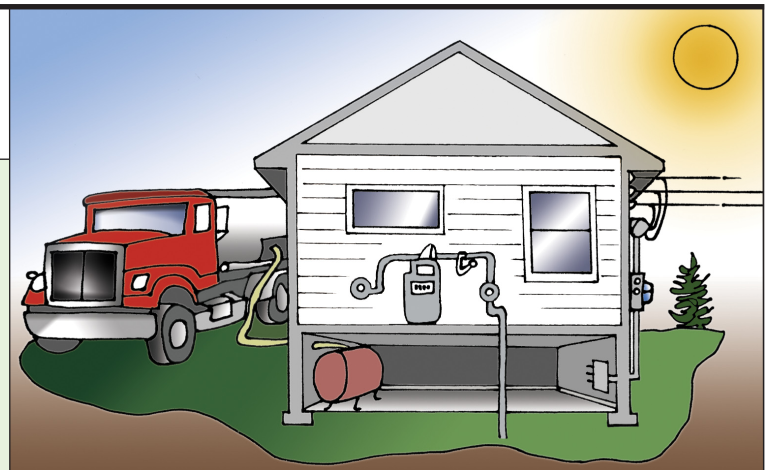
Taking action

KieranTimberlake has learned a lot by measuring and seeking to minimize its own carbon footprint, according to Bates. "We monitor our own activities, and it allows us to use ourselves as a test bed for different types of strategies," he says. It also helps to have clients who are inspired to reduce their emissions—that provides KieranTimberlake with the incentive to do the research and improve the performance of its designs. But that conversation goes both ways: "A key factor is communicating to the clients, in a language they can understand, what emissions are associated with their buildings," Bates suggests, adding that his firm converts carbon emissions into the equivalent vehicles on the road or acres of forest needed to offset those emissions. When clients can relate to the impacts in that way, they are more likely to support the effort. EPA has a handy online calculator for translating emissions into units that people can relate to at: www.epa.gov/cleanenergy/energy-resources/calculator.html.

With his 2030 Challenge, architect Edward Mazria, AIA, has invigorated the design professions to respond to climate change. While Mazria has chosen to emphasize a reduction in fossil-fuel energy use as his metric, the building industry as a whole is learning that it's important to measure and understand more than one number as we strive for more effective, and climate-friendly, buildings. When it comes to CO_2 emissions we are a long way from precision, but there is enough information to provide some guidance if you're willing to probe a little and use the resulting data constructively.

– Nadav Malin

BackPage Primer



Comparing Fuel Costs

One would think comparing the costs of different heating fuels and electric heat sources would be pretty easy. That's not the case. For starters, while we purchase some fuels by the energy content of the fuel, we purchase others by volume or weight—and we use different units for different fuels. Heating oil, propane, and kerosene are sold by the gallon, natural gas by the hundred cubic feet (ccf) or therm (100,000 Btus), firewood by the cord, wood pellets and coal by the ton, and electricity by the kilowatt-hour (kWh).

To further complicate matters, the amount of usable heat we get from a fuel also depends both on the efficiency of a given heating device and on how efficiently that heat is distributed to the conditioned space. The efficiency of combustion appliances varies widely, from a low of about 40% for older woodstoves to over 95% for condensing gas furnaces. Electric-resistance baseboard heaters are 100% efficient, while heat pumps, which use electricity to move heat from one place to another instead of converting the electricity directly into heat, range in efficiency from 200% to over 300%. (These numbers don't account for the "upsteam" energy costs of fuel production, nor do they begin to account for environmental costs—which are pretty significant with some forms of electricity generation.)

As for distribution efficiency, forced-air heating is often a lot worse than hydronic baseboard heating. If poorly sealed ducts are run through an unheated attic and insulated only to R-4, as is typical in the U.S., the heat-delivery efficiency will likely be only 60%–65%. Multiply that by a standard furnace efficiency of 78%, and you're getting only about half of the heat you've paid for.

Will you save money by switching to another fuel source? If you heat with a standard gas furnace (ducting assumptions as above) and spend $1.65/therm for the natural gas, you're spending about $33.05 per million Btu (MMBtu) for heat. That's about the same cost as electric baseboard heat at 11¢/kWh ($32.23/MMBtu), so you'd save money by switching to electric baseboard heating as long as your electricity price is no higher than 11¢/kWh. (You could also improve the cost-effectiveness of gas heating by improving the efficiency of your furnace or heat-distribution system.) Similarly, you could switch from gas to wood pellets and still save money as long as the price of pellets is below $350 per ton (which is significantly higher than today's going price). These changes don't factor in the cost of the new heating system.

Lots of fuel cost calculators, including a new one at BuildingGreen.com, perform this kind of analysis. Most compare fuel costs per million Btus (MMBtu) of delivered heat.

Keep in mind that today's fuel prices are no guarantee of what they will be next year—or next week! Costs of different energy sources rise and fall depending on many factors, including supply and demand. If a lot of people switch to pellet stoves, for example, the cost of those pellets will likely rise.

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