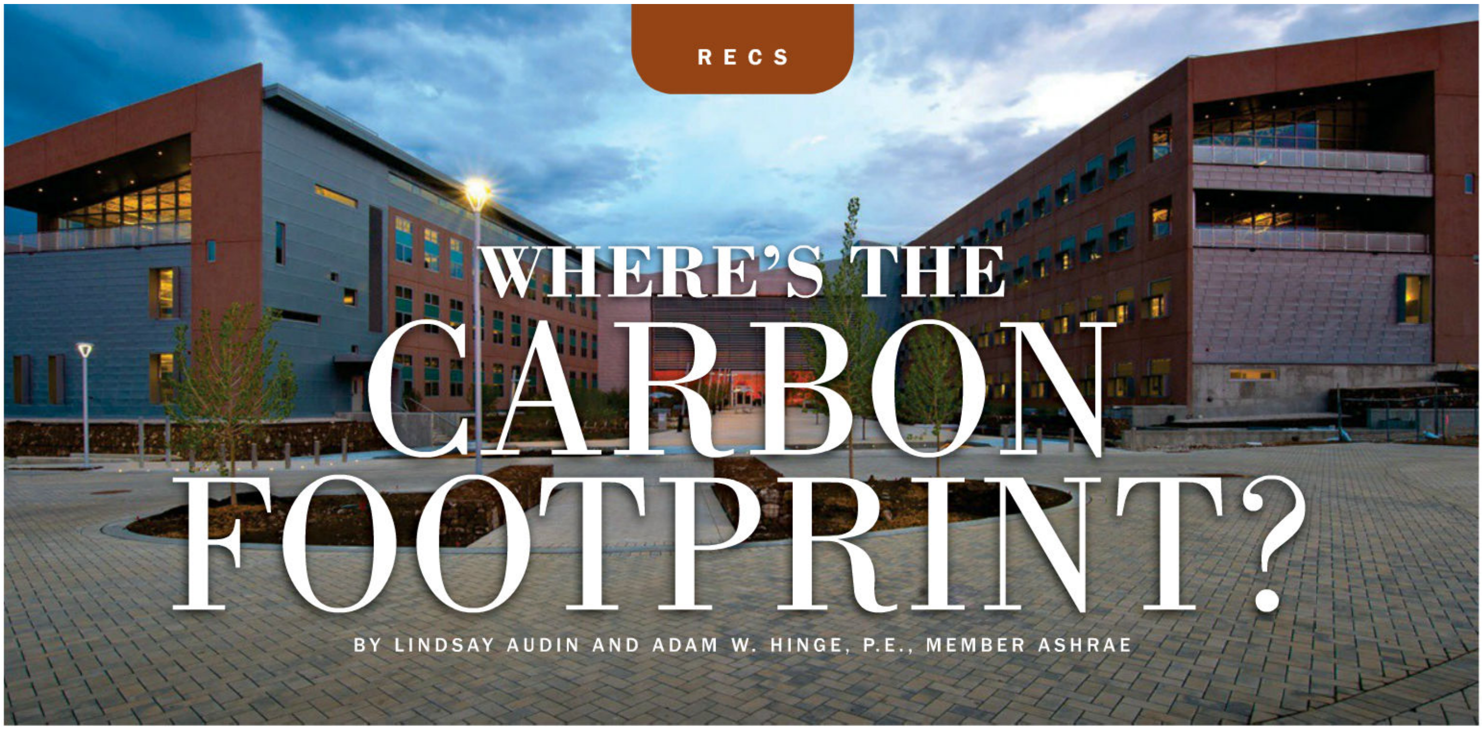
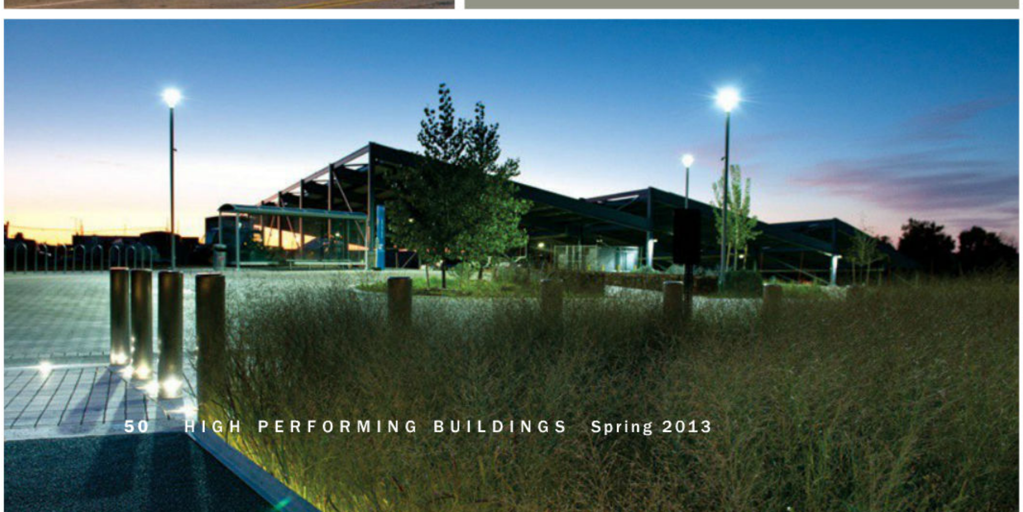


WHERE'S THE CARBON FOOTPRINT?

BY LINDSAY AUDIN AND ADAM W. HINGE, P.E., MEMBER ASHRAE

CHANGES ARE COMING TO THE **"ENERGY AT A GLANCE"** SIDEBAR INCLUDED IN EACH HIGH PERFORMING BUILDINGS CASE STUDY. TO SHOW A FACILITY'S CLIMATE IMPACT, ANNUAL CARBON DIOXIDE (CO_2) EMISSIONS WILL SOON ALSO BE QUANTIFIED.



While counting energy (e.g., kWhs, therms) consumed on site may tell us how efficiently a building is running, it doesn't tell us anything about the atmospheric carbon emissions that result from its operation. When comparing buildings, a higher energy use intensity (EUI), i.e., annual Btu/ft^2 · year, may mean more CO_2 emissions, but how much is unclear.

The mix of energy forms used to produce a building's electricity (e.g., coal versus gas versus solar) may also affect the climate impact, as may the choice of fuels used on site. Counting CO_2 emissions (generated on site and at off-site power plants) that stem from a facility's operation will focus attention on how we may reduce its climate impact.

How Do We Get From Energy To Emissions?

When calculating a building's energy efficiency, we look at site and source energy use. Site use is straightforward: It's developed from fuel bills and standard conversion factors (e.g., 1 therm = 100,000 Btu).

To account for energy coming from an off-site source (e.g., power plant or grid), however, involves factors addressing that source's efficiency of production and delivery. To do so, HPB currently relies on the methodology and conversion factors developed by the U.S. Environmental Protection Agency.

For electricity, HPB uses a national average factor of 3.34: Multiply site kWh use (converted into Btus) by 3.34 to determine power plant Btu consumption. Similar (but much lower) factors are applied to natural gas, fuel oil, etc. to reflect losses in their processing and delivery. When summed, total source energy is derived.

A similar approach may be taken with regard to CO_2 emissions. Following international standards for calculating greenhouse gas (GHG) emissions, many facilities have determined their "carbon footprints."

Daniel Hellmuth

Opposite (clockwiise from top): Courtesy of DOE/NREL–Dennis Schroeder; © Lucie Marusin; © CMTA Consulting Engineers; © Robb Williamson, courtesy of RNL; © Gayle Babcock

Opposite, clockwise from top

The National Renewable Energy Laboratory's Research Support Facility (RSF) in Golden, Colo., is designed to serve as a blueprint for net zero energy performance. Photovoltaic arrays totaling more than 1.6 MW are expected to meet the RSF's energy needs and are located on the roof, over the visitor parking lot in the form of shade canopies and over the staff parking structure.

The Great River Energy Headquarters in Maple Grove, Minn., reduces its carbon footprint through a combination of an energy-efficient building design, on-site renewable energy production via a 200 kW wind turbine and a 72 kW photovoltaic array, and the purchase of renewable energy credits.

Daylighting is one of several design strategies used to reduce Richardsville Elementary School's energy use to an annual EUI of 18.2 kBtu/ft^2. The low EUI made it economically feasible to produce an equivalent amount of electricity on an annual basis via on-site photovoltaic panels. Clerestory windows admit natural light to this central hallway that ends with a large window overlooking the gymnasium/cafeteria.

The visitor's parking lot adjacent to the National Renewable Energy Laboratory's Research Support Facility (RSF) in Golden, Colo., is shaded with a sawtooth roof supporting one of the facility's photovoltaic systems.

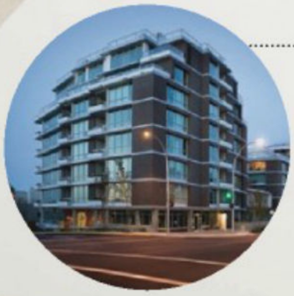
The Power House, built in 1928, once provided steam to a dozen buildings in downtown St. Louis and now houses the Cannon Design Regional Offices. The firm purchases renewable energy credits to offset 35% of the building's energy consumption.

Left

The Tyson Living Learning Center in Eureka, Mo., serves as the environmental field station for Washington University. The facility's on-site solar arrays are intended to produce more energy than the building consumes on a net annual basis. In addition to the rooftop array, two pole-mounted dual-axis solar arrays that move with the sun's position were added in spring 2010.

Reducing the Carbon Footprint

The buildings in the photos below highlight some of the ways building designers can reduce the carbon footprint.



An on-site biomass gasification plant provides carbon-neutral power to Dockside Green, a development of 1.3 million square feet of mixed residential, office, retail and industrial space in Victoria, BC, Canada. The plant converts locally sourced wood waste into a clean burning synthetic gas (syngas), which is used to produce heat and hot water.

Large windows in the 400-seat assembly room (chapel) at Holy Wisdom Monastery ensure that all areas receive ample natural light during the day. The Benedictine Sisters' mission of prayer, hospitality, justice and care for the earth guided the design of energy-efficient systems and selection of sustainable materials for their new monastery.

Holy Wisdom Monastery's rooftop solar panels provide 8% of the facility's energy needs. The system can be expanded to eventually provide all energy requirements on a net basis. The monastery in Middleton, Wis., purchases 100% renewable electricity to meet its electricity demand beyond what is supplied by the PV array.

As part of the $500 million Empire State ReBuilding program, owners sought to boost planned capital improvements by asking a team of experts to recommend sustainability measures that could be incorporated as part of planned renovations. The renovations let building owners offer state-of-the-art office amenities in a historic building while reducing energy use and carbon emissions.

Bottom photo: © Empire State Building; 2nd and 3rd photos: © FotoGrafx, courtesy of Hoffman LLC; top photo: © Perkins+Will Canada Architects Co.

Those standards divide carbon emissions into three "Scopes": On-site CO_2 emissions are Scope 1, while CO_2 emitted at an off-site source (e.g., power plant) is Scope 2. Scope 3 covers emissions from sources not directly related to energy use, such as leaked refrigerants and vapors from industrial solvents. (See *For More Information* sidebar on Page 57.)

The main GHG resulting from running buildings is CO_2 from burning fossil fuels, both on site and at power plants.

Because of the complexities involved with Scope 3 determinations, HPB will follow EPA's lead on this issue and ask those submitting articles for only their Scope 1 and 2 emissions. Together, they typically cover 95+% of CO_2 due to building operations. Future articles will show a building's annual CO_2 emissions per square foot, much as EUI is presently provided. That number will appear in the "Energy at a Glance" section of each article.

Factors exist for converting on-site energy units to pounds of Scope 1 CO_2. Burning enough coal to generate 1 million Btus, for example, releases about 210 lbs of CO_2, while burning natural gas to generate the same amount of energy produces about half that amount.

The dominant source of Scope 2 emissions is CO_2 at power plants, whose emission rates (in lb/MWh) vary widely. A MWh (i.e., 1,000 kWh) produced in California (dominated by nuclear, hydro, and gas-fired generation) may release about 560 lbs of CO_2, while producing a MWh in Colorado (where 63% of power comes from coal-fired plants) would send over 1,700 lbs of CO_2 into the atmosphere.

© Lucie Marusin

A wind turbine at Great River Energy Headquarters generates approximately 5% to 10% of the building's annual energy needs, while the rooftop photovoltaic array generates approximately 2% to 6% of the building's electricity needs. Great River Energy obtained a 15-year-old wind turbine that was previously used in Denmark. It was converted to a single-speed machine to fit the lower wind speed of the Great River Energy site.

ARE RECS OR OFFSETS "EQUIVALENT" TO ON-SITE RENEWABLE CONTRIBUTIONS?

Some argue that purchasing RECs or offsets is an easy "out" to avoid what might be done more ambitiously through deeper efficiency or on-site renewables. Unlike the easily metered clean kWh generated on site by a PV system owned and controlled by a facility, the tons of GHG avoided by RECs and offsets are based on unseen and likely nonconcurrent activities outside the control of those facilities.

While REC and offset markets are well regulated in the U.S., there have been high profile cases overseas where offsets were found to not provide the intended "additionality" (i.e., would not have resulted without the purchase of the REC). Even in the U.S., some unscrupulous sellers of fake offsets (lacking appropriate certification) have been brought up on fraud charges. This is an area where policy makers are closely watching developments and there will likely be more changes in the coming years.

A facility's emission rate can be found by entering its zip code at EPA's Power Profiler Web page. (See *For More Information* sidebar on Page 57.) ASHRAE Standard 105 (Standard Methods of Measuring, Expressing and Comparing Building Energy Performance), currently under review, proposes a similar approach.

How May CO_2 Emissions Impact Building Design?

Designing a building with only Btus and/or dollars in mind, without concern for its CO_2 climate impact, defeats one of the main reasons for making a building more energy efficient. In Canada and many European countries, CO_2 emissions have a price. As occurs with the incremental cost for a more efficient piece of HVAC equipment, the cost of CO_2 then becomes part of the financial analysis of a building's design.

In most of the US, however, releasing CO_2 into the atmosphere has no direct cost to a building, but such cost may be indirectly charged via its electric bills. In California, however, that state's 2013 cap-and-trade program directly charges large facilities (those annually emitting over 25,000 metric tons of carbon on site) for their emissions. Because many power plants fall into that category, other facilities see that impact via their electric bills. In some other states, various programs may add emission-related charges to their electric bills.

If we were charged for disposal of CO_2 emissions in the same ways we incur maintenance and replacement costs (e.g, to properly dispose of linear fluorescent lamps), that cost would be factored into a design's economics, possibly altering one's equipment choices. For example:

An electric heat pump system powered from a grid heavily dependent on coal may cause more source CO_2 to be emitted than a high-efficiency natural gas boiler would emit on site.

Because of its overall higher thermal efficiency, an on-site gas-fired

BOUNDARY ISSUES FOR ON-SITE RENEWABLE ENERGY

In many cases, it may cost less to buy RECs or offsets to cut a building's carbon footprint than to install on-site renewable energy sources. The critical decision for designers and owners is how far the energy consumption can be cost-effectively cut with efficiency and conservation measures, and then what could be made up with renewable sources.

The building, or site "boundary," becomes critical. For many buildings, insufficient space exists on them for PV panels, but nearby parking, or other ground-mounted, structures may allow for enough PV or other renewable resources to generate all electricity needed for the building.

In the revision to ASHRAE Standard 105, and other related projects, much debate has gone into where one draws the boundary for what can be considered on-site generation. An important decision point for building design teams is whether to strive toward securing all energy from on-site renewables, or reduce the carbon footprint by also purchasing RECs and/or offsets.

Left to far right

Photo courtesy of The Alliance for Sustainable Colorado

© David Wakely

The Alliance Center, built in 1908 as a warehouse, is owned and operated as a multi-tenant nonprofit center by the nonprofit Alliance for Sustainable Colorado in Denver. Annual energy use dropped from 56 kBtu/ft^2 to 42 kBtu/ft^2 after a 2004 renovation, which implemented various conservation measures. Carbon emissions associated with the all-electric building's energy consumption are offset by the purchase of Green-e certified wind energy credits.

One of Adobe Systems Inc.'s latest energy-efficiency projects involves remodeling office spaces, removing most office walls and placing desks in open layout "neighborhoods." Lamps, HVAC and plug load turn off automatically when no motion is detected. The open-plan layout takes advantage of daylighting, reducing the need for artificial light. This project has reduced energy use by 65% on the renovated floors, further reducing Adobe's carbon footprint.

The Alliance Center's tenants, largely environmentally focused organizations, are partners in making the building sustainable. A brainstorming session involving tenants and Alliance staff identified ways to make the building work better for them. Some measures that have already been implemented include an eGo Car Share option and setting up a building "green team."

The Alliance for Sustainable Colorado seeks to use the Alliance Center to demonstrate the potential for high resource efficiency in existing buildings. Plans for an upcoming deep renovation aim to further improve energy performance, while showing how such improvements can improve tenant well-being and satisfaction, and the building's financial performance and asset value.

cogeneration plant producing heat and power may yield lower overall CO_2 emissions than electricity taken from a relatively clean gas-fired utility power plant.

Renewable Energy and Carbon Offsets: On-Site vs. Off-Site Options

On-site renewable energy systems, e.g. photovoltaic (PV) panels, are part of a building's infrastructure and the owner's investment (though sometimes installed and operated by a third party). Their energy output directly reduces electricity purchased for the facility.

Off-site renewable energy is usually procured through a contract to purchase zero- or low-carbon electricity. That cleaner energy is deemed to have "environmental attributes" in addition to its energy. Those attributes may be purchased separately from the electricity through renewable energy certificates (RECs).

Just as a building may purchase equipment and fuels that minimize its on-site CO_2 emissions, so may it buy RECs to counter its off-site emissions. Those payments go to those generating the clean power that displaces dirty power elsewhere on the grid. Since all CO_2 emissions go into the same global atmosphere, reducing them anywhere has the same climate impact as reducing them on site.

ACCOUNTING ISSUES WITH RECS: AVOIDING DOUBLE COUNTING

RECs are a tradable commodity. When a facility generates its own renewable power (e.g., from solar panels), it owns the RECs related to those kWhs. If it does not sell them, it may count them against the emissions from its own total power consumption. If it sells them, however, it cannot take carbon credit for its on-site use of solar power.

If the panels are instead owned by a third-party developer selling that power to a host facility, the RECs from that renewable power may belong to the developer, not the facility. Those RECs, therefore, cannot be counted against the facility's own emissions.

For the RECs to really reduce a building's carbon footprint, it is critical that the building team submitting an article to HPB review its REC and/or offset contract and show how many units were being annually purchased and for how long from the date of article submission.

Doing so minimizes the likelihood of buying a one-year supply and then ceasing shortly thereafter, merely as a way to look good in its submission. If using solar or wind power, a submitter should indicate that its RECs belong to it (not a third-party developer), thereby allowing it to count power from such systems as having zero carbon impact.

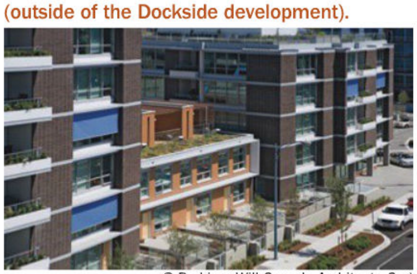
Photo courtesy of The Alliance for Sustainable Colorado

Photo courtesy of The Alliance for Sustainable Colorado

By definition, a single REC represents the environmental attributes — the reduced emissions of CO_2, sulfur oxide (SO_x) and nitrogen oxides (NO_x) — of one MWh of electricity generated by renewable power sources. That renewable power need not be received at or even near a facility, and is typically generated within 18 months of the date of purchase.

Right Kiowa County Schools in Greensburg, Kan., reduced its carbon footprint with a 50 kW on-site wind turbine. A city wind farm provides the remainder of the schools' electricity demand. The school and wind farm are part of the community's sustainable master plan developed after most the town was destroyed by an EF-5 tornado in 2007.

Below Synergy, the first phase of Dockside Green in Victoria, BC, Canada, includes four detached buildings: a nine-story and a six-story residential tower with commercial units on the ground floor, and a two-story and four-story residential building with townhouses. The biomass gasification system makes the development carbon neutral on a net annual basis without the purchase of green power certificates. This is made possible by selling heat to a neighboring building (outside of the Dockside development).



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Independent verification processes exist to certify that RECs are related to actual or soon-to-be generated renewable power. For details, see www.green-e.org. Many colleges, universities, corporations and cities now buy RECs covering 15–25% (or more) of their power.

The amount of avoided CO_2 from a REC varies depending on the location of its renewable power source. A REC based on a wind farm in New York, for example, that feeds its renewable power into a relatively low-carbon grid (less than 585 lb/MWh), does not displace as much CO_2 as one based on a wind farm in Wyoming where most power is generated by coal (yielding over a ton of CO_2 per MWh). The source point for RECs may therefore impact the amount of CO_2 that is avoided by them.

The Alliance Center, which is operated as a multi-tenant nonprofit center by the Alliance for Sustainable Colorado in Denver, provides an excellent example for applying RECs. An all-electric building, it buys enough RECs to fully offset the

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Top left Conservation and in-house energy generation combined have reduced or avoided carbon dioxide emissions for Adobe Systems Inc.'s headquarters facilities in San Jose, Calif., by 56%. Adobe makes up the difference by purchasing renewable energy certificates/credits (RECs) and verifiable emissions reduction credits (VERs). Adobe's energy and carbon credits subsidize energy from wind farms in Massachusetts and the burning of biomethane from dairies in California to produce electricity for the energy grid.

Top right A 140 kW crystalline PV array mounted on a parking shade structure and a 208 kW thin-film array mounted on the roof provide more energy than Richardsville (Ky.) Elementary consumes on a net annual basis.

Bottom left Kiowa County Schools uses simple and passive building systems, such as daylighting in the library and throughout the facility, to maximize efficiency and reduce energy use and costs. The result is a school that uses less than half the energy used by a school built to code.

Bottom right Richardsville Elementary School is the first the first full-scale net zero energy school in the United States. To reduce energy consumption, the school uses laptop computers, alternative methods to prepare lunches and building strategies such as dedicated outdoor air systems with dynamic reset.

emissions of the coal-fired plants that provide most of its power. Its carbon impact is therefore zero, regardless of its Btu consumption.

Unlike the RECs that counter emissions from power plant electricity, "carbon offsets" may be used to counter emissions from other carbon sources, such as boilers. Like RECs, offsets represent reductions in emissions and are publicly traded, but differ from RECs in three important ways:

- By definition, one offset represents one metric ton (2,204 lbs) of CO_2; its carbon impact is therefore irrespective of the location of its origin.
- Offsets do not relate to power production; instead, they result from a variety of carbon avoidance or absorption methods.
- Offsets cannot be counted against any emissions other than carbon (e.g., NO_x or SO_x).

Carbon offsets may be generated by planting trees that absorb CO_2, capping landfills that would otherwise release methane (a GHG 20+ times worse than CO_2), or using other methods to keep GHGs from entering the atmosphere.

Offsets are generally used to counter carbon emissions from

FOR MORE INFORMATION

Source, Site Energy Methodology and Conversion Factors

ENERGY STAR. "Understanding Source and Site Energy."

http://tinyurl.com/site-source

Definition of "Scopes" of Emissions

Greenhouse Gas Protocol. "FAQ."

http://tinyurl.com/a3aut27

Determine A Facility's Emission Rate

EPA. "How clean is the electricity I use? —Power Profiler."

http://tinyurl.com/powerprofiler

Renewable/Clean Energy Purchase Contracts

DOE. "Green Power Marketing."

http://tinyurl.com/doegrnpower

on-site consumption of fossil fuels. For example, to negate the carbon impact of burning natural gas in a boiler, a facility may buy "green" natural gas that includes sufficient carbon offsets to achieve that result off site.

The increase in energy cost for RECs or offsets varies with market forces and the base costs of electricity and natural gas, but is typically 5–10%. Many see it as a small contribution toward reducing a facility's climate impact. In the case of the Alliance Center, the extra cost was about half a penny per kWh.

The Net Result

Choosing high-efficiency HVAC equipment may cut a facility's energy use and cost, and generating some of its power on site with solar panels further reduces its climate impact. Following those actions by purchasing RECs and/or offsets may further cut—or, as some maintain, even eliminate—its remaining climate impact.

Watch as future issues of HPB document how buildings go that extra mile toward cutting their climate and energy impacts. ●

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