Buildings account for 38% of carbon dioxide (CO2) emitted in the United States, according to the U.S. Green Building Council, primarily due to the use of fossil fuels to provide energy for the heating, cooling, and operation of buildings. The percentage of CO2 emissions associated with buildings climbs higher still when accounting for the energy required to harvest, manufacture, and transport building construction materials, not to mention the energy associated with occupant business travel and commuting patterns. In addition to releasing CO2, fossil fuel combustion emits other greenhouse gases (GHG) such as nitrogen oxides (NOx) and methane (CH4). This issue of e-News focuses on the relationship between building energy efficiency and CO2 emission reductions, methods for GHG accounting, and strategies for designing a net-zero carbon building.

Definitions of what constitutes a net zero carbon or carbon neutral building vary. At a minimum, a net zero carbon building balances the amount of CO2 released by the building operating energy consumption with an equivalent amount of GHGs sequestered and/or purchased carbon offsets. Operating energy includes heating, cooling, ventilation, lighting, and equipment loads. Of course, renewable energy generated onsite can be a large part of the strategy for reducing carbon-based energy consumption. An alternative definition of what constitutes carbon neutral, which goes beyond the energy associated with the building operation, is Holistic Carbon Neutral Design. As defined by Architecture 2030, Holistic Carbon Neutral Design must take into account the embodied energy and GHG emissions associated with the extraction of resources used to create building materials, the transportation of these materials to the site, the physical construction of the buildings, the operation of buildings, and the activities of the building occupants as they carry on business.

Strategies for a Net Zero Carbon Building

Regardless of which definition one uses, reducing the energy consumption in buildings is a key component of designing a net zero carbon building and such a strategy should use an integrated design approach that includes use of climate-adaptive design strategies, high-efficiency equipment, and appropriate building controls.

Passive Building Elements and High-Efficiency Technologies

Climate-adaptive design utilizes passive building elements that directly interact with local climatic conditions and reduce the need for mechanical heating and cooling, thus reducing energy consumption. Examples of climate-adaptive design strategies include shading, evaporative cooling, thermal mass, and insulation.

Early in the design of a building, designers and builders should conduct a site resource analysis to determine the solar, wind, daylight, and rainfall resources.
available to the building. The building can be designed for optimal site orientation to maximize use of daylight and reduce electric lighting loads. Shading strategies should be optimized to increase solar heat gain in the winter and inhibit heat gain in the summer while preventing excessive glare.

Wind flow patterns should be assessed to determine opportunities for natural ventilation (see e-News #61, Natural Ventilation). In favorable climates and building types, natural ventilation can be used as an alternative to mechanical air-conditioning, saving 10%-30% of total energy consumption. Natural ventilation design can be coupled with thermal massing strategies to regulate diurnal temperature swings inside the building. During the day the capacitive properties of the mass absorb and store heat from solar radiation and internal heat gains (see e-News #64, Thermal Mass).

Landscaping can also play a role in CO2 mitigation. Not only can trees provide shading, transpiration cooling, and stormwater retention in some cases, but if the site has adequate space, trees can be planted for purposes of carbon sequestration. In addition, landscaping designed to conserve irrigation water can also play a significant role in reducing emissions, as water and energy use are closely related, due to water processing, and transportation requirements.

Once passive building elements have been incorporated to maximize the efficiency of the building envelope, high-efficiency technologies for lighting, HVAC, and end-use loads must be identified to minimize energy consumption. Automated building controls may be included to tailor the operations of building mechanical equipment to the actual schedules and uses of the building occupants.

Renewable Energy Options
An analysis of the site and the building’s energy needs will help determine if photovoltaic, solar thermal systems, or onsite wind generation technologies are appropriate and viable options for the building. Solar thermal panels may be used to provide hot water for space heating, domestic hot water, or process hot water.

Figure 1. EPA’s Target Finder Tool (see sidebar, Accounting for Carbon Emissions)

Resources
- The Climate Registry, www.climateregistry.org
- Climate Action Reserve, www.climateactionreserve.org
Any CO₂ emissions associated with the non-renewable energy consumption for the building can then be addressed by purchasing carbon offsets. Carbon offsets allow businesses to offset their own CO₂ emissions by reducing or displacing GHGs in another location. Offsets are typically achieved through financial support of projects that reduce the emission of greenhouse gases in the short or long term, commonly through the purchase of carbon offsets, or through participation in voluntary utility programs, such as SMUD’s Greenergy® Program and PG&E’s ClimateSmart™ program.

**Planning Ahead and the Future of Greenhouse Gas Regulation**

California has been a longtime leader in the effort to reduce GHGs. These efforts were codified in 2006 through the California Global Warming Solutions Act of 2006 (California Assembly Bill 32 or AB 32), which requires the development of a comprehensive program of regulatory and market mechanisms to achieve real, quantifiable, cost-effective reductions of GHG. Under this legislation, aggregate GHG emissions for the entire state of California must be reduced to 1990 levels by 2020. Currently, the facilities required to report GHG emissions include cement plants, petroleum refineries, electricity generation and cogeneration facilities, retail electricity providers and marketers, and general stationary combustion facilities that emit over 25,000 tons of CO₂e on an annual basis.

Owners and operators of facilities not required to report GHG emissions under California law—or those who want to understand their entity’s entire GHG footprint—should consider calculating, verifying, and reporting their emissions on a voluntary basis to The Climate Registry.

Should facilities and industry sectors not yet regulated by AB 32 begin planning now for future laws and regulations on GHG emissions? Arguably, building designers who pursue high-performance strategies for reducing a building’s carbon footprint are positioning that building well for the possibility of future regulation.

**Where Do You Draw the Line?**

To implement an effective GHG management program, it is important to first understand the source of building GHG emissions. Operating energy—for HVAC, lighting, and other energy end uses—accounts for nearly 70% of building CO₂ emissions, according to the American Institute of Architects Carbon Neutral Design Project. Therefore, a successful GHG management program, whether for design of a new building or for an existing building, must evaluate and manage, at a minimum, building energy performance and consumption.

Although operating energy is the primary component of buildings’ carbon footprint, the embodied energy and associated CO₂ emissions inherent in the building materials contribute to CO₂ emissions as well. According to Architecture 2030, the embodied energy of building materials—throughout the entire lifecycle of a product including raw material extraction, transport, manufacture, assembly, installation, disassembly, deconstruction, and/or decomposition—accounts for 15-20% of the energy used by a building over a 50-year period. Design teams have an opportunity to influence carbon emissions by specifying materials that have a low embodied energy and therefore require less burning of fossil fuels during production. The embodied energy and carbon of selected building materials is shown in Table 1.

A more comprehensive carbon management program may also evaluate occupant business travel and commuting patterns and emissions associated with product supply chains. Building rating systems, such as Leadership in Energy and Environmental Design (LEED®), take into account proximity to public transit and amenities such as showering facilities that encourage bicycling and walking to work.

### Table 1. Embodied Energy and Embodied Carbon of Common Building Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Embodied Energy [MJ/kg]</th>
<th>Embodied Carbon [kgCO₂e/kg]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum - Virgin</td>
<td>218.0</td>
<td>11.46</td>
</tr>
<tr>
<td>Aluminum - Recycled</td>
<td>28.8</td>
<td>1.69</td>
</tr>
<tr>
<td>Common Brick</td>
<td>3.0</td>
<td>0.22</td>
</tr>
<tr>
<td>Carpet - Typical</td>
<td>74.4</td>
<td>3.89</td>
</tr>
<tr>
<td>Portland Cement</td>
<td>4.6</td>
<td>0.83</td>
</tr>
<tr>
<td>Concrete - Typical</td>
<td>1.0</td>
<td>0.13</td>
</tr>
<tr>
<td>Copper</td>
<td>40 to 55</td>
<td>2.19 to 3.83</td>
</tr>
<tr>
<td>Glass</td>
<td>15.0</td>
<td>0.85</td>
</tr>
<tr>
<td>Insulation - Average</td>
<td>45.1</td>
<td>1.86</td>
</tr>
<tr>
<td>Linoleum</td>
<td>25.0</td>
<td>1.21</td>
</tr>
<tr>
<td>Plastics - Average</td>
<td>80.5</td>
<td>2.53</td>
</tr>
<tr>
<td>Steel - Virgin</td>
<td>35.3</td>
<td>2.75</td>
</tr>
<tr>
<td>Steel - Recycled</td>
<td>9.5</td>
<td>0.43</td>
</tr>
<tr>
<td>Stone</td>
<td>1.0</td>
<td>0.06</td>
</tr>
<tr>
<td>Timber</td>
<td>8.5</td>
<td>0.46</td>
</tr>
</tbody>
</table>

(continued on page 4)
California utilities offer outstanding educational opportunities that focus on the design, construction and operation of energy efficient buildings. Listed here are a few of the many upcoming classes and events; for complete schedules, visit each utility's website.

**Title 24 Energy Efficiency Standards for 2008/2009**
This class is designed for architects, builders, planners, inspectors, and anyone interested in learning about updated Title 24 codes and standards. Attendees will learn the latest version of the standards including envelope, lighting, and mechanical requirements that affect building design for new construction projects beginning in 2009. The new standards are aimed at further reducing peak energy consumption and incorporating greater energy efficiency measures. This course is offered 8/18/09 in Irwindale. See: https://www.sce.com/ECR/EnergyCenterClassSchedule.aspx?SORT=D&ORG=ALL

**BOMA BEEP Building an Energy Awareness Program**
This class focuses on the key components of an energy awareness program for buildings. It covers how to create an energy awareness program and how to educate owners, tenants, brokers, leasing, and sales staff about the benefits of improved energy performance. Offered in San Francisco and via the Internet on 8/11/2009. See http://www.pge.com/mybusiness/edusafety/training/pec/classes/index.jsp#classresults

**Sustainable HVAC Design**
This workshop will help owners, construction and operations professionals and LEED AP's increase their knowledge of sustainable HVAC design through two primary concepts. 1) Designing energy and water efficient HVAC utilizing lighting, day lighting, and water integration strategies 2.) Designing systems that minimize the cost of operations. This course is offered 9/16/09 in San Diego. See: http://seminars.sdge.com

**LEED Core Concepts & Strategies**
This workshop provides essential knowledge of the Leadership in Energy & Environmental Design (LEED) Rating Systems and sustainable building concepts for those seeking a better understanding of LEED or pursuing Green Building Certification Institute's LEED Green Associate (Tier I) credential. By presenting LEED concepts at the credit category level – across building types and rating systems – and basics on the building certification process, this workshop provides the foundation required for any 300-level LEED education offering. Real project examples help demonstrate and reinforce learning. This course is offered 8/13/09 in Sacramento. See: https://usage.smud.org/ETCstudent/ClassDescription.asp?id=523

GHG regulation. The AB 32 Climate Change Scoping Plan Document, which outlines the steps for how the AB 32 initiative will be implemented, includes recommended strategies for energy efficiency such as Zero Net Energy (ZNE) Buildings, more stringent codes and standards, and cap-and-trade systems. Some of these strategies may become mandatory in the future to meet the aggressive goals established under AB 32.

At the federal level, in March 2009, the U.S. Environmental Protection Agency issued the Proposed Mandatory GHG Reporting Rule, which would require annual reporting of GHG emissions starting in 2011 from suppliers of fossil fuels or industrial greenhouse gases (which includes specified manufacturers of metals, chemicals, oil and gas), manufacturers of vehicles and engines, and facilities that emit 25,000 metric tons or more per year of GHG emissions. Approximately 13,000 facilities, accounting for about 85–90% percent of U.S. greenhouse gas emissions, would be covered under the proposal. Meanwhile, Congress is considering both carbon tax and cap-and-trade mechanisms for addressing carbon emissions.