Historically the amount of CO2 in the atmosphere hovered just under 300 parts per million (ppm), but it's now approaching 400 ppm. CO2 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 CO2, 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-Conditioning 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

> Units of Carbon
>
> Several related metrics are used to describe greenhouse gas emissions. The most common measurement is the mass of carbon dioxide (CO2), in pounds in the U.S. and in kilograms or metric tons internationally. Until recently, U.S. government documents t…

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 off the table, such

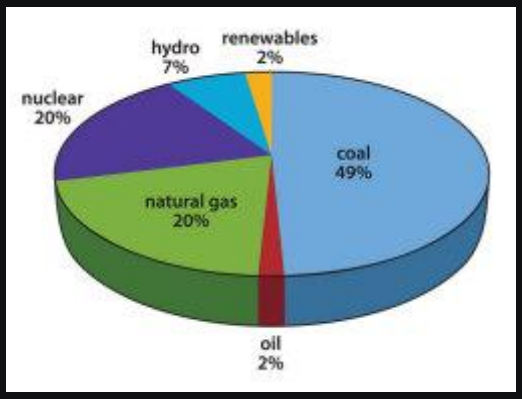
as emissions from transportation to and from the building, providing water to the building, and creating the building itself. These other sources grow in relative significance as the building's operations get more efficient: "The more you improve the energy performance, the more your carbon footprint 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.

CO2 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



U.S. National Average Fuel Mix for Generating Electricity

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.

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). 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 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

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

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 CO2 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

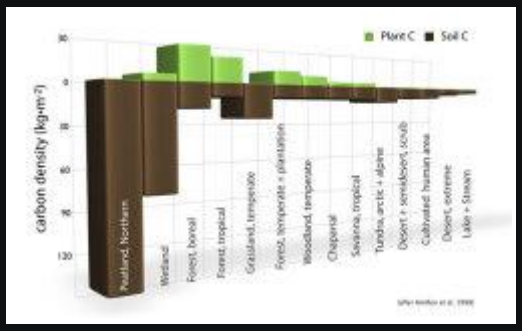
The energy used to treat and transport potable water is substantial, especially in dry regions. Pumping water over the Tehachapi Mountains from Northern to Southern California represents an extreme case: the energy used to deliver water to Southern California homes amounts to about one-third as much 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-ft2 (12,500-m2)office building accounts for anywhere from 5 to 823 metric tons of carbon dioxide equivalent (CO2e), 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.

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



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

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" CO2e. 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

Construction Carbon Calculators

Build Carbon Neutral combines on-site energy use with data on the CO2 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 over…

Read More…

"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 CO2 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.

How to Count

Based on the simplified method described in the sidebar 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

The Quick-and-Dirty Carbon Footprint Calculation

Some energy-modeling software now provides results in pounds of CO2 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 num…

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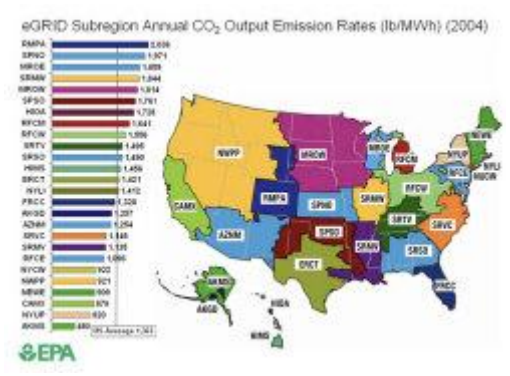
In June 2008 Integrated Environmental Solutions, Ltd., released VE-Ware, a free plug-in for Autodesk's Revit Architecture and Revit MEP software that generates a carbon footprint report for a modeled building. Carbon-emission reports are already built into EnergyPlus, which now has an energy simulation 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



This map shows the subregions of the United States electric utility grid, along with the carbon intensity of electricity production in each subregion in pounds of CO2 per thousand kilowatt hours, as stored in the Emissions & Generation Resource Integrated Database (eGRID) for 2004

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 CO2 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 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

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 ft³	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

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

Combustion and Precombustion Emissions of Greenhouse Gases From Heating 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 table), 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 sources such as nuclear and renewable energy, which have low or no combustion-related emissions.

Of all the fuels, precombustion CO2e 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 nonrenew-able fuels, range from about 2 pounds of CO2e per million Btus for nuclear energy to 225 pounds for coal.

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

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

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

Greenhouse Gases By Energy Content of Power Plant Fuels

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.

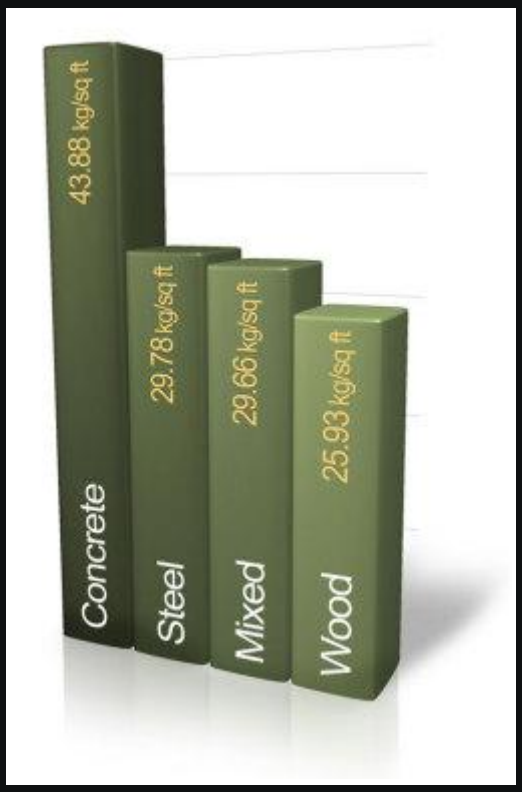
Durability of reductions

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



Estimates of carbon dioxide embodied in the structural materials for four common structural systems

Measures that shift electric power demand from peak to off-peak times may not directly reduce CO2 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 CO2 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.

Headquartered in Washington, D.C., the U.S. Green Building Council http://www.usgbc.org is the nation’s leading coalition for the advancement of buildings that are environmentally responsible, profitable, and healthy places to live and work. Established in 1993, the Council offers various products and services to include the LEED Green Building Rating System, an annual International Green Building Conference and Exposition, membership summits, information exchange, education, and policy advocacy.

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Climate change is a rapidly escalating emergency, and we have a lot of hard work to do in order to mitigate its effects. For building professionals, that has typically meant increasing energy efficiency and pushing for renewable energy production, thus reducing the amount of carbon generated by the fossil fuels we burn in order to operate our buildings.

But as crucial as that is, it's not enough: we also need to think about the greenhouse gases that are emitted to construct our buildings in the first place—the *embodied carbon*. The manufacture of building materials makes up 11% of total global greenhouse gas emissions, according to data from the United Nations Environment Programme.

That 11% might sound small compared with the impact of operational energy (28%), but for new construction, embodied carbon matters just as much as energy efficiency and renewables. That's because the emissions we produce between now and 2050 will determine whether we meet the goals of the 2015 Paris climate accord and prevent the worst effects of climate change.

"We are making global progress in reducing operating emissions," said Erin McDade, program manager at Architecture 2030. "According to the best scientific data and consensus, we have to phase out all fossil fuel emissions by 2050. … Without embodied carbon, we will not meet our climate targets."

DEFINING EMBODIED CARBON

Definitions of embodied carbon differ. Some view the embodied carbon of a building as including the entire life cycle of the materials, even the operational phase of the building—for example, taking into account multiple replacement cycles of finishes over time. A full life-cycle view of embodied carbon would account for impacts of landfilling or recycling materials as well.

For simplicity in this report, we are focusing on *initial embodied carbon*—the impacts associated with extracting, manufacturing, and transporting materials to the jobsite. "Carbon" is used to indicate all greenhouse gas emissions, not just carbon dioxide.

So where do building professionals come in?

Design teams have a huge role to play. This report focuses on how architects and designers, working with other key members of the project team, can find low-cost and no-cost ways to reduce the embodied carbon of new construction projects.

Does It Need to Be New?

The very first question to ask for any project is whether new construction is needed. By avoiding the use of new materials, we avoid their impacts altogether. Building reuse and incorporation of salvaged building materials can greatly reduce the embodied carbon of construction.

And while we're at it, it's also vital to think about the end of life of new buildings before they're even built. It doesn't make sense to emit carbon twice or three times when the same building could serve two or three different uses over its lifetime. Consider design for future uses of whole buildings and design for deconstruction of systems so that materials can have a second life in another building.

Assessing Embodied Carbon

Once you've identified embodied carbon as a problem to be solved, what happens next?

The first step is to identify carbon "hot spots"—materials or systems that contribute the most to a building's embodied greenhouse gas emissions. That way, project teams can prioritize the materials that make the most difference and can start finding solutions that have the biggest impact.

The most widely accepted method for assessing embodied carbon is whole-building life-cycle assessment (WBLCA), but other tools can supplement this as a first step.

By replacing portland cement and using other carbon-reducing strategies, the team was able to cut the embodied carbon of the proposed Mexico City Airport project by 130 million kilograms.

Rendering: Foster+Partners

Getting started: free databases

To get a general sense of proportion and start getting a feel for the carbon footprint of common materials, there are a few free resources available. One is the Bath Inventory of Carbon and Energy (ICE), which has the advantage of being a long-respected source of embodied carbon data. The main drawback of ICE is that it's not updated frequently; data are also specific to the U.K. BEES (Building for Environmental and Economic Sustainability) is a similar tool offering North American data.

A newer resource is the Quartz database, which has basic environmental-impact and health-related data on 102 common building materials. Carbon data come from thinkstep, an internationally respected life-cycle analysis firm, and are specific to the U.S.

Keep in mind, though, that these resources are a first step: they can give you a sense of the baseline embodied carbon of brick or aluminum or foam insulation, but they don't tell you a lot more than that. (The carbon footprint is listed under "global warming potential" and is expressed in kilograms of carbon dioxide equivalent.) It's not even really appropriate to compare materials because their embodied carbon is listed here by weight. You wouldn't want to compare a kilogram of brick to a kilogram of aluminum; that makes no sense in the context of a building project.

NEW: EMBODIED CARBON GUIDANCE FOR DESIGNERS

Architecture 2030 is introducing the Carbon Smart Materials Palette, a tool laypeople like architects and designers can use to identify and take action on embodied carbon “hot spots” in building materials.

Working with a network of life-cycle assessment experts, Architecture 2030 developed the tool to provide “high-level and easy-to-digest information” about specific building materials like steel, concrete, finishes, and insulation, according to Erin McDade, program manager at Architecture 2030. Each “swatch” in the palette includes a material’s basic attributes, information about how the material is produced and where its embodied carbon footprint comes from, and design guidance for reducing its footprint.

Users can learn more about the Carbon Smart Materials Palette on the Architecture 2030 website.

Digging deeper: EPDs

Some of these problems are solved when you look at environmental product declarations (EPDs) for the carbon footprint of specific products. EPDs are usually based on “functional units” rather than weight, and many will provide the carbon footprint of a specific product or set of products rather than a generic baseline. (The exception is a so-called industry-wide EPD, whose job is to set a baseline to compare with product-specific EPDs.)

An EPD consists of life-cycle assessment (LCA) information summarized in an easier-to-read format. It looks at a number of impact categories beyond global warming potential (like smog and eutrophication), but it’s the go-to place to learn about the carbon footprint of a specific product.

But EPDs have drawbacks as well, the biggest one being that laypeople are not in a good position to compare their results. You definitely can’t compare steel to concrete, for example, and it’s a tricky business even to compare one concrete mix to another. For more on (not) comparing EPDs, see Apples to Pineapples: Four Reasons You Can’t Compare EPDs and Wood, Concrete, and Steel and Their Incomparable EPDs.

The gold standard: whole-building life-cycle assessment

The only way to get a really clear picture of how one material or system compares to another in the context of a building project is to use whole-building life-cycle assessment, or WBLCA. This process looks at multiple impacts of building materials, including global warming potential, over their entire life cycle—from extraction and manufacturing through the landfill or recycling plant.

Although WBLCA requires specialized software and training, the good news is that this software is designed to be used by building professionals. The software can also be used to conduct more limited studies, like comparisons of different structural systems or enclosure scenarios. Studies like these can be key to reducing the embodied carbon of a building because they allow designers to view multiple ways of accomplishing the same goals. Two major tools dominate the WBLCA market in North America—Athena Impact Estimator and Tally.

The Carbon Leadership Forum, a network of experts on the carbon impacts of the building industry, has developed an LCA practice guide aimed at building professionals. Makers of WBLCA software tools also offer trainings to help users navigate the software and interpret results.

Architecture firm Mithun used life-cycle assessment tools to assess the benefits of cement replacement and the use of wood instead of concrete piers for the Louisiana Children's Museum in New Orleans.

Photo: Mithun (Photography by Michael Fiegenschuh)

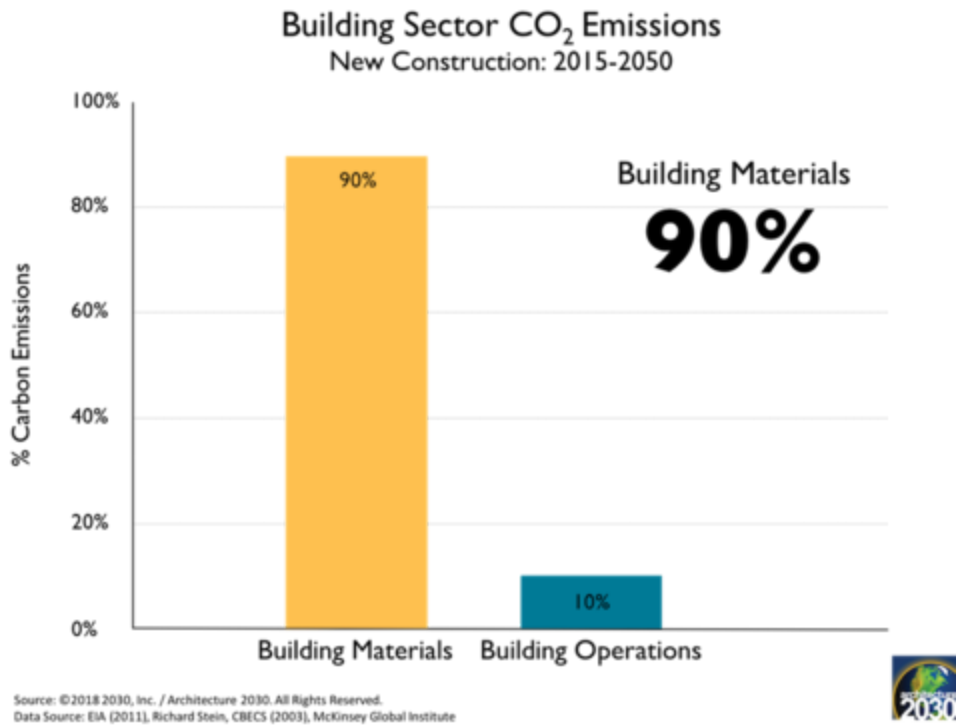
Optimizing Structural Systems

Not every project has a budget for a full-scale whole-building life-cycle assessment (although many firms are doing more limited LCA work on projects on their own time). Luckily, there are takeaways from this process that project teams can apply to their everyday work without additional expense or, in some cases, even without client buy-in or knowledge needed.

One of the most important takeaways from whole-building LCA is that structural systems almost always comprise the largest source of embodied carbon in the building—up to 80%, depending on the building type. So the first goal when looking to reduce the embodied carbon of a project is to target the structural system. Concrete, steel, and wood can all be optimized in different ways to reduce impacts.

In all this, it's important to get the structural engineer involved early. "The form of the building often takes shape even before we get into schematic design," noted Mark Webster, P.E., a structural engineer with Simpson Gumpertz & Heger. "It would be great if architects would reach out earlier to us [structural engineers] to help them make decisions related to building form and structural materials." He added, "It's increasingly obvious, the role that we have to play in terms of embodied impacts with respect to climate change."

Concrete and cement



If things don't change with how we treat embodied carbon, impacts will total 90% of the carbon released from newly constructed buildings between 2015 and 2050.

Image: Architecture 2030

Concrete has a large footprint because of the carbon-emitting process used to make one of its most important ingredients—the binder portland cement (see Reducing Environmental Impacts of Cement and Concrete). By some estimates, production of portland cement is responsible for 5% of total global CO_2 emissions. Replacing some cement with supplemental cementitious materials (SCMs) like fly ash or blast-furnace slag is a go-to way for project teams to reduce the embodied carbon of the concrete in their projects.

But that's not always as simple as it might sound, and structural engineers have some advice about how to do it right.

TAKEAWAYS: CONCRETE AND CEMENT

- Cement is responsible for concrete's **large carbon footprint**; a ton of cement represents about a ton of greenhouse gas emissions.
- Fly ash and blast-furnace slag can improve certain properties of the concrete but can also **take longer to cure** and can affect the final color.
- All buildings—even wood buildings—contain a **significant amount of concrete**.

- Avoid over-engineering without good reason: work with the structural engineer to ensure you're **using only as much concrete as you really need**.
- Consider working with the structural engineer on a **performance-based concrete specification** that sets environmental requirements.
- When calculating carbon reductions from using supplemental cementitious materials, **choose an honest baseline**—not a 100% cement mix, which is rare.

Engineering firm Walter P Moore has conducted about 20 whole-building LCAs in pursuit of the Building Life-Cycle Impact Reduction credit under LEED version 4, according to Dirk Kestner, P.E., director of sustainable design. Kestner's takeaway? Every project—even those with wood structural systems—contains substantial amounts of concrete, and cement content is one of the largest contributors to embodied carbon on a project.

"One thing that people … need to start doing is thinking about how they specify their concrete and stop talking about it as 'percent fly ash,'" said Kestner. "It's about getting cement content down and using only what you need."

Reducing cement content can take many forms, he said, including simply using less by specifying higher-quality aggregate or reducing water content. Kestner says successful lower-impact concrete specifications can be performance-based—stating the structural requirements (how much strength is needed when) and environmental requirements (like global warming potential per yard of concrete) rather than specifying a percentage of cement and SCMs. In other words, you might be able to reduce impacts further by asking for exactly what you want. Getting the structural engineer in direct dialogue with the ready-mix supplier is essential to this approach, he said.

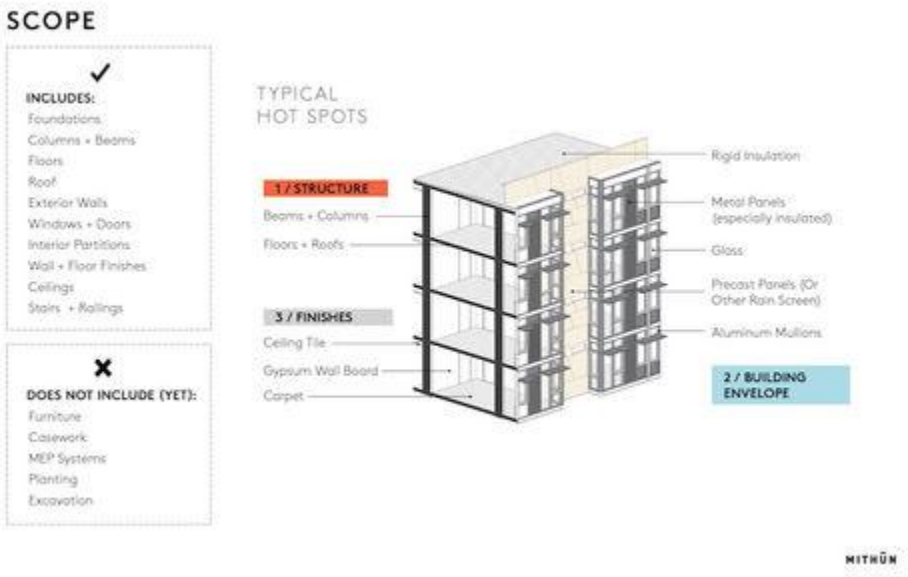
Cure times and subtle color differences can be a barrier when using SCMs, according to Meghan Lewis, a former associate at Mithun, but "concrete in the foundation is not as time sensitive," and you don't have to worry about color there, either. "You can have a huge impact just focusing on the foundation," she suggested. That includes working with the structural engineer to ensure the foundation isn't unnecessarily overdesigned—using less concrete in the first place. All this can be done without added costs.

For the proposed Mexico City Airport project, Arup conducted extensive life-cycle assessment studies to reduce embodied carbon (the project is pursuing LEED v4 certification). Although the team spent most of the analysis time on modeling the enclosure correctly, in the end, according to Arup's Frances Yang, S.E., it was the concrete mixes as well as the efficiency of the unique structural steel design that helped cut the total embodied carbon of the planned building by 10% compared with a

benchmark building. Embodied carbon reductions totaled 130 million kilograms of CO_2 equivalent, she said—which is like taking 28,000 cars off the road for a year.

Yang emphasized the importance of using reasonable regional benchmarks for concrete, since it's already commonplace to replace some cement content with SCMs. (The team also studied the structural systems of several other airports with similar spans to establish a baseline tonnage of steel, she said.) The National Ready Mix Concrete Association publishes benchmark data that can be used for this purpose. "I don't think it's right to choose an all-cement mix" as a baseline for all mixes, Yang said. "Go with what you have experience seeing."

Arup also worked with the Athena Sustainable Materials Institute, developer of Athena Impact Estimator tool, to ensure that all data were specific to the region—an important detail since the software's default data don't extend beyond regions in the U.S. and Canada.



This diagram shows the typical hot spots that are found while using LCA tools, helping designers identify where to spend time to make the biggest impact.

Image: Mithun (Meghan Lewis)

Steel

By weight, steel has a much higher embodied carbon footprint than concrete does—with one ton of steel representing approximately a ton of greenhouse gas emissions. According to the World Steel Association, steel production is responsible for 6.6% of

greenhouse gas emissions globally—more than portland cement (see Better Steel, Lower Impacts). Those global numbers reflect use of dirtier technology in much of the world, which is still using basic oxygen furnaces (BOF) rather than electric arc furnaces (EAF). In North America, the industry has mostly switched over to EAF technology—the process used to recycle steel. This, along with a cleaner electrical grid, has resulted in a 36% reduction in the industry's carbon footprint since 1990, according to Mark Thimons, P.E., vice president, sustainability, at the Steel Market Development Institute.

TAKEAWAYS: STEEL

- A ton of steel represents about **a ton of greenhouse gas emissions**.
- North American steel generally has a **lower carbon footprint** than steel from overseas.
- Concrete buildings use a lot steel for reinforcement; this can be **90%–100% recycled steel** if choosing North American products.
- Avoid over-engineering without good reason: consider a **braced frame rather than a moment frame**, and work with the structural engineer to manage the architectural impacts.

So that's the first rule of thumb for reducing the embodied carbon of steel on a project: specify steel produced in North America—or, if that's not possible, at least specify recycled steel, which uses the better EAF technology.

The only other real option for reducing steel's footprint is to use less—a practice that's even promoted by the Steel Market Development Institute, a trade group. Aside from choosing North American steel, "the other advice that we always give to architects and especially engineers is just to be as efficient as possible in designs," Thimons told BuildingGreen. "We really encourage the concept of working with an integrative process. It can result in some of those kinds of savings; more efficient designs result in better and lower environmental footprints."

Structural engineer Mark Webster agrees, advocating for "approaches like composite design, where the steel and concrete slab work together and can reduce the size of the beams." He added that "choice of lateral system can have a big impact on the quantity of steel" as well. Braced frames with diagonal braces use far less steel than moment frames, for example. "You end up with a lot more steel using those moment-resisting frames," he said. "For architects, it's nice to use moment frames because you don't have diagonal braces," but braced frames can be strategically designed to reduce the architectural impact. That's a good reason to get the structural engineer involved early when looking to reduce embodied carbon.

Structural wood

You may have heard (including from BuildingGreen) that building with wood instead of concrete or steel has major carbon benefits. It seems to make sense, since wood products sequester carbon, while concrete and steel are made by burning fossil fuels. Interest in building with mass timber structural products like cross-laminated timber (CLT) has skyrocketed, in part because of the presumed lower embodied carbon impacts.

But a few scientists are asking everyone to slow down, contending that LCAs have grossly overestimated the benefits of wood (see Wood: What's Good).

"Wood is very tricky right now," said Stephanie Carlisle, principal at KieranTimberlake and the lead developer of the Tally whole-building LCA software tool. "There is a big debate happening." And that's frustrating for designers who want guidance they can use.

TAKEAWAYS: STRUCTURAL WOOD

- The **carbon impacts of wood** are a source of contention, with a few scientists claiming that LCAs greatly overestimate the benefits.
- What's good for steel and concrete is good for wood: **use only what you need**.
- **Read more...**

"The more we've dug, the more [the numbers] seem to be all over the place," said Arup's Yang. "There is so much uncertainty carried with them."

This uncertainty has many sources.

First of all, LCAs mostly give wood a free pass when it comes to the state of the forest after harvesting. But a lot of carbon in forests is stored in the soil and below it, and it's unclear how much carbon and methane (a more potent greenhouse gas) is released when harvesting … and how much that depends on *how* the wood is harvested.

Second, there is the question of whether trees are being grown and replaced in such a way that we can truly assume carbon neutrality from forestry. As an example, for Douglas fir in the Pacific Northwest, a harvest cycle of 40 to 45 years is standard in business-as-usual (BAU) forestry practices, according to Mark Harmon, Ph.D., professor at Oregon State University. Harmon coauthored a recent paper implicating the Oregon timber industry as the largest source of carbon emissions in the state. The study found that an 80-year harvest cycle would be more beneficial for carbon storage

in the forest because the longer time period allows the trees to build to their optimum volume before harvesting.

Harmon compares a forest to a “leaky bucket”: “There is carbon pouring into the bucket [from absorbing CO_2] but always carbon flowing out” as well from harvesting, decomposition, and fires, he explained. “The thing that determines how leaky it is, is related to how long the ‘water’ [carbon] stays in the bucket. … A 45-year forest is a much leakier bucket than a 90-year one” because carbon is leaving it much more quickly. At 75 to 100 years of age, though, Douglas fir stops growing so quickly, meaning carbon storage slows, so it makes the most sense to harvest the trees then.

Also, as this example shows, there is the issue of regional differences. Douglas fir reaches its optimum volume at a different age than, say, southern yellow pine. And a Douglas fir forest will yield a different volume of wood at harvest than a southern yellow pine forest. So each will sequester different amounts of carbon per unit (whether you’re measuring by feet or kilograms or some other metric). It’s hard to generalize about the benefits or drawbacks of wood, or even about appropriate forestry practices across the board. (This, incidentally, is why Forest Stewardship Council standards differ by region.)

Once the wood is harvested, it requires significant energy to be kiln-dried; most of this energy comes from burning waste wood, which is given a free pass as “carbon neutral” by the U.S. Environmental Protection Agency. But a contentious 2010 report commissioned by the Commonwealth of Massachusetts calls that carbon neutrality into question, saying that the carbon footprint of burning woody biomass depends on a number of factors, including forestry practices, and stating that in some cases burning wood is worse than burning fossil fuels.

There’s also the fact that wood products continue to sequester carbon as long as they are in use, but the length of use is all over the map. Harmon’s group assumed a useful life of 30 years, while others argue for 60 or even 100.

And what happens when the wood is ultimately disposed of? It’s not clear how quickly wood products decay and emit methane in landfills. This dispute is reflected in WBLCA tools, with Athena Impact Estimator assuming relative stability and Tally assuming quicker releases. (Currently, neither Athena nor Tally gives wood initial “credit” for sequestering carbon in a whole-building LCA, although this is optional in Tally.)

CARBON AND FSC

Wood products certified to the Forest Stewardship Council (FSC) standard have far better environmental credentials than wood products without certification, for a variety of reasons (see Certified Wood: How SFI Compares to FSC). FSC standards require a high level of

ecosystem protection and help ensure social equity. And FSC upholds its standards by stripping companies of certification if they don't follow the rules.

But can FSC wood claim a lower carbon footprint as well? Several signatories to a letter released by the Sierra Club earlier this year say it can.

Read more...

"For those of us in the building industry, it gets really complicated," sums up Kate Simonen, AIA, S.E., associate professor of architecture at the University of Washington, adding that people tend to have emotional rather than scientific responses to the available data. "I have not found anybody who has made a fully rigorous connection that satisfies both of the extreme sides of the story, which makes it really difficult to interpret."

Simonen advises building professionals to use the material that makes the most sense for their projects and to optimize its use however they can. "If you take the average concrete building and compare it to an average wood building, you might see that many different studies show wood tends to have a lower carbon footprint," she noted. "That doesn't say you couldn't have optimized the concrete system to be at a similar level."

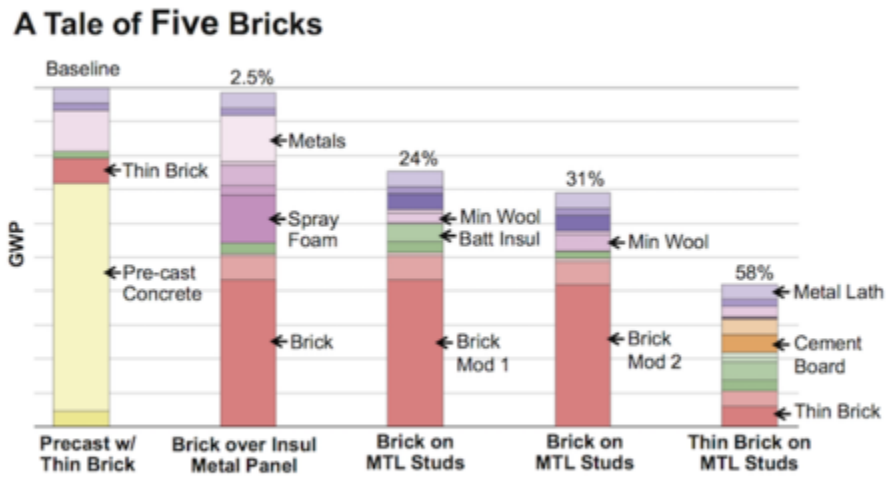
Speaking of optimizing, "you can have twice as much wood between the most optimum and least optimum configuration" in the same building, said Simonen. It's better to follow the same rules for wood as you would for concrete or steel and use only what you need.

Additionally, a huge trend toward mass timber might not be a great thing for forests, Simonen continued. "It is not necessarily better for the environment to start radically increasing the amount of wood. If we started cutting down way more wood, we are changing the rate at which we remove carbon from the forest." Hence, we would need to plan ahead for that eventuality and start planting more trees now to meet the demand in the coming decades.

And let's not forget the other impacts beyond embodied carbon that all our building materials have, cautions structural engineer Kestner. "Some impacts like smog and eutrophication and acidification might be closer to each other" when comparing wood with other systems, he said. "You wouldn't want to only look at carbon."

Kestner added that, given the small number of mass-timber-producing plants in North America, it's important to take transportation impacts into account as well. "I think that one thing that should certainly be considered if you are using CLT and shipping it a very

large distance is to understand the transportation impacts as you make your decisions," he said.



Architect Brad Benke studied the impacts of brick façade systems and discovered that five functionally equivalent wall types had very different impacts. Thin brick on metal studs, shown at the far right, reduced embodied carbon 58% compared with a baseline wall system (thin brick with precast concrete).

Image: LMN Architects

The upshot? Wood can be beneficial for its reduced footprint, but don't use wood as a get-out-of-carbon-jail-free card. Consider which materials and systems make the most sense for the project, and optimize how you use them, preferably with whole-building life-cycle assessment as a guide. And when using wood, choose FSC-certified products—or salvaged wood, to extend the carbon benefit of using wood products.

Considering Enclosures

Structural systems bear the bulk of the embodied carbon footprint of buildings, but the enclosure is also significant, representing up to 15% of the global warming impact of a typical commercial office building, according to Duncan Cox, associate at Thornton Tomasetti. (This number varies considerably by building type, he emphasized.)

TAKEAWAYS: ENCLOSURE SYSTEMS

- Structural systems are the **most significant source of embodied carbon**, but enclosures are also significant.
- Enclosure systems are under the **architect's direct control**.
- Because of aluminum's high embodied carbon, **curtainwall systems** have very large impacts. They also have high operational impacts, so it's best to minimize their use.
- Some types of **foam insulation** (notably extruded polystyrene) have blowing agents with massive global warming potential. Seek alternatives.

Cox said that, based on WBLCA studies he's conducted over the years, the carbon hot spots in the enclosure tend to be aluminum curtainwall and foam insulation (the latter because of high-embodied-carbon blowing agents). "When you start playing around with window-to-wall ratios, you can have quite a big impact" because of curtainwall's footprint, he said. The embodied carbon of curtainwall (not to mention the aluminum shading systems that often come with it) is just one more reason to minimize its use, since it has operational energy impacts as well (see Rethinking the All-Glass Building).

On opaque walls, cladding choices can also make a big difference (see Cladding: More Than Just a Pretty Façade). Brad Benke, AIA, formerly of LMN Architects, recently conducted an LCA considering different wall systems. "If you only have time to do one thing, hire a good engineer and work to reduce the structural load," he said, but his firm has invested in in-house LCA studies for the envelope. This helps because the firm is seeking ways to reduce impacts across the portfolio—not just on the super-green projects—and "architects are able to make decisions about wall types; they do it all the time." Benke added, "An important opportunity for architects … is being able to make changes without having to ask the owner a ton of questions or spend significant time coordinating with consultants."

With that goal in mind, Benke looked at ten different wall systems, comparing their embodied impacts, then conducted a secondary study looking at five functionally equivalent brick wall types. The winner? Thin brick on metal studs had the lowest embodied carbon among the options, showing a 58% reduction from the baseline building (thin brick with precast concrete). The best part is that this lower-embodied-carbon wall, to a casual observer, looks and functions just the same. Benke said this was a finding that could be shared across the firm to help "improve the baseline of every project rather than just high-profile projects." He added, "We really believe that a lot of firms could be doing work like this. … We don't have a lot of time to *not* do this work. It's critical to start now."

TAKEAWAYS: EMBODIED CARBON

- Embodied carbon is an **urgent issue** because the emissions we release in the next 20 to 30 years are critical to keeping global temperatures at tolerable levels.
- **Read more...**

Letting Go of Guilt

"I think it's really easy to get trapped in a lot of guilt," said Carlisle, because the building industry is responsible for such a large percentage of global carbon emissions. But, she said, "There is room to do something on every project. ... I hope that can be really empowering for people." She added, "We have an obligation to get involved."

to enhance occupant comfort and health leads to _____
Social Benefits
1/2 of global greenhouse emissions can be attributed to buildings
T
The benefits of sustainable design and construction offer the potential to change the way in which we as humans face the challenges of the next decade
T
Which of the following is NOT an economic benefit for sustainable construction:
a. Reducing operating cost
b. Improving the image of the building
c. Creating new business opportunities
d. Reducing the civil infrastructure costs
C
In the Construction Industry, Sustainable design and construction is also commonly referred to as which of the following?
a. Environmentally Friendly Building
b. High Performance Building
c. All of these choices
d. Green building
C
Which of the following is an example of an environmental benefit?
a. Improving the image of the building

b. Reducing civil infrastructure costs
c. Improving occupants health and comfort
d. Improving air and water quality
D
The use of sustainable technologies and practices creates new employment opportunities.
True
Which of the following is NOT a goal of Sustainable Development Goals (SDGs)?
A. Universal Education
B. Gender Equality
C. Climate Action
D. Zero Hunger
A
Three main benefits that result from sustainable design and construction?
Environmental, Economic, Social
Sustainable design and construction tactics can result in significant social benefit to both facility stakeholders and society at large
T
Which of the following uses the least amount of energy:
a. Using a space heater
b. Cooking
c. Lighting
d. Using a water heater
Cooking
To improve overall quality of life is not an environmental selling point for sustainable construction
True
Which of the following is NOT part of goal 7 -focused on environmental sustainability -of Millennium Development Goals (MDGs)?
A. Achieve universal environmental education
B. Reduce biodiversity loss
C. Access to safe drinking water
D. Improvement in the lives of slum-dwelling
A
Which of the following is NOT an environmental selling point for sustainable construction?
a. Reduced waste streams
b. Improved overall quality of life
c. Reduced global warming
d. Improved air and water quality

B

Which of the following is NOT a goal of Millennium Development Goals (MDGs)?

A. To achieve universal primary education

B. To develop a global partnership for development

C. To reduce child mortality

D. To ensure affordable and clean energy

D

Sustainable construction is referred to as all of the following except:

a. Green building

b. Feasible building

c. High-performance building

d. Environmentally friendly building

B

There is no need for the construction industry to consider implementing the concept of sustainability or sustainable development

False

Operation of the building is _____ energy

Operational

Manufacturing of building materials is considered _____ energy

Embodied of embedded

Transport of the materials from production plants to building sites is _____ energy

Grey

Construction of the building is ____ energy

Induced

To improve air and water quality and reduce global warming leads to _____ benefits

Environmental

Which of the following choices are best practices in sustainable construction?

a. All of these choices

b. Eliminating toxins

c. Reducing resource consumption

d. Use of recyclable resources

A

According to the Brundtland report in 1987, which of the following is NOT a necessary action to achieve sustainable development?

A. Eliminate poverty and deprivation

B. Conserve and enhance natural resources

C. Empower ecological decision-makers regarding sustainable development

D. Incorporate economic growth and ecological decision-making

C

Eco-driving is one of the 25 energy efficiency policy recommendations prepared by the G8.
True
When was the actual term of 'sustainable development' expressed for the first time?
World Conservation Strategy meeting -1980
Regarding the sustainability movement, what are the main realizations became progressively evident as early as the late 1800s?
Human activities were fundamentally changing the landscape & Increasing destructive impacts of chemical and physical agents released into the biosphere by human industrial activities
The U.S. has invested in the development of new energy assets and technologies to achieve high-performance and net-zero-energy buildings.
True
In the United States, many organizations either reference or explicitly incorporate the USGBC LEED GREEN Building Rating System as an evaluation mechanism and/or support tool.
True
Which one of the following is NOT an activity that supports the Implementation element phase of sustainability policies?
A. Training
B. Leadership
C. Demonstration projects
D. Technical support
B
Four basic elements of a Sustainability program:
Inspiration, Motivation, Implementation, Evaluation
Similar in form to Environmental Management System, Sustainability Management System plans take a broader focus to include social and economic goals relevant for the business being managed.
True
Which one of the following is a potential Policy Option that brings about sustainability policies and programs?
A. Endures and encourage performance
B. Incentives/subsidies
C. Performance monitoring and reporting
D. All of these options
A
The mandatory green building code adopted by the state of California which sets a new framework for recognizing and codifying the risks to public health and safety is known as:

CALGreen

Proper placement locations and appropriate shaped openings for recycling bins, which encourage a desired recycling behavior, is an example of which of the following?

A. Tragedy of Commons

B. Market-Based Instrument (MBI)

C. Product Semantics

D. Community-Based Social Marketing (CBSM)

D

According to the Copenhagen Accord, actions should be taken to keep a maximum increase to below _____ degrees Celsius to mitigate climate change.

2

According to the Brundtland definition of sustainable development, a sustainable society is one that:

Meets the needs of the present without compromising the ability of future generations to meet their own needs

3 pillars of sustainability

social, environmental, economic

In terms of forming a sustainability team, the Horizontal Approach to sustainability teams involves training everyone at a particular level or key function within a firm to leave basic skills and capabilities pertaining to sustainability.

False

Which one of the following is an Evaluation Option regarding sustainability policies and programs?

A. Operational performance monitoring and reporting

B. Demonstration projects

C. Require a specific level of performance

D. All of these options

A

Based on the Triple Bottom Line of sustainability, where does the "Environmental Justice" stand?

Shared area of Environmental and Social Pillars

When examining policy options, what are the three main categories that emerge when designing a sustainability policy or program?

Social

Economic

Environmental

Along with the development of sustainability objectives at the corporate level, a key element of corporate sustainability is forming an effective corporate sustainability team.

True

Green power is electricity produced from renewable resources including solar, wind, geothermal, biomass and low-impact hydro
True
Green building rating systems provide a way to help the construction market improve in terms of meeting green project goals.
True
The Earth Smart symbol is not a recognized standard, and it is not a reliable basis for decision-making during product selection.
True
Which of the following statements is true.
A. Ecological Footprint analysis is a variant on Life-Cycle assessment.
B. Life-Cycle Assessment and Ecological Footprint analysis are the same thing.
C. Life-Cycle Assessment is a variant on Ecological Footprint analysis.
D. Life-Cycle Assessment and Ecological Footprint analysis are only for measuring the sustainability of materials.
A
Choosing a product because its upstream environmental impacts are reduced is an optimal choice even if the product does not perform well in use and has to be replaced frequently.
False
Which of the following is NOT a harmful chemical to be used in buildings, according to the Red List developed by the International Living Future institution?
A. Mercury
B. Polystyrene
C. Lead
D. Polyvinyl Chloride (PVC)
B
Counting Carbon: Understanding Carbon Footprints of Buildings.
According to Counting Carbon, when seeking to identify opportunities for reducing carbon emissions, assigning ownership of those emissions is:
Not that important
Counting Carbon: Understanding Carbon Footprints of Buildings
The carbon emitted per unit of energy used in buildings depends on:
A. what kind of building the energy is used in
B. how the energy is generated
C. all of the above
D. how the energy is used
B
One of the most important takeaways from whole-building Life Cycle Assessment is that structural systems almost always comprise the largest source of embodied carbon in

the building—up to ____, depending on the building type, according to The Urgency of Embodied Carbon article.
80%
Electric arc furnaces, along with a cleaner electrical grid, has resulted in a ____ reduction in the industry's carbon footprint since ____ according to The Urgency of Embodied Carbon article.
36%, 1990
Which of the following is the type of projects that LEED can be applied to?
A. All of these
B. Design and Construction
C. Neighborhood Development
D. Homes
A
Rating categories for the CASBEE rating system
B. Excellent (S), Very good (A), Good (B+), Fairly poor , and poor (C)
Products with longer service lives and lower maintenance costs will typically have _____ life-cycle cost.
lower
A product's emissions, including solid waste, liquid waste, and air pollution, are tracked in a life-cycle assessment.
True
The phases of a construction material life cycle do NOT include:
Select one:
A. effect of use
B. use of material
C. downstream of use
D. upstream of use
A
Counting Carbon: Understanding Carbon Footprints of Buildings.
At atmospheric pressure and ambient temperatures, the volume of one ton of carbon is about the volume of:
A house
Counting Carbon: Understanding Carbon Footprints of Buildings.
The term "precombustion emissions" refers to:
A. emissions released from natural systems prior to the human invention of fire
B. emissions a power plant releases as it is warming up
C. none of the above
D. emissions associated with extracting and refining a fuel
D

In the Urgency of Embodied Carbon Article, the Gold Standard and most widely accepted method for assessing embodied carbon is ____, but other tools can supplement this as a first step.
A. Monkey tree analytics (MTA)
B. Whole-building life-cycle assessment (WBLCA)
C. Ordered embodied carbon (OEC)
D. Aerial carbon reduction assessment (ACRA)
B
Thin brick on metal studs showed a ____ in embodied carbon from the baseline building (thin brick with precast concrete) in a comparison of ten different wall systems from The Urgency of Embodied Carbon article.
A. 45% reduction
B. 58% reduction
C. 10% reduction
D. 25% increase
B
Which of the following is the first major cornerstone (or birth of) sustainability movement?
a. Setting the first earth day
b. Publication of Silent Spring by Rachel Carson
c. Organizing the World Conservation Strategy meeting
d. Organizing the first conference on Human Environment
B
Misleading claims about the environmental benefits of a product, company, or other entity are known as:
Select one:
a. brainwashing
b. greenwashing
c. envirowashing
d. whitewashing
B
To choose a green product, which information would NOT help you to evaluate the sustainability of that product?
a. Where are the raw materials from?
b. Are there any third-party backup certifications for green labels?
c. Are the ingredients natural?
d. Are there any comparable alternative products?
C
Which one is NOT the fundamental components for sustainable development?
Select one:

a. economic growth
b. social equity
c. public safety
d. environmental protection
C
The evolution of sustainability science has included many insights about how natural systems and stocks of natural resources require constraints on human behavior if sustainability requirements for future generations are to be obtained. In this regard, one human behavior theory that influences the overall sustainability equation is "Tragedy of Commons." Which of the following is an example of this theory)?
Thousands of farms are located along the Mississippi River and its tributaries through the central U.S. As water washes into the river after a heavy rain, it brings with it nutrients from fertilizers added to farmland. These materials flow downriver and eventually enter the Gulf of Mexico, where they create conditions for a dead zone — a region of the ecosystem that cannot support any living creatures.
Products with (1) longer service lives, and (2) lower maintenance costs will typically have _____ life-cycle cost.
(1) Lower (2) Lower
Which of the following is NOT a LEED level of certification?
Select one:
a. Platinum
b. Gold
c. Certified
d. Green
D
Which of the following is NOT a legitimate effect of construction activity on the environment?
Select one:
a. Soil erosion
b. Ozone depletion
c. Crop contamination
d. Global warming
C
In order to produce 1,000 kWh of electricity, which statement is true?
a. The emitted carbon dioxide (CO2) is the same for Coal and Natural Gas as a source of energy as long as it is the same amount of 1,000 kWh of electricity
b. If we use Coal as the source of energy, more carbon dioxide (CO2) will be emitted than we use Natural Gas
c. The source of energy is not the needed information to calculate the emitted carbon dioxide (CO2)

d. If we use Natural Gas as the source of energy, more carbon dioxide (CO2) will be emitted than we use Coal
B
Who plays the strongest role in the success of a sustainability program for built facilities?
Owners and supporting personnel
Sustainability programs generally consist of four basic elements. In which step would you cover program compliance and/or the effectiveness of the policy?
a. Inspiration
b. Evaluation
c. Motivation
d. Implementation
B
According to the pillars of sustainability theory (week vs. strong sustainability), a product that considers both "Environmental" and "social" aspects is:
Bearable
_____ is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to development, implementation, and enforcement of environmental laws, regulations, and policies.
Environmental Justice
Which of the following is a social benefit of sustainable design and construction?
a. Heighten aesthetic qualities
b. Minimize occupant absenteeism
c. Conserve natural resources
d. Improve occupant productivity
A
The carbon emitted per unit of energy used in buildings depends on:
Select one:
a. what kind of building the energy is used in
b. how the energy is used
c. how the energy is generated
d. all of the items
D
LEED is one of the most well-known green building rating systems worldwide, developed by the United States. What does LEED stand for?
Leadership in Energy & Environmental Design
The approach of identifying the potential hazards during the earliest stage of the project and changing the design to prevent them during construction is called _____.
Prevention through design

Based on the hierarchy of controls for safety and health, which one of the following has the highest level of effectiveness?
Select one:
A. Provide protection for the people exposed to the hazard.
B. Create barriers between the hazard and people at risk
C. All of these items have the same level of effectiveness.
D. Change the design to remove the hazard
D
The outcome of the pre-design phase is typically a set of requirements describing the functional expectations the owner has for the facility, known as "Programme of Requirements". Which one of the following is NOT a major element?
A. Budget review and analysis
B. Proposed project schedule and constraints
C. List of available contractors and suppliers
D. Project definition and scope
C
Which of the following is NOT a rapidly renewable material?
Select one:
A. Gravel
B. Bamboo
C. Wool
D. Linoleum
A
The highest demand for energy in the built environment is typically during _____.
Mid-afternoon in the hottest part of summer
Which of the following is not an energy efficiency method used in the Trees Atlanta building?
Select one:
A. task lighting
B. bioswales
C. glazing
D. daylighting
B
Which one of the following is an option for terminating the lifecycle of a facility?
A. Deconstruction
B. All of these options
C. Disposal
D. Demolition
B

_____ is one of the processes for a built facility to improve its performance in the end-of-life cycle phase.
Rehabilitation
When energy demand exceeds supply, the system becomes so unstable that safety mechanisms activated to take part of the grid offline. This is known as a _____.
Blackout
Choosing a _____ site for a building might offer a tax credit or development incentive for the developer.
Brownfield
Based on the people's place library in Canada, _____ system is used to remove oils and sediment from water before it enters local waterways.
A. Rainwater Harvesting
B. Hydration Station
C. All of these items
D. Stormceptor catchment
D
Which phase in the lifecycle of a built facility has the greatest opportunity to influence the environmental impacts?
Pre-Design
Which one of the following is NOT true about Bioswales?
A. It helps to remove contaminants from runoff
B. It is often used in conjunction with alternative pavement
C. It is a vegetated area to absorb stormwater runoff
D. It allows stormwater to infiltrate the site
D
The Trees Atlanta project team faced which concern when considering energy efficiency?
Cost
Which of the following is NOT a resulting document from the Design Phase?
Select one:
A. Schematic design
B. Performance Criteria
C. Conceptual design
D. Construction documents
B
Trees have positive effects on the following EXCEPT:
Select one:
A. property value
B. water quality

C. air quality
D. water retention
B
Which of the following is not a sustainability-related track in integrative design steps?
A. Material analysis
B. Resource analysis & modeling
C. Energy analysis
D. Ecological site planning
C
Which of the following can help reduce the risk of wildfire around buildings by keeping areas near buildings clear of flammable vegetation and debris?
Select one:
A. Group plants
B. Irrigation
C. Trees
D. Zoned landscaping
D
Multi-function materials (3):
1. Structural insulated panels (SIPs)
2. Insulated Concrete Forms (ICFs)
3. Aerated autoclaved concrete (AAC)
A preconstruction manager has following the responsibilities except:
Select one:
a. working with the design and owner teams during the design phase
b. providing a complete picture of the budget
c. evaluating the decisions in planning and design phase
d. none of the options
D
According to your textbook, _____ reduces air emissions resulting from diesel combustion and reduces dependence on non-renewable resources.
Biodiesel
Dry processes (rather than wet processes) help to suppress dust and particulates.
False
During construction, process waste can be reduced by:
a. protection of installed work
b. all of the options
c. careful coordination of subcontractors
d. effective materials management
B

In the Trees Atlanta building, the _____ is responsible for keeping a waste management report throughout the demolition and construction process.
General contractor
Sustainable construction personnel should prevent pollution by ordering more material than necessary to get the job done.
False
Plastic products, when exposed to UV radiation, begin to _____.
photodegrade
The ____ program does not involve a rating system but is based on the premise that buildings in a neighborhood can form a district to meet, collectively, the goals of the Architecture 2030 Challenge.
2030 districts
The district-scale programs discussed in this article that encourage sustainable development are:
Select one:
a. LEED for Communities
b. All of the above
c. 2030 Districts
d. EcoDistricts
e. Living Community Challenge
B
Communities establish EcoDistricts to support a range of neighborhood-scale projects that increase performance across the full spectrum of sustainability such as: Select all that apply.
a. District energy and water management
b. Urban agriculture or community gardens
c. All of the above
d. Public art installations
C
The US Environmental Protection Agency (USEPA) recommends a six-week flush-out period for all areas in which construction has occurred prior to occupancy.
False
Ecosystems can only be restored where environmental conditions support ongoing sustainability and evolution.
True
The ESB team created different packages or combinations of energy-efficiency strategies with the following goals:
Select one:
a. Maximize NPV
b. All of the options

c. Maximize CO_2 savings for zero NPV
d. Balance CO_2 savings and NPV
B
A _____ plan includes an occupancy schedule, equipment run-time schedules, and design set points for heating, ventilation and air conditioning (HVAC) equipment.
General building operating
The Universal Waste Rule in the U. S. governs the proper disposal of products that contain hazardous components.
True
According to Clark Brockman, occupant loads accounted for _____ of the modeled energy use of the Oregon Sustainability Center.
50%
Universities are good candidates for net-zero-energy communities because:
a. they have access to "patient" capital, rather than investors who want a quick return
b. they have centralized energy infrastructure
c. all of the options
d. they are communities held entirely under common ownership
C
NREL and DOE have argued that net-zero-energy performance can be calculated on the basis of:
site energy, energy cost, greenhouse gas emissions
Fossil-fuel plants also emit ____ .
Select one:
a. Particulates that are linked to heart and respiratory problems
b. Sulfur dioxide that causes acid rain
c. Nitrogen oxides and other compounds that produce smog
d. All of the above
D
Over the last _____ years, lower PV costs and other factors have spurred PV industry growth, making solar power competitive with most fuel choices.
10
The statement of - All HVAC equipment should be regularly inspected and properly maintained to identify and fix problems before they create unhealthy conditions. - is an example practice of _____.
Green Housekeeping
Which one of the following is NOT a sustainable opportunity in the post-occupancy phase of a facility?
Select one:
a. Green waste management

b. Green site development
c. Green housekeeping
d. Green renovation
B
Building humidity levels should be monitored and maintained, with an indoor relative humidity level of _____.
30-50%
Optimizing the energy performance of an existing building can yield significant benefits such as _____.
Select one:
a. All of the options
b. Enhance productivity
c. Improve users' comfort and satisfaction
d. Reduce Operating Cost
A
Deconstruction is a process of demolishing a building and using the land for future construction.
False
The main types of solar panels made today is _____.
Thin film and crystalline silicon
In PNNL's 2009 study of the cost-effectiveness of net-zero-energy communities, the most cost-effective option for a small community of about 16,000 people was:
wind on leased land
Solar power is created_____, providing energy independence and greater resilience.
a. Hourly
b. Poorly
c. Internationally
d. Locally
D
According to Criterion Planners, ____ of building energy savings in a prototype LEED for Neighborhood Developments community comes from the use of district systems.
20%
Use of microinverters grew rapidly over the past few years, and they are now used in _____ of residential systems.
60%
Which of the following two strategies reduced the glazing in the Reedy Fork Elementary School building?
Select one:
a. reflective ceilings and daylighting

b. All of the options.
c. reflective pools and light shelves
d. reflective ceilings and light shelves
D
Which of the following problems is addressed by the Clean Construction USA program?
Select one:
a. health issues due to air pollution
b. water scarcity
c. emission of diesel exhaust
d. fuel scarcity
C
A new type of drywall developed by Serious Materials is made with _____ % recycled materials.
80
The construction industry (including architects, engineers, and contractors) is responsible for designing, assembling, maintaining and decommissioning built environment.
T
Which one of the following is NOT a key area of nanotechnology application in construction?
Select one:
a. nano-lubricants
b. nano-molecular structure
c. nano-concrete
d. nano-coating materials
C
6D GIS models were used in the Masdar City to perform the following tasks except:
Select one:
a. managing change orders
b. managing contractors on site
c. visualizing energy and water use
d. monitoring power supply
D
According to you textbook,_____ is the predominant structural and finishing material for the Reedy Fork Elementary School building.{
Locally manufactured masonry
The Reedy Fork Elementary School building collects rainwater from the roofs and stores it in a sump.
true

Fluorescent lights are used in the Reedy Fork Elementary School building to maximize the energy saved by the daylighting systems.
true
The Reedy Fork Elementary School building indoor walls are painted with light colors to improve lighting.
True
Life cycle of the BE
Pre-design (defining)
Design (Transforming)
Construction (building)
Post Occupancy (using)
End of life (Deconstructing)
_____ are the people directly benefiting from the project or those who provide the financing for it, such as owners, tenants, users, and clients.
Internal Stakeholders
_____ are the people involved or affected by the project significantly, such as contractors, designers, and government agencies.
External Stakeholders
4 stages of sustainable planning:
1. Awareness and visioning
2. Baseline mapping
3. Creative solutions
4. Decide on priorities
4 pre-design sustainable opportunities
1. Facility options ID
2. Portfolio management and resource allocation
3. Sustainability goals and requirements establishment
4. Project delivery planning
Hierarchy of controls for safety
Elimination
Substitution
Engineering controls
Administrative controls
PPE

cooking
Which of the following uses the least amount of energy:
Economic benefits
To create, expand, and shape markets for green product and services leads to _____
True

T/F
The use of sustainable technologies and practices creates new employment opportunities.
improved overall quality of life
Which of the following is NOT an environmental selling point for sustainable construction?
Reducing resource consumption
Use of recyclable resources
Eliminating toxins
Which of the following choices are best practices in sustainable construction?
Improving air and water quality
Which of the following is an example of an environmental benefit?
True
T/F
The benefits of sustainable design and construction offer the potential to change the way in which we as humans face the challenges of the next decade.
Green building
Environmentally Friendly Building
High Performance Buildings
In the Construction Industry, Sustainable design and construction is also commonly referred to as which of the following?
True
T/F
Sustainable design and construction tactics can result in significant social benefit to both facility stakeholders and society at large.
Achieve universal environmental education
Which of the following is NOT part of goal 7 -focused on environmental sustainability -of Millennium Development Goals (MDGs)?
True
T/F
Buildings in the US consume about 16% of the total water withdrawals, in the amount of nearly 39 billion gallons per day.
Universal education
Which of the following is NOT a goal of Sustainable Development Goals (SDGs)?
True
T/F
The use of sustainable technologies and practices creates new employment opportunities.
Environmental Benefits

To improve air and water quality & Reduce global warming leads to _____

False

T/F

One half of global greenhouse emissions can be attributed to buildings.

Improved overall quality of life

Which of the following is NOT an environmental selling point for sustainable construction?

Feasible building

Sustainable construction is referred to as all of the following except:

To ensure affordable and clean energy

Which of the following is NOT a goal of Millennium Development Goals (MDGs)?

Creating new business opportunities

Which of the following is NOT an Economic benefit for sustainable construction.

Social Benefits

To enhance occupant comfort and health leads to _____

False

T/F

According to the definition of "Weak" sustainability, not all resources are interchangeable, although they may be complementary.

False

T/F

The Sustainable design and construction movement in Japan is a top-down process.

True

T/F

Eco-driving is one of the 25 energy efficiency policy recommendations prepared by the G8.

Political

Which one of the following is NOT a pillar of sustainability, according to Triple Bottom Line?

True

T/F

To achieve the goals of sustainability, the United Nations Environment Programme (UNEP) built their headquarters to be climate-neutral.

True

T/F

Similar in form to Environmental Management System, Sustainability Management System plans take a broader focus to include social and economic goals relevant for the business being managed.

Technical Support

According to the textbook, having an experienced engineer on staff to provide direct assistance to state agencies and the private sector is an example of a sustainability policy brought about by what component of the Implementation element phase?
Guidance Documents
According to the textbook, School districts that adopt a sustainable school design program, such as the WA sustainable school design protocol, in replacement of the LEED rating system is an example of a sustainable policy brought about by what component in the Implementation element phase?
Policy, Programme, and Evaluation
When examining policy options, what are the three main categories that emerge when designing a sustainability policy or program?
Government Activities
Rewarding sustainable practices like making expedited permitting available to an organization that is planning new construction when they submit a green building checklist, such as LEED, is an example of a sustainable policy brought about by which component of the Inspiration element phase?
Human activities were fundamentally changing the landscape & Increasing destructive impacts of chemical and physical agents released into the biosphere by human industrial activities
Regarding the sustainability movement, what are the main realizations became progressively evident as early as the late 1800s?
True
T/F
"Silent Spring" was published to describe the negative impacts of modern chemicals (e.g. hazards of industrial chemicals, effect of insecticides, and sprays in agriculture).
true
T/F
Market-based instruments influence the behavior of the market by incorporating costs that are often externalized to others or to society.
CALGreen
The mandatory green building code adopted by the state of California which sets a new framework for recognizing and codifying the risks to public health and safety is known as:
north-south
To achieve maximum daylight and minimum heat intake, the United Nations Office Complex was built in _____ orientation.
Design, construction, and delivery of the capital project
According to your textbook, the stakeholders that collaborate in the delivery of green capital projects must deal with a number of unique qualities that characterize more sustainable projects. Which of the following is NOT one of them?

Endures and encourages performance
Which one of the following is a potential Policy Option that brings about sustainability policies and programs?
Improved image/reputation of environmental leadership both within the organization and with respect to other organizations.
Which one of the following is a potential social reward of a sustainability program?
False
T/F
Sustainability policies for capital projects should solely focus on establishing sustainability standards for those capital projects.
True
T/F
Along with the development of sustainability objectives at the corporate level, a key element of corporate sustainability is forming an effective corporate sustainability team.
US Environmental Protection Agency;
Perform in the top 25% of all products in its class
According to Energy Star, which is developed by _____, a product must _____ in order to display the Energy Star logo.
brownfield
The Duke Energy Center site was classified as a _____ site because the nearby land was a gas station.
rural scale
Which of the followings is NOT a scale of CASBEE rating system:
False
T/F
Transportation is not considered in the life-cycle analysis of a product.
False
T/F
Downstream impacts are all of the side-effects a product has before it is actually used.
effects of use
The phases of a construction material life cycle do NOT include:
A house
Counting Carbon: Understanding Carbon Footprints of Buildings.
At atmospheric pressure and ambient temperatures, the volume of one ton of carbon is about the volume of:
50%
Counting Carbon: Understanding Carbon Footprints of Buildings
Coal accounts for about what share of U.S. electricity generation:
Whole-Building life-cycle Assessment (WBLCA)

In the Urgency of Embodied Carbon Article, the Gold Standard and most widely accepted method for assessing embodied carbon is _____, but other tools can supplement this as a first step.
construction
Building reuse and incorporation of salvaged building materials can greatly reduce the embodied carbon of _____, according to The Urgency of Embodied Carbon article.
true
T/F
Green power is electricity produced from renewable resources, including solar, wind, geothermal, biomass and low-impact hydro.
Indoor air quality
Which one of the following is NOT a performance goal category for LEED?
Natural systems
Which one of the following is not a project type that can be certified within the LEED rating system?
true
T/F
A product's emissions, including solid waste, liquid waste, and air pollution, are tracked in a life-cycle assessment.
Life-cycle Assessment
_____ is used to get more information about a product and used as a basis for some green product certifications.
lower
Products with longer service lives and lower maintenance costs will typically have _____ life-cycle cost.
not that important
Counting Carbon: Understanding Carbon Footprints of Buildings
According to Counting Carbon, when seeking to identify opportunities for reducing carbon emissions, assigning ownership of those emissions is:
below current levels
Counting Carbon: Understanding Carbon Footprints of Buildings
The "350.org" campaign to limit concentrations of CO2 in the atmosphere describes a target in parts per million (ppm) that is:
80%
One of the most important takeaways from whole-building Life Cycle Assessment is that structural systems almost always comprise the largest source of embodied carbon in the building—up to _____, depending on the building type, according to The Urgency of Embodied Carbon article.
40 to 45

The Urgency of Embodied Carbon article describes the business-as-usual (BAU) forestry practices harvest cycle as ____ years, but a study found that an 80-year harvest cycle would be more beneficial for carbon storage in order for the trees to reach their optimum volume before harvesting.

What does BREEAM stand for?
Building Research Establishment Environmental Assessment Method
Green Star is the Green Assessment utilized in which country?
Australia
How many performance areas are in the Living Building Challenge
7
CASBEE was developed by and for use in Cambodia
False
Green Building Assessment Systems(GBAS) are used in how many countries?
over 60
What are the two major GBAS in the US?
LEED and Green Globes
Living Building Challenge is the least demanding GBAS in North America.
False
CASBEE is the rating systerm used by United Kingdom
False
The United States utilizes which of the following Green Building Assessment Systems?
LEED, Green Globles
The United Kingdom utilizes which of the following Green Building Assessment Systems?
BREAM
Germany utilizes which of the following Green Building Assessment Systems?
DGNB
Which of the following is NOT one of the three major sustainability areas of evaluation?
Technology Quality
Which system listed is not used in the United States?
CASBEE
Green Star is the major Japanese green building assessment scheme and is similar in many respects to BREEAM and LEED in its approach and structure.
False
what minimum percentage is required to obtain an Outstanding BREEAM rating?
85%
What is the purpose of a Green Building Assessment System?
To score or rate the impact of a buildings design

In the "seven categories and 20 imperatives of the Living Building Challenge", which one is not included in the PLACE imperatives?
Civilized Environment
which LEED category is for energy and Atmosphere
BD+C
How many building types are featured in the LEED rating system?
5
All of the following are contained in the LEED Building Design and Construction Rating system except
Education and Mentoring
All the following are requirements for the LEED BD+C Minimum program EXCEPT
Must register the project with the GBCI

Construction actually have little to no effects on the environment, and thereby has no effect on global warming.
False
To create, expand, and shape markets for green product and services leads to economic benefits
Buildings in the US consume about 16% of the total water withdrawals, in the amount of near 39 billiion gallons per day.
true
which of the following choices are best practices in sustainable construction?
all of these choices,
(use of recyclable resources, reducing resource consumption, and eliminating toxins.)
which of the follwing is not an economic benefit for sustainable construction
creating new business opportunities
which of the following is NOT part of goal 7-focused on environmental sustainability -of millennium development goals (MDG's)
Achieve universal environmental education
the use of sustainable technologies and practices creates new employment opportunities.
true
which of the following is not an environmental selling point for sustainable construction?
improved overall quality of life
which of the following is NOT a goal of millennium develop goals (MDGs)
to ensure affordable and clean energy
which of the following is an example of an environmental benefit?
improving air and water quality
the benefits of sustainable design and construction offer the potential to change the way in which we as humans face the challenges of the next decade.

true
sustainable design and construction tactics can result in significant social benefit to both facility stakeholders and society at large.
true
to improve air and water quality and reduce global warming leads to
environmental benefits
there is no need for the construction industry to consider implementing the concept of sustainablity or sustainable development
false
which of the following is NOT a goal of sustainable development goals (SGSs)
universal education
The use of sustainable technologies and practices create new employment opportunities
true
which of the following uses the least amount of energy
cooking
sustainable construction is referred to as all of the following except
feasible building
to enhance occupant comfort and health leads to
social benefits
one half of global greenhouse emission can be attributed to buildings
false
the sustainable design and construction movement in Japan is a top-down process
false
which one of the following is NOT a pillar of sustainability, according to Triple Bottom Line?
Political
"Silent Spring" was published to describe the negative impacts of modern chemicals (e.g. hazards of industrial chemicals, effect of insecticides, and sprays in agriculture).
true
eco-driving is one of the 25 energy efficiency policy recommendations prepared by the G8.
true
the U.S. has invested in the development of new energy asets and technologies to achieve high-performance and net-zero-energy building
true
According to the textbook, having experienced engineer on staff to provide direct assistance to state agencies and the private sector is an example of a sustainability policy brought about by what component of the implementation element phase?
technical support

based on the model in your textbook, where does "environmental justice" stand in the triple bottom line of sustainability
the shared area of environmental and social pillars
which one of the following is a potential policy option that brings about sustainability policies and programs?
endures and encourages performance
which one of the following is NOT a construction sector trend that was a precursor to sustainablity
leadership energy environmental design (LEED)
sustainability policies for capital projects should solely focus on establishing sustainability standards for those capital projects
false
according to the Copenhagen Accord, actions should be taken to keep a maximum increase to below_____degrees Celsius to mitigrate climate change.
2
The Jevons Paradox describes a phenomenon in which resource use decrease following an improvement in the efficiency of a technology or process that uses the resources
false
eco-driving is one of the 25 energy efficiency policy recommendations prepared by the G8.
True
Proper placement locations and appropriate shaped openings for recycling bins, which encourage a desired recycling behavior, is an example of which of the following
community based social marketing (CBSM)
Which of the following events resulted in forming Agenda 21, a program created for global action in all areas of sustainable development?
the UN Conference on Environment and and Development in 1992
In the United States, many organizations either reference or explicitly incorporate the USGBC LEED GREEN building rating system as an evaluation mechanism and/or support tool.
True
which one of the following is an evalutation option regarding sustainability policies and programs
operational performance monitoring and reporting
which one of the following is a potential environmental reward of a sustainability program
increase in sustainable site development practices and improvements in transportation efficiency

special weapons and tactics (SWAT) is an approach within a corporation that can be used to develop and roll out sustainability teams
true
when examining policy options, what are the three main categories that emerge when designing a sustainability policy program
policy, program, evaluation
Which one of the following are levels of certificaiton for the LEED rating system
platinum, gold, silver, certified
which of the following is NOT a major area in BREEM rating points
regional priority
which one of the following is not a project type that can be certified within the LEED rating system?
natural systems
Keeping track of all raw materials, energy, and waste associated with a product is part of
life-cycle assessment
choosing a product because its upstream environmental impacts are reduced is an optimal choice even if the product does not perform well in use and has to be replaced frequently.
false
the whole lifecycle of a product should be considered in making material selection decisions
true
Counting Carbon: Understanding Carbon Footprints of buildings
THe "350.org" campaign to limit concentrations of CO2 in the atmosphere describes a target in parts per million (ppm) that is
below current levels
Counting carbon: understanding Carbon footprints of buildings
From most carbon-intensive to least carbon-intensive, the rank of common fossil fuels is
coal, fuel oil, natural gas
thin brick on metal studs showed a ___ in embodied carbon from the baseline building (thin brick with precast concrete) in a comparison of ten different wall systems from the Urgency of Embodied Carbon article
58% reduction
Replacing some cement with supplemental cementitious materials (SCMs) like ____or____ is a go to way for project teams to reduce the embodied carbon of the concrete in their projects as described in the The Urgency of Embodied Carbon article.
Fly ash; blast furnace slag
What does BREEM stand for, and where is its origin
Building Research Establishment Environmental Assessment Method: UK

Green Globes requires expertise and formal training to apply the rating system effectively to a project
false
which of the following is NOT a scale of CASBEE rating system:
rural scale
_____ is used to get more information about a product and used as a basis for some green product certifications
life cycle assessment
downstream impacts are all of the side effects a product has before it is actually used
false
products with longer service lives and lower maintenance cost will typically have _____ life cycle cost
lower
counting carbon: understanding carbon footprints of buildings
According to counting carbon, when seeking to identify opportunities for reducing carbon emmissions, assigning ownership of those emissions is
not that important
counting carbon: understanding carbon footprints of buildings
Including both precombustion and combustion emissions, coal-derived power is roughly how many times more baron intensive than nuclear power
50 times
the urgency of embodied carbon articles describe the business-as-usual (BAU) forestry practices harvest cycle as ____ years, but a study found that an 80-year harvest cycle would be more beneficial for carbon storage in order for the trees to reach their optimum volume before harvesting
40 to 50
Structural systems are the most significant source of embodied carbon, but are also significant as stated in the Urgency of Embodied Carbon article
enclosures

Which of the following is NOT part of goal 7 -focused on environment sustainability -of Millennium Development Goals (MDGs)?
A. Achieve universal environmental education
B. Reduce biodiversity loss
C. Access to safe drinking water
D. Improvement in the lives of slum-dwelling
D. Improvement in the lives of slum-dwelling
(T/F) Improving the image of buildings would be considered a social benefit?
False
(T/F) To improve overall quality of life is not an environmental selling point for sustainable construction?

True
(T/F) The use of sustainable technologies and practices creates new employment opportunities.
True
Which of the following is NOT an environmental selling point for sustainable construction?
A. Reduced waste streams
B. Improved air and water quality
C. Improved overall quality of life
D. Reduced global warming
C. Improved overall quality of life
Manufacturing of building materials is considered_____ energy?
A. Embodied of embedded
B. Induced
C. Operational
D. Grey
A. Embodied of embedded
Construction of the building is_____ energy?
A. Embodied of embedded
B. Induced
C. Operational
D. Grey
B. Induced
Operation of the building is_____ energy?
A. Embodied of embedded
B. Induced
C. Operational
D. Grey
C. Operational
Transport of materials from production plants to building sites is_____ energy?
A. Embodied of embedded
B. Induced
C. Operational
D. Grey
D. Grey
Energy in the building sector is consumed during all of the following except:
A. Scheduling the time of use
B. Manufacturing of the building materials
C. Construction of buildings
D. Demolition of the building

E. Recycling of the building parts
A. Scheduling the time of use
Which of the following is NOT an economic benefit for sustainable construction?
A. Reducing operation cost
B. Creating new business opportunities
C. Improving the image of the building
D. Reducing the civil infrastructure costs
C. Improving the image of the building
(T/F) The benefits of sustainable design and construction offer the potential to change the way in which we as humans face the challenges of the next decade.
True
Which of the following is an example of an environmental benefit?
A. Improving the images of the building
B. Improving occupants health and comfort
C. Reducing civil infrastructure costs
D. Improving air and water quality
D. Improving air and water quality
Which of the following uses the least amount of energy?
A. Cooking
B. Lighting
C. Using a water heater
D. Using a space heater
A. Cooking
To improve air and water quality & Reduce global warming leads to?
A. Environmental benefits
B. Social benefits
C. Economic benefits
D. Political benefits
A. Environmental benefits
(T/F) Construction actually have little to no effects on the environment, and thereby has no impact on global warming.
False
To create, expand, and shape markets for green product and services leads to?
A. Environmental benefits
B. Social benefits
C. Economic benefits
D. Political benefits
C. Economic benefits
Which of the following is NOT a goal of Sustainable Development Goals (SDGs)?
A. Universal Education

B. Gender Equality
C. Climate Action
D. Zero Hunger
A. Universal Education
(T/F) Buildings in the US consume about 16% of the total water withdrawals, in the amount of nearly 39 billion gallons per day
True
(T/F) One half of global greenhouse emissions can be attributed to buildings.
False
Which of the following choices are best practices in sustainable construction?
a. Use of recyclable resources
b. Eliminating toxins
c. Reducing resource consumption
d. All of these choices
d. All of these choices
To enhance occupant comfort and health leads to:
A. Environmental benefits
B. Social benefits
C. Economic benefits
D. Political benefits
B. Social benefits
Which of the following is NOT a goal of Millennium Development Goals (MDGs)?
A. To achieve universal primary education
B. To develop a global partnership for development
C. To reduce child mortality
D. To ensure affordable and clean energy
D. To ensure affordable and clean energy
What three main benefits that result from sustainable design and construction?
a. Political, Environmental, Global
b. Environmental, Economic, Social
c. Social, Environmental, Global
d. Economic, Political, Global
b. Environmental, Economic, Social
(T/F) Sustainable design and construction tactics can result in significant social benefit to both facility stakeholders and society at large.
True
(T/F) To achieve the goals of sustainability, the United Nations Environment Programme (UNEP) built their headquarters to be climate-neutral.
True

Proper placement locations and appropriate shaped openings for recycling bins, which encourage a desired recycling behavior, is an example of which of the following?
A. Tragedy of Commons
B. Market-Based Instrument (MBI)
C. Product Semantics
D. Community-Based Social Marketing (CBSM)
D. Community-Based Social Marketing (CBSM)
Which of the following events resulted in forming Agenda 21, a program created for global action in all areas of sustainable development?
A. World Conservation Strategy meeting in 1980
B. The UN World Commission on Environmental and Development in 1987
C. The UN Conference on Environment and Development in 1992
D. World Bank report in 1995
C. The UN Conference on Environment and Development in 1992
Overfishing of a particular type of fish, causing low populations of that fish even in spawning areas and risking marine life ecosystem endangerment or extinction. This is an example of which of the following?
A. Jevons Paradox
B. Tragedy of the Commons
C. The Precautionary Principles
D. Rebound E
B. Tragedy of the Commons
_____is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to development, implementation, and enforcement of environmental laws, regulations, and policies.
A. Environmental ecology
B. Social ecology
C. Economic ecology
D. Political ecology
A. Environmental ecology
Which one of the following is a potential environmental reward of a sustainability program?
A. Reduced environmental management and compliance costs.
B. Improved image/reputation of environmental leadership both within the organization and with respect to other organizations.
C. Increase in sustainable site development practices and improvements in transportation efficiency
D. None of these options.
C. Increase in sustainable site development practices and improvements in transportation efficiency

According to the textbook, School districts that adopt a sustainable school design program, such as the WA sustainable school design protocol, in replacement of the LEED rating system is an example of a sustainable policy brought about by what component in the Implementation element phase?
A. Demonstration projects
B. Guidance documents
C. Leadership
D. Technical support
B. Guidance documents
Which one of the following is a potential Policy Option that brings about sustainability policies and programs?
A. Endures and encourage performance
B. Incentives/subsidies
C. Performance monitoring and reporting
D. All of these options
A. Endures and encourage performance
Which one of the following is a potential Programme Option that brings about sustainability policies and programs?
A. Creating a working group to develop standards and plans
B. Modifying organizational practices
C. Obtaining Third-party certification or evaluation
D. All of these options
B. Modifying organizational practices
Based on your textbook, what are the four basic elements of a Sustainability Program?
A. Motivation, Direction, Implementation, Evaluation
B. Inspiration, Motivation, Innovation, Implementation
C. Inspiration, Motivation, Implementation, Evaluation
D. Inspiration, Direction, Innovation, Implementation
C. Inspiration, Motivation, Implementation, Evaluation
(T/F) Market-based instruments influence the behavior of the market by incorporating costs that are often externalized to others or to society.
True
The phenomenon where increased efficiency leads to increased demand that offsets the amount of resources saved through efficiency called _____.
A. The productivity principle
B. The tragedy of the commons
C. Rebound effect
D. Ecological Rucksack
C. Rebound Effect

According to the Copenhagen Accord, actions should be taken to keep a maximum increase to below _____ degrees Celsius to mitigate climate change.
A. 0.5
B. 2
C. 5
D. 7.2
B. 2
(T/F) The U.S. has invested in the development of new energy assets and technologies to achieve high-performance and net-zero-energy buildings.
True
Which one of the following is NOT a pillar of sustainability, according to Triple Bottom Line?
A. Social
B. Economy
C. Political
D. Environmental
C. Political
(T/F) In the United States, many organizations either reference or explicitly incorporate the USGBC LEED GREEN Building Rating System as an evaluation mechanism and/or support tool.
True
_____options provide funding, implementation, or other needed resources to make sustainability easier to achieve.
Programme
Circumstances such as the climate in Main, where extremely high energy costs make sustainable construction more attractive, is an example of a sustainable policy brought about from which components of the Inspiration element phase?
A. Leadership
B. Facing opponents
C. Government activities
D. Prevailing conditions
D. Prevailing conditions
According to your textbook, the stakeholders that collaborate in the delivery of green capital projects must deal with a number of unique qualities that characterize more sustainable projects. Which of the following is NOT one of them?
A. Requirements for additional information and documentation
B. Existence of incentives and resources not available to other projects
C. Design, construction, and delivery of the capital project
D. Procurement of unusual products with limited resources
C. Design, construction, and delivery of the capital project

According to ISO 14001, what are the four steps of a continuous improvement cycle?
A. Design - Construction - Operation - Demolition
B. Plan - Do - Check - Act
C. Objectives - Risks - Controls - Alignment
D. Inspiration - Motivation - Implementation - Evaluation
B. Plan - Do - Check - Act
(T/F) Improving the image of buildings would be considered a social benefit.
False
Sustainable construction is referred to as all of the following except:
a. Environmentally friendly building
b. High-performance building
c. Feasible building
d. Green building
c. Feasible building
Which of the following is the largest energy consumer?
a. Industrial
b. buildings
c. Transportation
d. Land
b. buildings
(T/F) Pollutant levels indoor are often higher than pollutant levels outdoor
True
(T/F) There is no need for the construction industry to consider implementing the concept of sustainability or sustainable development.
False
In the Construction Industry, Sustainable design and construction is also commonly referred to as which of the following?
a. All of these choices
b. High Performance Building
c. Environmentally Friendly Building
d. Green building
a. All of these choices
Which of the following is the type of projects that LEED can be applied to?
A. All of these
B. Neighborhood Development
C. Design and Construction
D. Homes
A. All of these
Which of the followings is NOT a scale of CASBEE rating system:
A. urban scale

B. rural scale
C. housing scale
D. building scale
B. rural scale
(T/F) Green building rating systems provide a way to help the construction market improve in terms of meeting green project goals.
True
_____is used to get more information about a product and used as a basis for some green product certifications.
A. Product database
B. Environmental analysis
C. Inspection
D. Life-cycle assessment
D. Life-cycle assessment
Keeping track of all raw materials, energy, and waste associated with a product is part of:
A. material assessment
B. life-cycle assessment
C. product assessment
D. environmental assessment
B. life-cycle assessment
The phases of a construction material life cycle do NOT include:
A. use of material
B. effect of use
C. downstream of use
D. upstream of use
B. effect of use
Counting Carbon: Understanding Carbon Footprints of Buildings From most carbon-intensive to least carbon-intensive, the rank of common fossil fuels is:
A. coal, fuel oil, natural gas
B. fuel oil, natural gas, coal
C. natural gas, coal, fuel oil
D. coal, natural gas, fuel oil
A. coal, fuel oil, natural gas
Counting Carbon: Understanding Carbon Footprints of Buildings Including both precombustion and combustion emissions, coal-derived power is roughly how many times more carbon intensive than nuclear power:
A. 10 times
B. 100 times
C. 2 times

D. 50 times
D. 50 times
The Urgency of Embodied Carbon states that the manufacture of building _____ makes up 11% of total global greenhouse gas emissions.
A. Methane
B. Mass
C. Materials
D. Monkeys
C. Materials
In the Urgency of Embodied Carbon Article, the Gold Standard and most widely accepted method for assessing embodied carbon is _____, but other tools can supplement this as a first step.
A. Whole-building life-cycle assessment (WBLCA)
B. Ordered embodied carbon (OEC)
C. Monkey tree analytics (MTA)
D. Aerial carbon reduction assessment (ACRA)
A. Whole-building life-cycle assessment (WBLCA)
What does BREEM stand for, and where is its origin?
A. Building Research Establishment Environmental Assessment Method; UK
B. Building Research Economic Environmental Analysis Method; UK
C. Building Research Economic Environmental Analysis Method; US
D. Building Research Establishment Environmental Assessment Method; US
A. Building Research Establishment Environmental Assessment Method; UK
The Duke Energy Center building has a green roof with the following advantages except:
A. reduced heat island effect
B. increased CO2
C. mitigation of storm water
D. reduced heating and cooling loads
B. increased CO2
The Duke Energy Center site was classified as a _____ site because the nearby land was a gas station.
A. urban
B. brownfield
C. greenfield
D. rural
B. brownfield
(T/F) Transportation is not considered in the life-cycle analysis of a product.
False

Keeping track of all raw materials, energy, and waste associated with a product is part of:
A. life-cycle assessment
B. environmental assessment
C. product assessment
D. material assessment
A. life-cycle assessment
(T/F) A product's emissions, including solid waste, liquid waste, and air pollution, are tracked in a life-cycle assessment.
True
Counting Carbon: Understanding Carbon Footprints of Buildings The "350.org" campaign to limit concentrations of CO2 in the atmosphere describes a target in parts per million (ppm) that is:
A. at current levels
B. below current levels
C. 50% above current levels
D. 10% above current levels
B. below current levels
Counting Carbon: Understanding Carbon Footprints of Buildings At atmospheric pressure and ambient temperatures, the volume of one ton of carbon is about the volume of:
A. a house
B. a car
C. a skyscraper
D. a supermarket
A. a house
The Urgency of Embodied Carbon states that the manufacture of building ____ makes up 11% of total global greenhouse gas emissions.
A. Mass
B. Monkeys
C. Methane
D. Materials
D. Materials
The Urgency of Embodied Carbon states that the biggest Environmental Product Declaration (EPD) drawback is that laypeople are not in a good position to compare results. You definitely can't compare steel to concrete, for example, and it's a tricky business even to compare _____.
A. One concrete mix to another
B. Bananas to oranges
C. One monkey to another

D. Trees to hovels
A. One concrete mix to another
Which one of the following are the rating categories for the LEED rating system?
A. None of the items
B. Certified, Not Certified
C. Excellent (S), Very good (A), Good (B+), Fairly poor (, and poor (C)
D. Platinum, Gold, Silver, Certified
D. Platinum, Gold, Silver, Certified
The Duke Energy Center building has a green roof with the following advantages except:
A. mitigation of storm water
B. reduced heat island effect
C. increased CO2
D. reduced heating and cooling loads
C. increased CO2
_____ contain key information about sustainability initiatives of an organization and are often self-reported to measure sustainability.
A. Corporate sustainability reports
B. Cost reports
C. Sustainability measurement reports
D. Sustainable strategy reports
A. Corporate sustainability reports
Which of the following statements is true.

A. Life-Cycle Assessment is a variant on Ecological Footprint analysis.
B. Life-Cycle Assessment and Ecological Footprint analysis are only for measuring the sustainability of materials.
C. Ecological Footprint analysis is a variant on Life-Cycle assessment.
D. Life-Cycle Assessment and Ecological Footprint analysis are the same thing.
C. Ecological Footprint analysis is a variant on Life-Cycle assessment.
(T/F) A product's emissions, including solid waste, liquid waste, and air pollution, are tracked in a life-cycle assessment.
True
Counting Carbon: Understanding Carbon Footprints of Buildings Precombustion emissions of common fossil fuels are, in relation to combustion emissions:
A. 2% to 4%
B. 5% to 20%
C. less than 1%
D. over 20%
B. 5% to 20%

Counting Carbon: Understanding Carbon Footprints of BuildingsThe term "precombustion emissions" refers to:
A. none of the above
B. emissions associated with extracting and refining a fuel
C. emissions released from natural systems prior to the human invention of fire
D. emissions a power plant releases as it is warming up
B. emissions associated with extracting and refining a fuel
Structural systems are the most significant source of embodied carbon, but ____ are also significant as stated in The Urgency of Embodied Carbon article.
A. Windows
B. Sidewalks
C. Enclosures
D. Lights
C. Enclosures
Building reuse and incorporation of salvaged building materials can greatly reduce the embodied carbon of ____, according to The Urgency of Embodied Carbon article.
A. Remodeling
B. Construction
C. Heating system upgrades
D. Transportation
B. Construction
Which directory lists green building materials with its qualifications and manufacturer?
A. Environmental Resource Guide
B. GreenSpec database
C. The Handbook of Sustainable Building
D. Green Building Handbook
B. GreenSpec database
According to the Green Star Australia rating system, what is the maximum number of stars a project can get and how many stars are required for a project to be certified as "Australian Excellence"?
A. 6 and 5
B. 5 and 4
C. 6 and 4
D. 6 and 6
C. 6 and 4
(T/F) Certified buildings are generally known by their certification level rather than the specific profile of points they have achieved.
True
Products with longer service lives and lower maintenance costs will typically have _____ life-cycle cost.

A. significant
B. lower
C. higher
D. same
B. lower
The phases of a construction material life cycle do NOT include:
A. upstream of use
B. use of material
C. effect of use
D. downstream of use
C. effect of use
Which of the following statements is true?
A. Ecological Footprint analysis is a variant on Life-Cycle assessment.
B. Life-Cycle Assessment and Ecological Footprint analysis are the same thing.
C. Life-Cycle Assessment is a variant on Ecological Footprint analysis.
D. Life-Cycle Assessment and Ecological Footprint analysis are only for measuring the sustainability of materials
A. Ecological Footprint analysis is a variant on Life-Cycle assessment.
Counting Carbon: Understanding Carbon Footprints of Buildings The carbon emitted per unit of energy used in buildings depends on:
A. how the energy is generated
B. what kind of building the energy is used in
C. how the energy is used
D. all of the above
A. how the energy is generated
Counting Carbon: Understanding Carbon Footprints of Buildings The "350.org" campaign to limit concentrations of CO2 in the atmosphere describes a target in parts per million (ppm) that is:
A. 10% above current levels
B. below current levels
C. at current levels
D. 50% above current levels
B. below current levels
Replacing some cement with supplemental cementitious materials (SCMs) like ____ or ____ is a go-to way for project teams to reduce the embodied carbon of the concrete in their projects as described in The Urgency of Embodied Carbon article.
A. Fly ash; blast-furnace slag
B. Glue; clay
C. Dry sawdust; shredded newspaper
D. Dense cardboard; crushed glass

A. Fly ash; blast-furnace slag
Electric arc furnaces, along with a cleaner electrical grid, has resulted in a ____ reduction in the industry's carbon footprint since ____ according to The Urgency of Embodied Carbon article.
A. 42%; 1988
B. 74%; 2005
C. 15%; 2000
D. 36%; 1990
D. 36%; 1990
(T/F) Green power is electricity produced from renewable resources, including solar, wind, geothermal, biomass and low-impact hydro.
True
The Duke Energy Center site was classified as a _____ site because the nearby land was a gas station.
A. brownfield
B. rural
C. greenfield
D. urban
A. brownfield
Which of the following is NOT a harmful chemical to be used in buildings, according to the Red List developed by the International Living Future institution?
A. Mercury
B. Lead
C. Polystyrene
D. Polyvinyl Chloride (PVC)
C. Polystyrene
(T/F) The whole lifecycle of a product should be considered in making material selection decisions.
True
(T/F) Downstream impacts are all of the side-effects a product has before it is actually used.
False
Counting Carbon: Understanding Carbon Footprints of Buildings Carbon is the most important human-generated greenhouse gas on the basis of its:
A. measurability compared with other gases
B. overall impact due to the quantities with which it is released
C. Controllability
D. molecule-for-molecule heat trapping ability
B. overall impact due to the quantities with which it is released

The Duke Energy Center site was classified as a _____ site because the nearby land was a gas station.
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C. greenfield
D. urban
A. brownfield
Which of the following is the type of projects that LEED can be applied to?
A. Neighborhood Development
B. All of these
C. Homes
D. Design and Construction
B. All of these