Better Steel, Lower Impacts

Steel’s reputation for high embodied energy and carbon emissions are well documented, but improvements in processing, product selection, and end use can minimize these impacts.

by Brent Ehrlich

Steel is ubiquitous in commercial buildings, found in everything from rebar in concrete footings to metal roofing. If protected from moisture and corrosion, steel will last 100 years or more, and at the end of its service life, it can be recycled back into structural components with no loss in performance. There are few materials that combine the strength, ductility, durability, and versatility of steel.

This performance comes at a high environmental cost, however. The iron and steel industry is one of the world’s largest industrial energy consumers, and one of the largest emitters of CO₂ in the world. Steel production accounts for about 6.6% of the world’s anthropogenic CO₂ emissions, according to the World Steel Association. That is more than cement at 5%, which is often demonized for its carbon emissions.

But the U.S. steel industry has been gradually improving its environmental footprint while improving product performance along the way. To better understand these industry changes and limitations, and how architects and engineers can optimize the use of steel to improve its sustainability, one has to know more about how steel is made.

Renovating Our Rustbelt

The image of 1960s-era coal-fired, smog-shrouded steel mills languishing in a rustbelt town is seared into our collective consciousness. It’s a symbol of a dying, polluted industry, yet the steel that came from these mills was used to create our transportation, industrial, and urban infrastructures. As late as the 1970s, steel mills were still consuming as much as 35 million Btu worth of coal per ton of steel, with few emissions controls to prevent air pollution.

Changing from blast furnace-basic oxygen furnaces (BOFs; that use mostly iron ore) to more efficient electric arc furnaces (EAFs; that use recycled steel scrap as feedstock) have cleared the air in the U.S. and reversed some of this legacy. And from the early 1990s to 2010, as the percent of steel made in the U.S. using EAFs rose from 38% to 61%, the energy required to produce steel in the U.S. dropped by 37%, according to the steel industry. But worldwide, 70% of steel is still made using BOFs.

“We are proud of those manufacturing efficiencies,” says Lawrence Kavanagh, president of the Steel Marketing Development Institute. Kavanagh points to a 2011 U.S. Department of Energy (DOE) study that showed that, globally, the U.S. achieved the second lowest energy use per ton of steel produced behind South Korea, stating “and we have probably caught them by now because of changes to our electricity grid and use of natural gas.”

Today producing a ton of steel using BOF still requires about 20 million Btu of energy and generates about two tons of CO₂; whereas a ton of steel made using EAF consumes about 10 million Btu and generates about a ton of CO₂ according to the U.S. DOE. Though the improvements since the 1970s are notable, these are still significant environmental impacts.
Making the most of a valuable commodity

The fact that it takes a lot of energy to make doesn’t necessarily make steel a bad building material, says Kate Simonen, AIA, assistant professor of architecture at the University of Washington. “We just need to treat it as if it was really precious and use it efficiently.”

We tend to take steel for granted, but it can be used in ways that concrete and wood can’t. Without steel’s strength, ductility, and light weight, the Empire State Building (LEED Gold), Union Square (LEED Platinum) in Seattle, and other iconic buildings that dominate our urban skyline could not have been built. Advances in 3D modeling and engineering tools now allow architects to design and build steel buildings in ways that were unimaginable 20 years ago. And the rise of modular, prefabrication techniques are streamlining how buildings are constructed—the Broad Sustainable Building firm in China reportedly erected a 57-story skyscraper in 19 working days!

Not all steel structures are as well designed, engineered, or constructed, however, and short-lived steel buildings inflict a heavy environmental cost. In the white paper, Structure and Carbon: How Materials Affect the Climate, Mark Webster, P.E., senior structural engineer at Simpson Gumpertz & Heger, explains that for steel-framed skyscrapers, the right path.

Emissions Reductions of DRI-EAF Systems (Compared to BOF)

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Percent Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide (CO)</td>
<td>96%</td>
</tr>
<tr>
<td>VOCs</td>
<td>87%</td>
</tr>
<tr>
<td>Sulfur Dioxide (SO₂)</td>
<td>78%</td>
</tr>
<tr>
<td>Nitrogen Oxides (NO₂)</td>
<td>65%</td>
</tr>
<tr>
<td>Mercury</td>
<td>58%</td>
</tr>
<tr>
<td>Carbon Dioxide (CO₂)</td>
<td>41%</td>
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</tbody>
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Source: U.S. Department of Energy

Though Cox agrees that steel lends itself to deconstruction, he says, “It would be very difficult to use one structural element and lift it elsewhere.” Most likely it would be less expensive to build it from scratch.

Webster says there are several steps engineers can take to maximize steel performance and reduce its environmental impact, such as:

- use castellated beams or trussed members, which have higher strength-to-weight ratios than wide-flanged beams and use less steel, making for a lighter structure
- use catenary structures (think Saarinen’s Dulles Airport terminal) or braced frames rather than the beams and columns used in moment-resisting frames to resist lateral loads

As a general rule, Cox looks for flexible grid layouts and floor-to-floor heights, and makes sure the loading capacity has the ability to adapt. “There is a bit of a fine balance trying to get it at the right level so that the clients are happy and we are happy that we are on the right path.”
the building envelope and elsewhere. The energy saved over the life of the building would likely more than make up for the embodied energy from the bolts’ manufacturing.

**Concrete and steel**

Concrete buildings contain a lot of steel and steel buildings contain a lot of concrete: rebar and other steel products are used extensively in concrete buildings; and concrete is used for foundations, flooring, and other elements in steel buildings. Webster says that in one of his firm’s projects, concrete accounted for 63% of the overall structural global warming potential (GWP) and the rebar accounted for 15%.

Webster says you can save steel using composite steel designs where you put shear studs on metal deck, but the drawback is that they are not deconstructable. His firm is working on a research project with Northeastern University to test a deconstructable composite beam system that can be used in place of the standard “throw-away” systems. The deconstructable system uses precast planks that are clamped to the beam; this combination provides the performance of a composite system but can be disassembled later.

**Steel from Raw Ore**

Iron ore is one of the most abundant elements in the earth’s crust but refining it is energy intensive and, on the massive scale on which it’s done, the impacts are significant.

**Open pits are forever**

Iron is extracted from large open pit mines, where the surface (overburden) and waste rock are removed to get to the iron oxide ore. The iron ore is crushed and iron oxide is removed using magnets rather than hazardous chemicals like those used to refine copper and many other metals. The concentrated iron powder is mixed with water and clay and baked to form pellets that are shipped worldwide for use in steel mills. To get a sense of the scale of these mining operations and their impacts, the Hull–Rust–Mahoning Mine in Hibbing, Minnesota, is more than 8 miles long, 3 miles wide, and 800 feet deep. This and other large open pit mines will never be returned to their original states. The tradeoff? The mine has produced 690 million tons of iron ore since opening in 1895 and is still in producing ore.

**Blast furnaces and carbon**

As noted, the BOF process generates most of the CO₂ and hazardous emissions in the steel industry, much of it due to its use of coal. About 13% of the world’s coal is used to make steel (approximately 1544 lbs/ton for BOF and 330 lbs/ton for EAF) according to the World Coal Association—but most of that coal is not used as a primary energy source. It is used for its carbon.

According to Keith Lindemulder, environmental business development manager at Nucor, a major U.S. steel producer, “Iron ore is an iron oxide, so what you have to do is strip that oxygen molecule off.” Steelmakers achieve this using coke, and creating coke requires heating coal in oxygen-free ovens at up to 2,000°F for 18 or more hours to drive off impurities. (Nucor does not use the BOF process, more on that later.)

Creating coke generates hydrogen and process gases that are used as fuel for the plant, but it also creates carcinogens, particulates, and other toxic byproducts, including polycyclic aromatic hydrocarbons (PAHs),
formaldehyde, benzene, ammonia, nitrogen oxides (NOx), cadmium, arsenic, and mercury. Some of these are collected and sold, and some are captured by emission controls, but coke plants remain significant sources of pollution that can create environmental, health, and social justice problems—especially in countries with few emissions regulations.

Why there’s so much carbon in steel

Iron is refined in massive, brick-lined blast furnaces that can be more than 300 feet tall. Iron ore pellets, limestone, and coke are added to the top of the blast furnace while oxygen is forced in near the base. In the blast furnace the following takes place:

- The carbon/coke reacts with oxygen to form CO2; the carbon then reacts with the CO2 to form two carbon monoxide (CO) molecules. In a process called reduction, the CO strips the oxygen from the iron oxide and becomes CO2 while the iron oxide becomes iron.

- The limestone undergoes calcination at these temperatures (similar to portland cement; see Can Concrete Save Us? Locking Up Carbon in Building Materials) and captures impurities while releasing more CO2 for the reaction. The waste from this process is known as slag.

- The iron and slag sink to the bottom of the furnace where they separate into layers and are drained off.

- The liquid iron, sometimes known as pig iron, is usually transferred from the blast furnace to a BOF vessel while the waste slag is cooled and collected. (Slag is used as lightweight aggregate but ground granulated blast furnace slag is often used to replace portland cement in concrete—so, ironically, this carbon-intensive byproduct can improve concrete’s performance and reduce its carbon footprint.)

Iron from a blast furnace contains up to 7% carbon and would be too brittle for commercial use, so pure oxygen is pumped into the BOF vessel at high pressure to remove the carbon from the iron. The steel from a BOF ends up below 2% carbon (cast iron is around 4%); chromium, nickel, copper, and other metals can be added afterwards to a secondary vessel to meet specific performance requirements.

The intense reaction also generates heat, so up to 35% scrap steel is added to the mix. Any more than that could cool it too much and shut off the reaction—and BOF operations almost never shut down. According to Kavanagh, “about every 20 years a blast furnace comes up for maintenance. So somebody who owns a blast furnace has to decide if that is the technology they want to stay with. If they say yes, they do the maintenance and they are committed to that tech for another 20 years.”

Electric Arc Furnaces: Making the Most of Recycled Content

Electric arc furnaces, also called mini-mills, use electrical current and up to 100% recycled scrap iron to make new steel. In EAFs, scrap steel is dropped into crucible-like vessels, the lid is shut, and graphite electrodes (also made from coke) are slowly lowered in. Electric current then arcs back and forth between the electrodes, raising the temperature to more than 3,000°F for about an hour. The metal composition of the scrap, the temperature, the addition of oxygen, and other factors are carefully controlled to produce specific steel types, including stainless steel. Some EAF operations use alternating current (AC) and some use direct current (DC). DC units are more energy efficient and require fewer electrodes—and the coke used to make them.

EAFs using 100% recycled content are the most energy-efficient system for producing steel. They can make steel on demand, unlike BOF systems, and because they are smaller and have
fewer emissions, they can be located closer to potential jobsites or cleaner energy sources. EAF facilities still consume a lot of energy, however. Nucor’s Gallatin EAF facility in Kentucky uses an efficient DC-based system but is designed to operate for short periods at up to 850 volts and 135,000 amps—that’s 144 megawatts.

**Direct reduced iron: Iron without blast furnaces**

BOF systems are the most common technology for turning iron ore into iron and steel, but there are a number of more environmentally friendly technologies that don’t require coal or blast furnaces. In the future we may be able to produce iron from combining powdered iron oxide and natural gas directly in a furnace, but today, the direct reduced iron (DRI) system is the most well-known alternative to BOF.

The DRI process uses hydrogen and carbon monoxide taken from natural gas (coal byproduct can also be used) to strip the oxygen from iron oxide and produce iron. The temperatures in these systems are not high enough to melt the iron so it comes out as solid “sponge iron.” When located next to an EAF, this hot iron is added directly to the system to provide additional heat to the furnace, further lowering energy demands. This sponge iron can also be compressed for shipping.

According to the DOE, the DRI-EAF process can significantly reduce emissions when compared with conventional BOF systems.

DRI systems are not new and are more common in areas such as the Middle East, which has abundant natural gas and little scrap iron. Though DRI systems have had limited traction in the U.S. where energy is inexpensive and there is a lot of steel scrap, two new facilities have recently been built: the Voestalpine Group’s plant in Corpus Christi, Texas and Nucor’s plant in Convent, Louisiana, which will feed its EAF mini-mills.

Despite these advances, there are logistical and economic reasons that might keep these technologies from being adopted. Kavanagh says, “Steel makers are selecting their processing equipment based on the energy available to them, scrap supply in the region, raw material availability, and the products they want to make.”

**Hot- and Cold-Rolled Steel**

After steel is poured into slabs and allowed to cool down to about 1,700°F, those slabs can be rolled and shaped into hot-rolled steel products. The production process for hot-rolled steel typically uses an EAF and is energy-efficient, but hot-rolled steel is not as strong as cold-rolled, so it is used for beams, angles, rebar, and other shapes. When rolled into sheets, it is used for pipe, hollow structural steel, and other materials.

Cold-rolled steel (better known as cold-formed steel) on the other hand, is allowed to cool to room temperature. The cold-rolling process increases the strength of the material, making it appropriate for cold-formed framing, decking, joists, and other structural products. When rolled into sheets it becomes the sheet metal found in appliances, ductwork, and other applications. Cold-formed steel products used outdoors, such as roofing, or that are at risk from corrosion are often galvanized.

Though galvanized sheet steel can be made using either EAF or BOF technologies, Lindemulder notes that cold-formed galvanized framing in North America is typically a mix, resulting in a larger environmental footprint than that of EAF alone.

**Stainless Steel**

Stainless steel is produced in EAFs from recycled stainless steel scrap and metal alloys that contain at least 10.5% chromium and no more than 1.2% carbon, according to the Stainless Steel Industry of North America. Varying amounts of chromium, nickel, molybdenum, and other metals can create more than 150 types of stainless steel, providing corrosion resistance, chloride resistance, reduced electrical conductivity, or other performance characteristics.

Stainless steel is best known for its corrosion resistance. Standard steel oxidizes, building layers of rust that flake off and degrade the metal over time. In stainless steel, the chromium oxidizes and forms a thin protective barrier that reforms if damaged. Stainless steel is extremely durable and can be cleaned easily, but it also represents more than twice the embodied energy as conventional “mild” steel, according to the ICE v2.0 Database.

Chromium is a necessary human nutrient that helps convert food to fuel, regulates insulin, and provides us with energy, but it exists in a number of forms. The form found in stainless steel (trivalent chromium or chromium 3+) is not considered dangerous. Acidic food can pick up chromium from stainless steel cooking pans, and you do not want to ingest too much, but it is not the carcinogenic hexavalent chromium (chromium 6+) of Erin Brokovich fame (see Chromium-6: Health and Life-Cycle Hazards). Hexavalent chromium can be formed when welding stainless steel, however, so precautions have to be taken to prevent worker exposure.

**Protecting Steel**

Unlike stainless steel, standard steel will oxidize outdoors or in certain indoor environments where humidity can rise above 70% (in HVAC ducts, for instance). In building interiors where the temperature and humidity are carefully controlled, steel structures may not require an anti-corrosion coating. In fact, Cox does not typically recommend coating structural steel. But exterior steel and some interior structural steel need protecting, and the two most common methods are galvanization and powder coatings.

**Galvanization**

Galvanization involves applying a thin layer of nearly pure zinc onto the steel surface. This creates a barrier so that oxygen can’t reach the steel, and it also creates an electrochemical mechanism, kind of like a battery, so if
the surface is scratched, the zinc near the exposed steel becomes the reactive anode and slowly corrodes instead of the steel that has become the cathode. These zinc layers are relatively soft and can be damaged, but if left intact they can protect steel for up to 60 years, according to the American Galvanizers Association. A topcoat of paint over the galvanization will further extend its life.

In a “hot dip” galvanization process, steel goods are thoroughly cleaned by being dipped in alternate baths of degreasers, acid solutions, water, and flux to remove grease residue and oxides from production. The steel is then immersed in a kettle of molten zinc at more than 800°F for about 10 minutes before being removed for cooling (aluminum and zinc/ aluminum mixes are also used). Sheet goods that undergo galvanization are cleaned and run through a furnace containing gases that remove all oxidation. The sheets are kept in a vacuum as they enter the hot zinc to prevent any additional oxidation. The sheets are kept in a vacuum as they enter the hot zinc to prevent any additional oxidation.

Powder and other coatings

For other interior steel applications where coatings are necessary, there are a number of options, including epoxies, polyurethanes, acrylics, and ceramics. BuildingGreen does not recommend epoxies because they contain bisphenol-A (BPA), but look for other low-VOC options that meet the Master Painter Institute’s X-Green Standard. Coatings used on handrails and other surfaces where durability is key can contain hazardous ingredients, however, and since surface prep and priming are particularly important with these coatings, it is best to have them applied offsite in a controlled environment.

Powder coating is one of the most common steel coatings because it provides an even, durable surface. It can have environmental and health advantages as well because there is little waste and no onsite emissions. These coatings are applied in a controlled environment where the metal is electrically grounded and the powder is given a positive charge; when the powder is sprayed it bonds solely to the metal in an even, thin coat. There is little overspray. The steel is then heated and the coating chemically bonds to the metal.

Powder coatings can be made from acrylic, polyester, or epoxy, but the most popular coating is polyvinylidene difluoride (PVDF). This fluoropolymer is mixed with acrylics and used on cladding, roofing, and many architectural elements because it is durable, UV-resistant, and repels dirt, minimizing maintenance. PVDF has a long history of solid performance. Its fluoropolymer chemistry is problematic, however.

Fluoropolymers are complex compounds with a complicated environmental story. Some “long-chain” fluoropolymers, such as PFOA, are known carcinogens and persistent organic pollutants (PFOA is no longer used commercially in the U.S.), but PVDF is a different class of compounds that is considered safe. Still, BuildingGreen generally recommends against using fluoropolymers because the same qualities that give them extreme durability cause them to persist in the environment indefinitely, and even “safe” fluoropolymers such as PVDF may use hazardous fluorocarbons in manufacturing. PVDF—like steel—is found in a number of building products, such as lithium ion batteries and water treatment products. For those using steel on the exterior, the tradeoff of long service life and low maintenance may override the unknown long-term environmental impacts.

Ceramic coatings are also available but are not yet being used in the building community. The 2012 BuildingGreen Top 10 Product Eoncoat is a two-layer system that reacts with the top layer of steel to form a ceramic coating. It is extremely durable and self-healing—further minimizing risk of corrosion—and it contains no VOCs or other hazardous ingredients.

Fire proofing

Steel can fail when exposed to temperatures as low as 900°F, so it is necessary to protect structural elements from fire. This can be done with drywall, mineral wool boards and batts, and by encasing steel in concrete.
There are a number of coatings that are also commonly used to protect steel from fire:

- Spray-applied fire-resistant materials (SFRMs) insulate steel from fire using a lightweight cement or gypsum containing mineral wool fibers. Because the coating is not very durable, is not moisture resistant (and can even lead to corrosion if the material stays wet), and is not particularly attractive, it should not be used where it can be dislodged or exposed to moisture.

- Intumescent coatings look more like paint, but when exposed to high temperatures expand to 50+ times their original thickness. The chemical reaction releases carbon dioxide and a char layer forms on the outside to slow down the fire and heat transfer. The main ingredients—ammonium polyphosphate, pentaerythritol, and melamine—are often held in a polyvinyl acetate (white glue) binder. Together, the system is not particularly hazardous.

## Steel Recycling and LCAs

In theory, steel can be recycled over and over without losing any performance, but some steel will never be recycled. According to a 2015 report by Dovetail Partners, separating steel from materials like plastic, contaminated coatings, and certain alloys can be too expensive to justify. And some will simply rust away, like an old car abandoned in the woods.

Nonetheless, the Steel Recycling Institute claims that recycling a ton of steel “conserves 2,500 pounds of iron ore, 1,400 pounds of coal, and 120 pounds of limestone.” Structural steel does well by industry standards and is typically recycled at a rate exceeding 97%.

Kavanagh says the U.S. steel industry recycles between 70 and 80 million tons of scrap annually. Nucor Corporation, the largest steel and steel products producer in North America and the largest steel recycler in the Western Hemisphere, used more than 17 million tons of scrap in 2016 according to Lindemulder. “Scrap steel is a primary feedstock for us,” he says, adding that North American rebar and structural steel from various producers contain 100% recycled content and are made using the EAF process. “From the environmental footprint perspective, we are not talking about major differences across North American producers.”

Recycled content is a strong predictor of steel’s environmental performance, but we need to pay attention to steel’s full life cycle assessment, according to Simonen. “From a metals perspective there is clearly a relationship between the two,” she says, as steel with more recycled content takes less energy to produce. Some LCA methods give a “credit” at end of life for materials that are recycled (avoiding primary production) resulting in “negative” environmental impacts. But there is not consensus in the building industry on whether assigning recycling credits for long-life metal products such as structural steel is appropriate.

The steel industry has released EPDs for several products, including light gauge products, roof and floor decking, open web steel joists, studs, and more. These use industry-averaged data for North American products developed by the World Steel Industry database. As Simonen points out in Wood, Concrete, and Steel—And Their Incomparable EPDs, steel is a commodity, which makes it harder to show the plant-by-plant differences between materials that can lead to environmental and performance gains.

For LEED, an industry-wide EPD contributes to the v4 EPDs credit, but at half the value of a product-specific EPD—and only if the steel manufacturer is listed as a contributor to the industry-wide EPD.

## How to spec sustainable steel products

Though there is concern about China dumping steel on the U.S. market, about 88% of the hot-formed structural steel used in the U.S. is domestic, according to the American Institute of Steel Construction. “All domestically produced structural products and domestically produced rebar are produced on an EAF,” says Lindemulder, making U.S. structural steel some of the cleanest available. That is fortunate for us, because, for the most part, “the supply chain is not driven by looking at the environmental footprint of the product at the time it is specified and the time it is ordered,” he says. “Regardless what process is used, it [steel] is produced to an engineering specification and that specification drives what the product looks like, not the process you use to produce it.”

The steel industry encourages the building industry to look at steel as a commodity, and not to try and cherry pick more sustainable mills. But for cold-formed steel products it does not hurt to ask for an EPD or the recycled content. If the mill is still using coal as primary fuel along with a BOF then it would be worth looking for an EAF alternative—though this will likely be a challenge. Cox states that once the contractor and purchasing manager get involved they will usually try to get it cheaper if they can source it elsewhere, complicating efforts to procure more sustainable products.
As mentioned, imported steel is typically manufactured with BOF technology in countries with questionable emissions requirements. According to Kavanagh, “One of the most important [sustainability] decisions an architect or engineer can make when designing a building is to make sure the steel is produced in North America.” So even if you can’t get the best of the best steel, buying American-made steel can make a significant difference in your building’s environmental footprint.

NEWS ANALYSIS

New Handbook Demystifies the Living Community Challenge

Seven communities are registered and more may be in the pipeline, with ILFI clarifying how existing communities can engage with the Living Community Challenge.

by Candace Pearson

With the publication of a handbook to accompany the standard, The Living Community Challenge (LCC) has become a more clearly defined program for practitioners and may be picking up steam as a result.

The Living Community Challenge Handbook 1.1, available on the International Living Future Institute (ILFI) website, is directed towards planners, designers, and contractors and offers guidance on such questions as:

• Do all buildings within the boundary need to be certified to the Living Building Challenge (LBC)?

• What’s the process for certification?

• How does the standard apply to existing communities?

Purpose of LCC

LCC was launched in 2014 as a way to approach regenerative building at a different scale (see Beyond Living Buildings: ILFI Expands Scope to Food, Products, Communities). The certification takes the basic principles behind the Living Building Challenge and applies them to whole neighborhoods and communities. Requirements include net positive energy, net positive water, and building materials free of Red List chemicals for all community facilities and infrastructure.

“The Living Community Challenge provides clarity of vision for what a community wants to be,” Alicia Daniels Uhlig, LCC and policy director at ILFI, further elaborated for BuildingGreen. “It is an elegant way to communicate with a diverse group within the community: laypeople, neighbors, colleagues. People will get behind a common vision if they understand you when you talk about it.”

Relationship to LBC

Not every building within the community boundary must be certified to LBC, but every building that is both constructed during the LCC development process and under the ownership of the entity leading the LCC certification has to meet that standard. Also, every LCC community must have at least one LBC-certified building.

In general, the LCC standard doesn’t focus on approaching buildings individually. Imperatives 1–6 may be distributed, or averaged out across the entire community. The net-positive-energy requirement, for example, allows for some buildings to produce much more renewable generation than they use, and some less, as long as in total, enough renewable energy is generated in the community to equal 105% of the community’s total energy consumption. The remaining requirements are targeted towards common spaces, or again, buildings belonging to the organization driving LCC certification (commonly assumed in the Handbook to be town government).

Certification process

Like the Living Building Challenge, LCC is performance-based, not prescriptive, but ILFI recognizes that it may take years for an entire community to be able to demonstrate 12 continuous months of net positive energy or net positive water. Therefore, the program uses various rendering: International Living Future Institute

As a pilot city for the Living Community Challenge, the First Hill neighborhood of Seattle has already begun to craft its vision plan.

This Seattle neighborhood found that the majority of energy required in the community could be generated using a rooftop collection strategy alone.
labels to describe projects that have reached certain milestones in the process.

After registering, for example, a project can either jump straight to creating a masterplan or take the optional, intermediary step of creating a vision plan. Vision plans define a proposed community boundary, key stakeholders, and a roadmap for community engagement. A masterplan must be more detailed and include a narrative as to how the community will achieve each Imperative.

Once ILFI approves these documents, the community would be considered LCC vision-plan- or masterplan-compliant. Once construction is underway, the project can be termed an “Emerging Living Community.” Only when a community has been operational long enough to demonstrate the performance requirements in LCC and is certified by the ILFI does it officially become a “Living Community.”

Some portions of the community may achieve LCC performance before others, so it is possible to have areas that are emerging and areas that are fully certified at the same time, according to the Handbook. “You’re going to need some time between the masterplan and full certification,” says Uhlig.

**A strategy for existing communities**

Providing the optional step for a vision plan was “mostly in response to the needs of existing communities, which may not be as straightforward or controlled as new developments,” said Uhlig.

This introductory step is meant to “convey purpose and create understanding amongst [the community’s] constituency,” according to the Handbook.

Choosing a reasonable boundary alone is a major undertaking and requires the community to build consensus. An LCC project can be any group of two or more buildings that also provides all the pedestrian infrastructure required by Imperative 04: Human-Powered Living. But it could also be defined as a whole neighborhood block or an entire city. Some teams might be tempted to draw boundaries that exclude infrastructure that are big energy or water hogs, but gerrymandering won’t be allowed, says Uhlig. “It’s really about a sphere of influence—a neighborhood association would go with their previously established boundary.”

**Rising interest**

To date, there are seven communities registered for the Living Community Challenge. ILFI has seen an uptick in interest since the Handbook was released, according to Uhlig, and she anticipates that a few vision plans may be ready to certify this year. But so far, even the title of vision plan-compliant has yet to be claimed.

**2017 AIA COTE Top Ten Awards Emphasize Buildings That Teach**

This year’s winning projects act as revolutionary models for a variety of challenging building types.

*by James Wilson*

The AIA Committee on the Environment (COTE) Top Ten Awards recognize projects that achieve high levels of sustainable performance while providing for excellent architectural function, use, and experience—in other words, projects that exemplify truly great design. For 2017, in addition to design intent, the application placed increased importance on actual performance and required submitting firms to provide metrics related to impact on community, ecology, water use, energy use, occupant health, resilience, and economy.

Among this year’s winning projects are healthcare facilities, educational buildings, a municipal salt shed, and a district energy plant. In addition to challenging building types, many of these projects faced tight budgets or climate constraints. (Five projects are located in the Northeast region of the U.S.)

This year’s winners share an underlying motivation to advance the larger cultural project of sustainability by actively fostering environmental knowledge and stewardship. All are nodes in an emergent network of low-impact and regenerative architecture, and several directly contribute to the development of sustainable design by doubling as “living labs” for technical research and experimentation with innovative building technologies.

**AIA Top Ten Plus Winner**

The Top Ten Plus award was created in 2013 to recognize projects that have followed through on performance goals.

**Brock Environmental Center: SmithGroupJJR, Virginia Beach, Virginia**

The Brock Environmental Center is an education, advocacy, and restoration hub for the Chesapeake Bay Foundation. The Center was a central part of a community-wide effort to save Virginia Beach’s Pleasure House Point Tract from private development. The preserved open space is now dedicated to environmental education and research.

Simulation tools were used to design the building’s form and fenestration,
and to optimize daylight, views, and ventilation. The building’s curved form and sweeping roof not only celebrate the natural features of the site, but also allow for maximum daylight access, passive solar heating, natural ventilation, and rainwater collection. A porch along the south façade of the building provides shading and prevents unwanted solar heat gain, while north-facing clerestory glazing provides glare-free daylight. Collected rainwater is treated and reused, meeting 100% of the project’s water demand.

The project team used a “dogtrot”—a proven vernacular design element—to further enhance the natural ventilation of the building. This open-air pass-through interrupts the building’s floor plate, creating a comfortable microclimate and promoting airflow to reduce horizontal stratification. Natural ventilation is coupled with a variable refrigerant flow (VRF) system utilizing 18 ground-source wells to improve efficiency. The exterior envelope is designed to reduce heating demand significantly and is assembled with high performance components: R-31 walls, R-50 roof, and R-7 windows.

These strategies, combined with two 10 kW wind turbines and a 45 kW PV array, result in a net-positive building that produces 80% more energy than needed each year.

**AIA Top Ten Winners**

**Discovery Elementary School: VMDO Architects, Arlington, Virginia**

The Discovery Elementary School serves as a model for net-zero-energy schools. The project is the first net-zero-energy school in the Mid-Atlantic, the largest in the U.S., and the second largest fully-conditioned net-zero-energy building of any type in North America. The school was originally budgeted to achieve LEED Silver only, but the project reached net zero without any increase to the original budget.

Designed to involve the students as stewards and teach environmental responsibility, the school includes features like a pollinator garden and bio-retention basins that also serve as outdoor classrooms. The solar calendar in the school’s entry plaza—a prominent educational feature—was planned with the direct involvement of the students, who worked with the architects to accurately mark solar positions on the equinoxes and summer solstice.

Passive design strategies, including a terraced building form, a high-thermal-mass exterior envelope—composed of a load-bearing insulated concrete wall system—and focused air-sealing efforts, significantly reduced the building’s energy demand. A 496 kW rooftop photovoltaic array can provide up to 10% more electricity than the building is anticipated to use, and the facility is designed to incorporate a battery storage system in the future.

In order to achieve net-zero energy with minimal materials, the project team implemented a thorough photovoltaic analysis process to evaluate all material and design decisions. For every product, system, equipment, or operations option, the team calculated the amount of PV that would be required to offset the related annual energy costs.

The Department of Energy recently launched the Zero Energy Schools Accelerator program at the school, creating a national partnership to advance zero energy schools by demonstrating that current technologies can be applied to achieve net zero at the same cost as conventional, code-compliant schools.

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### 2017 Top Ten: Performance Metrics

<table>
<thead>
<tr>
<th>NET SITE EUI (kBtu/Flyr)</th>
<th>NET EMBODIED CARBON (lbs/F)</th>
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<tbody>
<tr>
<td>Manhattan Salt Shed*</td>
<td>Brock Environmental Center</td>
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<tr>
<td>R.W. Kern Center</td>
<td>R.T. Fong General Hospital</td>
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<tr>
<td>Ng Teng Fong General Hospital</td>
<td>Milken Institute</td>
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<tr>
<td>Sbrega H5 Building</td>
<td>Discovery Elementary</td>
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<td>Eden Hall Campus (Barozzino Center)</td>
<td>Manhattan Salt Shed</td>
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<td>-50.0</td>
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*Predicted EUI based on energy model

Source: BuildingGreen, Inc.

Energy use intensity (EUI) and estimates of the carbon emissions from manufacturing and installation of the materials, as reported in the project submissions. EUI numbers are based on actual, measured performance except as indicated with asterisks.

**Bristol Community College John. J Sbrega Health and Science Building: Sasaki, Fall River, Massachusetts**

The Sbrega Health and Science Building at Bristol Community College was built to replace outdated labs with a hands-on learning environment. Designed by Sasaki, the project establishes a new sustainable model for lab buildings.

Despite the challenging building type and climate, the project reached net-zero energy without increasing the budget, which was based on a LEED Silver design. To accomplish this, Sasaki worked with the owner and the contractor to offset the premiums associated with net-zero technologies by achieving savings elsewhere.

The fume hoods in the laboratory spaces were found to be a significant driver of the building’s energy demand. By switching to filtration fume hoods and air quality monitors and

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implementing a number of correlating ventilation strategies—including decoupling ventilation from heating and cooling, and adding heat recovery—the design team was able to reduce the EUI by about 80%.

The Sbrega Building was awarded a Pathways to Zero grant by the Massachusetts Department of Energy Resources in recognition of the fact that the strategies the design team employed are proven, replicable, and do not require additional construction costs.

**Chatham University Eden Hall Campus: Mithun, Richland Township, Pennsylvania**

Mithun worked with Chatham University to design Eden Hall Campus, a model for sustainable land use practices in peri-urban areas—those shifting landscapes immediately surrounding cities. Conceived as a living lab to test and demonstrate various sustainable systems—including full-cycle water reuse systems, net-positive energy production, and zero waste operations—the campus serves as an immersive living and learning environment. A primary goal of the project was to demonstrate innovative strategies that are economically feasible and can be replicated elsewhere.

An extensive series of onsite workshops and collaborative design charrettes were used to develop the project’s vision and goals. The design team also participated in the development of a new educational model that utilizes buildings, site, and infrastructure as integral elements of the learning experience.

The project implements the concept of the “New Farm”—an area of sustainable production located adjacent to an urban area—by demonstrating sustainable land-use practices in an area where the urban and rural interface.

The campus’s energy systems, including photovoltaic panels, solar hot water, and geothermal co-generation are linked to create an energy loop that shares heat energy between buildings, increasing overall efficiency. The project team also linked the water treatment and reuse systems to the rainwater collection system to create a living system that is flexible and resilient.

**Milken Institute School of Public Health: Payette and Ayers Saint Gross, Washington, D.C.**

The Milken Institute offers a fresh and innovative example of what a campus building in a dense urban setting can be while also embodying the foundational values of public health: access to light, views, and fresh air.

The project team, led by Payette and Ayers Saint Gross, worked with students, faculty, and administration prior to design to identify key components to prioritize. The team used a thorough life-cycle cost analysis to determine that, with modest changes to building components and systems, the project could go beyond its goal of LEED Gold. Slightly higher-performing exterior glazing, an added heat recovery chiller, and expanded use of chilled beams were among the minor adjustments made to achieve improved performance.

Departing from conventional, hierarchical organizations of program, the building is designed around a central atrium, which provides a learning environment that promotes equity. This central, open core also provides occupants with abundant natural light and fresh air. In order to accommodate this feature, the project reduced the floor-to-floor height in order to add another floor within the allowable envelope. The result is a building that is open and light-filled despite its thick massing.

The open, sky-lit stair in the atrium connects all eight levels, encouraging occupants to engage in physical activity as they circulate through the building.

**Manhattan Districts 1/2/5 Garage and Spring Street Salt Shed: Dattner Architects and WXY architecture + urban design, New York, New York**

Dattner Architects and WXY architecture + urban design collaborated on the first LEED-certified Department of Sanitation facility in New York City, which was developed as part of the City’s initiative to site infrastructure in the community that it serves. The garage...
and salt shed buildings house 150 sanitation vehicles, maintenance equipment, and 250 workers.

Heated and cooled by municipal steam, the building is equipped with a waste steam recovery system that captures and manages the steam condensate and a green roof that captures 100% of the precipitation that falls onsite.

In response to concerns voiced by the community, the project team reduced the mass of the original design, minimized light and acoustic transmission, and conducted an extensive study to determine the optimal locations for entrances and exits, mitigating the facility’s impact on neighborhood traffic.

The building’s faceted architectural form serves as a sculptural landmark in the community. Though the community originally sought to block construction of the facility, it has now enthusiastically embraced the project, praising the use of design to successfully integrate critical services into the area while creating a delightful urban space for pedestrians.

The NYC Department of Design and Construction has featured the project in its Design and Construction Excellence 2.0 Guidelines, presenting it as an example of how future civic buildings can achieve sustainability and resiliency.

Ng Teng Fong General Hospital & Jurong Community Hospital: HOK, USA; CPG, Singapore; Studio 505, Australia, Singapore

The Green Mark Platinum-certified Ng Teng Fong General Hospital is Singapore’s first ground-up public medical campus and challenges the traditional model of a hospital. Whereas traditional hospitals in Singapore’s free public health system do not offer patients access to daylight, views, or ventilation, Ng Teng Fong sees these things as essential to the healing process. Thus the project centers on a sawtooth design to provide every patient with a window. In addition, 82% of the patient beds are primarily passively cooled and naturally ventilated. Only 30% of the entire facility requires air conditioning.

The project uses a cross-ventilation scheme allowing for high rates of ventilation in every patient room while avoiding cross-contamination. To achieve this, the design team performed a series of detailed analyses using computational fluid dynamics models.

The team also used climate analysis, daylight modeling, and energy models to optimize the design for energy efficiency. Solar thermal collectors provide 100% of the hospital’s hot water demand and a 100 kW photovoltaic array provides onsite renewable energy.

Responding to the hospital’s goal of creating a healthcare facility that is of and for the community it serves, the project team consulted community members at critical points throughout the process and designed a series of bridges to physically integrate the building into the surrounding neighborhood.

2017 Top Ten: Certifications

Living Building Challenge
Brook Environmental Center
R.W. Kern Center*

LEED Platinum / Green Mark Platinum
Brook Environmental Center
Milken Institute
Eden Hall Campus*
Ng Teng Fong General Hospital
Sbrega H+S Building*

LEED Gold
NOAA Inouye Center
Manhattan Garage + Salt Shed

LEED Silver
Discovery Elementary*

NOAA Daniel K. Inouye Regional Center: HOK with Ferraro Choi & WSP, Honolulu, Hawaii

The Daniel K. Inouye Regional Center, located on a historic landmark site in Honolulu, links and adapts two World War II-era airplane hangars to create a living laboratory for the National Oceanic and Atmospheric Administration (NOAA).

The biomimetic form of the research facility integrates systems for passive cooling, ventilation, and lighting by emulating the morphology of native trees. Like trees, which pull moisture...
from the soil up to their leaves and release it as water vapor creating a cooling effect around the canopy, the building’s hydronic cooling system pulls water from below the seabed into cooling coils on the roof. Prevailing breezes move across these coils creating a passive downdraft effect. Cooled, fresh air is dropped into the building through thermal chimneys and distributed via a raised floor system. This solution allowed the building to be naturally ventilated even though no operable windows were allowed due to anti-terrorism regulations.

This vernacular approach to passive ventilation was among the first installed on a contemporary building and the commissioning process has provided the project team with many valuable lessons about the strategy, enabling them to implement improved systems on a range of other projects.

Though the form of the existing building mass does not naturally allow for significant daylight access, the team designed a series of special light lanterns to capture and reflect sunlight deep into the building spaces.

R.W. Kern Center: Bruner/Cott & Associates, Amherst, Massachusetts

The multi-purpose R.W. Kern Center at Hampshire College, aspiring to Living Building Challenge certification, generates its own energy, captures and treats its own water, and processes its own waste. Providing space for classrooms, offices, a café, and a gallery, the net-zero-energy building was designed to foster community and attract prospective students.

By exposing the building systems and integrating interpretive signage throughout the Center’s spaces, the project team has designed the facility to be an educational tool for students and visitors. The school’s faculty have even been inspired to develop new courses that use the building as a living lab and that explore the building’s systems, mission, and meaning.

The facility’s water management system—including exposed cisterns, indoor greywater planters, and a landscaped raingarden—is a particularly powerful teaching tool and, as part of a Massachusetts Department of Environmental Protection pilot program, the Kern Center will serve as a model for future net-zero water projects.

The design team implemented composting toilets to reduce the building’s overall water use to 100 gallons per day, which is a mere 10% of the average water use for buildings of this type. Graywater from the building’s sinks is filtered through indoor planters and allowed to evaporate.

Stanford University Central Energy Facility: ZGF Architects LLC, Stanford, California

The Central Energy Facility at Stanford University is a model for sustainable industrial facilities. The plant replaces the university’s natural gas-powered cogeneration plant and steam loop with an electric ‘regeneration’ plant that supplies the campus with hot and chilled water. Waste heat is captured from the chilled water return loop and used to supply 93% of the campus’s heat and hot water demand. BioPCM, a phase change material installed in the building’s ceiling, mediates internal temperatures by providing additional thermal mass. This single facility reduces total campus emissions by 68% and potable water use by 18%.

Beyond housing the campus’s energy plant, the facility also functions as a comfortable, biophilic, indoor-outdoor workplace. The design of the trellis canopy creates dynamic light and shadow effects as the solar exposure shifts over the course of the day. The building also serves as a living laboratory, providing students and visitors views of the energy systems in operation. As the facility’s operators continue to experiment in real-time with these technologies, they will contribute to continued research and development of district energy systems.
What’s the Secret to High Performance?

A new report identifies common habits of the firms that produce the best-designed and most sustainable projects.

by James Wilson

The AIA Committee on the Environment (COTE) recently published “The Habits of High-Performance Firms,” a report outlining the key traits of “high-performance firms”—firms that have been awarded an AIA COTE Top Ten Award three or more times over the past 20 years. Researchers found that these repeat winners succeed by multiple measures of successful design; including the fact the average energy use reduction of their projects in 2015 was 51%.

As a follow-up to last year’s Lessons from the Leading Edge report,” AIA research intern Sandra Montalbo, and Lance Hosey, FAIA, studied ten high-performance firms to identify the qualities that distinguish these firms from the rest of the profession. Beyond commonalities related to firm age, size, and location, the study found similarities related to aspects of firm make-up, culture, and process that are uncommon or rare in the industry.

Gender-balance

One striking characteristic that differentiates high-performance firms is better-than-average gender distribution. In the 10 firms studied, there is an almost perfect balance between male and female staff, with women making up 46% of the staff on average—a proportion that is 50% larger than the profession as a whole. Women at these high-performing firms hold 34% of leadership positions, as compared to the industry average of 20%.

Strong cultural values

According to the report, “The most important differentiators for these high-performance firms may be their cultures. They have a strong vision and shared set of values, and cultivate a diverse community of collaborators who are empowered to think broadly and speak openly.”

A key cultural value shared by each of these firms involves a pledge to environmental responsibility and the mission of reducing the built environment’s carbon footprint. This value is communicated through the AIA 2030 Commitment, which all ten firms have signed, compared with less than three percent of AIA member firms.

Education

Most of the firms studied have instituted regular staff training to expand in-house capabilities and have a large percentage of LEED accredited staff—48%, more than twice the industry average. This level of in-house knowledge and LEED literacy corresponds with the fact that as a group, these firms actively use LEED on 92% of their projects.

In addition to in-house education initiatives, 90% of these firms have formed partnerships with academic institutions. By participating in the training of future building professionals, these firms are helping to create an accessible pool of candidates with valuable sustainable design skills from which they can then recruit.

Performance analysis

Rather than rely solely on outside consultants for energy and daylight modeling, these firms have developed their own internal analysis practices using a variety of accessible tools. The most popular is Sefaira—80% of high-performance firms report they

Seven Steps to Raise Your Firm’s Performance

1. Sign the 2030 Commitment and report data every year. 2030 Commitment goals and the progress made toward those goals should be clearly communicated to all staff and made a part of the organizational mission. Involving every member of the staff in this effort will promote a culture of awareness and collective effort and will emphasize the importance of tracking performance. [See: 2030 Culture: Six Selfish Reasons to Commit]

2. Look for opportunities to introduce integration into all aspects of your practice, from office operations and culture to design process. Find ways to improve communication and the sharing of knowledge between project teams and consultants. You can start by rethinking meetings. [See: How To Run a Great Workshop: 37 Tips and Ideas]

3. Start conducting performance analysis in-house. Sefaira has been the most widely used tool among high-performance firms, but various Grasshopper plug-ins are also becoming popular. Invest some time and money to build in-house modeling capabilities. [See: Energy Modeling for Early Design: Decisions; Climate Analysis for Architects]

4. Foster strong collaborative relationships with mechanical engineers and other performance analysis consultants. Involve these consultants in the design process as much as possible and seek to maximize learning from collaborations with these experts. [See: Topic Spotlight: Performance Modeling]

5. Develop internal education programs to regularly offer staff training opportunities and expand in-house capabilities. Encourage staff to pursue LEED accreditation by providing study resources and subsidizing exam fees. [See: Topic Spotlight: Green Building Education]

6. Conduct post-occupancy evaluations of your projects. If you can’t get clients to pay for them, experiment to find creative and inexpensive ways of conducting them anyway, even if it means doing simple or “lite” versions of POE. The important thing is to make a practice of doing POEs so the firm has a chance to learn from past successes and failures. Eventually the practice will pay off, and the more POEs your firm conducts, the more efficient and cost-effective the practice will become. [See: Topic Spotlight: Post-occupancy Evaluation]

7. Seek to make your staff gender-balanced and diverse. Honestly review hiring and promotion practices to build awareness of potentially latent prejudices or biases. [The JUST program offers some guidance in this area.]
are using the software to evaluate the impact of design decisions on energy use and daylight, among other factors.

In general, whether conducted in-house or with the assistance of consultants, high-performing firms analyze energy and other performance factors on the majority of their projects. The firms that were studied reported using energy modeling on 74% of projects and daylight modeling on 55% of projects.

Post-occupancy evaluation

Post-occupancy evaluation (POE) is another tool that high-performance firms use significantly more than the rest of the profession. High-performance firms reported conducting POEs on 41% of their projects in 2015—a proportion that is eight times the industry average. It should be noted that, of the high-performance firms studied, about half conduct POEs themselves instead of using external consultants.

For more insight into the unique cultures that can be found at high-performance firms, see the detailed profiles included at the end of the report.

For more information

AIA Committee on the Environment network.aia.org/committeeontheenvironment

NEWSBRIEFS

Architects Organize to Oppose Border Wall

The nation’s design professionals are speaking out in great numbers in response to the Trump administration’s agenda, including the plan to build a wall on the U.S.-Mexico border.

by James Wilson

The design disciplines have been very active in communicating both concerns and priorities to the new administration. Architects Advocate, a recently formed, nonpartisan network of designers, published an open letter to President Trump and Congress urging meaningful action on climate change. AIA Committee on the Environment (COTE) sent an open letter to new EPA Director Scott Pruitt urging him to preserve EPA programs that are critical for architectural practice, including various Energy Star tools and the Toxic Substances Control Act (TSCA) Chemical Substance Inventory. Each letter garnered signatures from over 700 design firms.

More recently, Architects / Designers / Planners for Social Responsibility (ADPSR), a public-benefit organization focused on the promotion of ecologically and socially responsible development, issued another open letter in response to the Department of Homeland Security’s request for proposals for prototypes of a border wall.

The message of the ADPSR letter is simple: the organization, representing more than 750 members across design professions, rejects any plan to build a border wall. The letter serves to reiterate the professional commitments of the design disciplines to protect public health, safety, and welfare, and describes how involvement with the construction of the border wall would violate the basic ethics of design. Describing the wall as a “project of hatred, racism, violence, and waste,” the letter outlines the organization’s objections to the wall, which include issues of human safety, international relations, and ecological impact.

Beyond stating these objections, the letter argues there are much better uses of both the money (an estimated $21.6 billion) and the design talent that would be involved in the border wall project, calling for these resources to be used instead to support homeland security by upgrading and restoring the country’s aging infrastructure, addressing urgent concerns of climate change in vulnerable regions, and devoting more attention to the nation’s housing crisis.

The ADPSR also encouraged its members to respond to the government’s solicitation by submitting alternative, “protest” bids that focus on supporting human rights and that highlight the design discipline’s investment in creating safe, healthy, humane solutions for the public good.

For more information

Architects / Designers / Planners for Social Responsibility www.adpsr.org

Could Passivhaus High-Rise Become the Norm?

Report indicates that designing tall urban residential buildings to the Passivhaus standard is achievable and worth the added cost.

by James Wilson

A study funded by New York State Energy Research and Development Authority (NYSERDA) indicates that the Passivhaus standard—notable for reducing heating- and cooling-related energy use by 70%-90%—could successfully be applied on tall residential buildings in dense urban environments like New York City at a viable cost. The detailed methodology and conclusions of the study are outlined in a report published last month.

Researchers compared a large, mixed-use multifamily housing project designed to achieve LEED Silver
certification (under LEED 2009)—currently under construction—to a theoretical Passivhaus version of the same building. They found that the Passivhaus version would use 47% less energy overall and require a 2.4% increase in capital costs.

Upgrading to Passivhaus could be accomplished using common construction methods and requiring minimal changes to aesthetic design, according to the report. It was determined that the 36% window-to-wall ratio of the original design could be maintained by upgrading the windows to include high-performance triple glazing and thermally broken frames.

The payback period for the upgrades was estimated to be 24 years, though the authors argue that certifying to the Passivhaus standard will likely become increasingly more cost-effective as the building industry gains familiarity.

Though the study demonstrates that the added cost may not be an insurmountable barrier, the report describes a number of other challenges that must still be addressed before the Passivhaus standard is adopted as a mainstream approach in urban high-rise construction. One significant challenge relates to the level of workmanship and coordination required during construction in order to successfully install the air barrier. Variable construction practices, product availability, and cultural use patterns also limit the current applicability of Passivhaus in certain locations and on particular building types.

Despite these challenges, it is clear that a paradigm shift is within view. Municipalities in Europe have mandated the Passivhaus standard in various ways and New York has introduced it as an energy code compliance path for new city buildings. With the publication of this optimistic feasibility study, it is possible that more U.S. municipalities will soon follow suit.

For more information

New York State Energy Research and Development Authority (NYSERDA) nyserda.ny.gov

PRODUCT NEWS & REVIEWS

New Options Emerging among Mass Timber Panels

Lots of glue, or all wood? Two new products highlight very different approaches to structural panels.

by Candace Pearson

Cross Laminated Timber (CLT)—prefabricated panels of wood whose strength, dimensional stability, rigidity, and large spans make it a replacement for structural steel or concrete—is currently far from a go-to building material in the U.S. However, in what is likely an indicator of explosive growth, new product offerings for North America are arising almost as quickly as new projects are constructed with the material.

Two of these new products, recently featured at the Mass Timber Conference in Portland, Oregon, lie at opposite ends of a spectrum: StructureCraft’s Dowel Laminated Timber panel, which cuts out nearly all glues and resins, and Freres Lumber’s Mass Plywood Panel, which utilizes wood veneers instead of whole lumber and relies on much more resin than typical CLT.

Both products promise lower profiles with longer spans than traditional CLT. So how do they compare?

Mass Plywood Panel

The Mass Plywood Panel (MPP) from Freres Lumber, takes the familiar concept of laminated veneer lumber and applies it to a panel. This product can use veneer from small-diameter
and low-value wood species instead of dimensional lumber and still maintain strength comparable to CLT. In fact, a 4-inch MPP panel can reach a span of 15 foot 3 inches, whereas a 4-1/8-inch CLT panel typically spans less than 14 feet.

The added strength and stiffness are achieved with much more adhesive than CLT, to laminate all the thin veneer layers together.

BuildingGreen has been hesitant about the adhesives used in engineered wood products because of formaldehyde offgassing (see Is Particleboard Deadly? Formaldehyde Emissions Explained). The MPP panel uses melamine urea formaldehyde resin, which is more stable than urea-formaldehyde, so there shouldn’t be very much free formaldehyde left in the final product.

However, the company has not yet completed the emissions testing to verify whether the product will meet California Air Resources Board (CARB) ultra-low emitting formaldehyde (ULEF) standards (a requirement for credit in LEED v4). Some CLT manufacturers have used a non-formaldehyde polyurethane resin (which BuildingGreen currently prefers in our product guide on Engineered Wood, acknowledging that the isocyanate components are still a major occupational hazard). However, Tyler Freres, vice president of sales, says this kind of resin has raised concerns about fire performance.

With its current formulation, preliminary testing indicates the product could achieve a two-hour fire rating, and Freres suspects that the “catalyzed glue bonds” are key to that performance.

According to estimates from Freres Lumber, the MPP uses 20% to 30% less wood than CLT, which may have a cost benefit (discussed later in the article) but also a negative impact on the carbon profile of the product. With less wood and more adhesive, the product will have higher embodied energy while storing less carbon.

**Dowel Laminated Timber**

StructureCraft’s Dowel Laminated Timber (DLT) on the other hand, does away with most of the glues and takes a step towards a 100% solid wood product by using a technology first conceived of in Switzerland. Boards are finger-jointed together with glues and laid up running in the same orientation (so they’re not cross-laminated—more on how strength can be added in the opposite direction later). Instead of laminating each layer with full coverage adhesive, a hole is drilled and a hardwood dowel (a wooden peg) is inserted into the stack of boards.

“It is the science of wood that holds the whole panel together,” explains Simon Lintz, business development manager for StructureCraft. “The dowels are dried to a very low moisture content. When they get inserted into the stack they absorb some moisture from the surrounding boards and swell, locking the panel together.” With this technology panels could reach up to 11 by 60 feet.

What happens as moisture content of the wood changes from season to season? The dowels are dried to such low moisture content that “there is no way they would loosen up enough to jeopardize the structural integrity of the panel if there’s been proper detailing and water management during installation,” says Lintz. For roof panels, membranes can be pre-applied during manufacturing, and for floor panels, temporary vapor barriers will be lapped and taped on. The dowels don’t serve much of a structural purpose anyway, according to StructureCraft, as every finger-jointed board will span between structural supports. Changing moisture could cause more movement than with a CLT panel, says Lintz, which could be a drawback in certain applications.

Like CLT, DLT is classified as heavy timber and is able to achieve fire resistance ratings of up to 2 hours, according to StructureCraft.

Minimizing the amount of resin used wasn’t the primary motivation for exploring this production process, according to Lintz, though the company has received more interest because of it. “Two separate architects that are pursuing Living Building Challenge (LBC) have told me this is their new favorite product,” says Lintz. (Formaldehyde is on the LBC Red List of prohibited chemicals, although there is currently an exception for phenol formaldehyde in structural products.)

Rather, StructureCraft was attracted to how the use of dowels could increase the efficiency and precision of the production process. The company has been doing nail-laminated timber for over a decade, but nailing all those boards together was a cumbersome process that wasn’t easy to automate. The company had learned to work within the needed tolerances, but they were still finding dimensional inconsistencies. Plus, a nail-laminated panel was difficult for trades: the metal fasteners presented an obstacle to cutting chases, for example.

Dowel lamination is much easier to automate, says Lintz, which makes for a “more refined, machined panel.” Since all of the wood fiber goes in the same direction, the panels have greater structural efficiency (10%–20% higher than CLT, according to the company) and can be built to longer spans.
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infill strips or achieving a two-way cantilever with screw patterns. MPP, on the other hand, could be a direct stand-in for CLT. “Engineers have expressed interest in our panels expressly for shear walls,” says Freres.

In terms of wood sourcing, the companies take different approaches. StructureCraft is Forest Stewardship Council (FSC) chain-of-custody certified and can source FSC-certified wood on request (although it notes that availability, especially on the West coast, is declining). Freres Lumber’s sister company, Freres Timber, manages 17,000 acres of forestland, some of which is certified by the American Tree Farm System (see Behind the Logos: Understanding Green Product Certifications). Additional lumber is sourced regionally in Oregon, where the company notes that the Oregon Forest Practices Act (OFPA) is in place. (However, watchdog groups have consistently noted problems with enforcement of logging rules in Oregon, particularly around pesticide use.)

Both companies say their products will be less expensive than CLT. “We can create a higher volume of material per hour because we don’t have to wait for the glue to set,” says Lintz. StructureCraft claims DLT will be up to 30% cheaper than CLT. Freres Lumber says it will minimize costs by using less high-value wood and passing on those savings to the customer. “Wood is by far the largest cost of manufacturing, so we anticipate that the stiffness and engineering qualities of structural composite lumber will allow lower cost of construction,” Freres told BuildingGreen.

Neither product is currently ready for prime time. Both companies are seeking to launch their products by the end of 2017 and plan to do more testing beforehand. But by all indications, the future of engineered wood products is in diversification and more options for different value systems.

Other comparisons

“DLT is not meant to go toe-to-toe with CLT,” says Lintz. “Because the fiber is all running in the same direction, DLT panels don’t have the same shear capacity.” As a result, their best application is most likely for a floor or roof panel. However, the company does offer some creative workarounds, such as joining two layers of DLT together with plywood

Photo: StructureCraft

Kiln-dried wooden pegs are inserted through the panel. As they absorb moisture from the surrounding boards, they swell and lock the layers together.

The precision means the company can also experiment with offering different profiles for aesthetic or practical effects. The company currently offers fluted, standard square-edge, chamfered edge, and reveal edge—profiles that give architects more design flexibility in using wood as an architectural finish. The panels can also be manufactured with grooves or dados, which can act as acoustic voids, or be filled with acoustic insulation or rock wool for even greater sound dampening.

There are more customization options as well. “I am really excited about the ability this creates for us to integrate services,” says Lintz. “We can easily create voids and chases to leave spaces for electrical or sprinkler systems.”

Social science research methods can generate innovative and sophisticated design solutions that respond to human needs and cultural values.

by James Wilson

Ethnography is defined as “the scientific description of the customs of individual peoples and cultures.” It is a method social scientists use to study and understand different communities and the places in which these communities are situated.

By using ethnography to enhance engagement with project stakeholders and their rich cultural values, designers can generate strategies that are responsive to the user perspective in more complex, nuanced ways.

Semantic ethnography

Architects can learn from and adapt several forms of ethnography used to study the cultural meanings and activities of people in their natural settings. Semantic ethnography is a particular variation of ethnography promoted by researchers like Galen Cranz, professor of architecture at UC–Berkeley, as one that is sympathetic to architectural practice. It is a method well-suited to design, leveraging information about the social context of a project to nourish creativity.

In her recently published textbook, Ethnography for Designers, Cranz writes that, “Semantic ethnography emphasizes the importance of what people can tell you in words, which means it emphasizes what people know that they know.” The focus is on accessing and interpreting the knowledge that people have about the environments they occupy. This is achieved with semantic interviewing.
Semantic interview: A listening tool

A semantic interview involves open-ended questioning and close listening to learn the specific language that people use to describe the places they use and inhabit. In contrast to conventional interviews, a semantic interview does not involve asking predetermined questions. Instead, the interviewer relies on a technique of active listening to develop an “unstructured” conversation, responding to the user’s answers with questions that follow up on specific terms used to describe experience.

For example, a designer researching an office building might start a semantic interview by asking a occupant to tell about their workday. The occupant might describe their daily routine and in the process mention a specific detail about sometimes being distracted by noise, or note a particular meeting room they prefer. The designer will then ask them to say more about the noise, or more about the room. From this basic starting point, the conversation may quickly lead to the sharing of many details about how the environment supports or frustrates the user’s needs. These details might then provoke unexpected and surprising insights that generate ideas for the designer.

In order to conduct an effective semantic interview, the interviewer must be careful to not ask leading questions and to keep their own biases and preconceptions from influencing the conversation.

**Quantity and quality**

This method leads to a better understanding of the different meanings people assign to their environments and can help architects respond to the particular needs of different stakeholder groups. Cranz argues that this special form of occupant engagement is an effective way to bring qualities, rather than just quantities, into design research, and she notes that, “Emphasis on qualities leaves the architect room for finding distinctive, physical expression of those qualities.”

**Responding to human needs**

Significant efforts have been made to better ensure that the built environment protects occupant health and provides for the physical needs of users, but what about their social needs? Ethnography offers a tool for responding to these needs as well. Using ethnographic methods to develop an awareness of the different levels at which people occupy and use an environment enhances a designer’s sensibility and craft.

**Research in practice**

Semantic interviewing can be applied in a number of ways to integrate research into design practice. It can be used to:

- gather potentially invaluable and inspirational information during the pre-occupancy, programming, and early design phases of a project;
- drive the goal setting process in integrative design workshops;
- support a community planning or participatory design process;
- gather qualitative information during post-occupancy evaluation, as a way to assess how well a project supports its users’ values and interests;
- assess the elements of design that are meant to delight or satisfy the occupant on an emotional level;
- study existing, “precedent” environments as a way to build knowledge of successful strategies and support project-specific research;
- and engage staff to involve them in the development of the firm’s mission statement or sustainability action plan.

**For more information**

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In *Ethnography for Designers* (Routledge, 2016), Galen Cranz describes a method of active listening that designers can use to access and interpret the knowledge people have about their environments.