Canada's Wood Innovation and Design Centre has an entirely wooden structure, showcasing the potential for high-rise wooden buildings that lock up carbon.

EMA PETER

# WOOD GROWS UP

*Timber buildings are getting safer, stronger and taller — and they could help to cool the planet.*

**BY JEFF TOLLEFSON**

One building stands out in the old logging town of Prince George, Canada. Encased in a sleek glass facade, the structure towers above most of its neighbours, beckoning from afar with the warm amber glow of Douglas fir. Constructed almost entirely from timber in 2014, the 8-storey, 30-metre building is among the tallest modern wooden structures in the world. But it is more than an architectural marvel. As the home of the Wood Innovation and Design Centre at the University of Northern British Columbia (UNBC), it is also an incubator for wooden buildings of the future — and a herald for a movement that could help to tackle global warming.

The building is less like a log cabin and more like a layered cake, constructed from wooden planks glued and pressed together, precision cut by factory lasers and then assembled on site. All told, the university avoided the release of more than 400 tonnes of carbon dioxide by eschewing energy-intensive concrete and steel, and the building locks up a further 1,100 tonnes of $CO_2$ that was harvested from the atmosphere by British Columbian trees. In total, that's enough to offset the emissions from 160 households for a year.

Wooden construction has ancient roots, but only in the past two decades have scientists, engineers and architects begun to recognize its potential to stave off global warming. By substituting concrete and steel with wood from sustainably managed forests, the building industry

could curb up to 31% of global carbon emissions, according to research[1] by Chad Oliver, a forest ecologist at Yale University in New Haven, Connecticut. In time, such a shift could help humanity to pull $CO_2$ out of the atmosphere, potentially reversing the course of climate change.

"It's the plywood miracle," says Christopher Schwalm, an ecologist at Woods Hole Research Center in Falmouth, Massachusetts. "This is something that could have a significant impact on the riddle that is global environmental change."

The renaissance in tall wooden buildings is already under way. Norway set a world height record in late 2015 with a 52.8-metre tower block; that was edged out in September 2016 by a 53-metre student dormitory at the University of British Columbia in Vancouver. This year, Austria will take the lead with the 84-metre HoHo building in Vienna, comprising a hotel, apartments and offices. The United States saw its first tall wooden building go up in Minneapolis, Minnesota, in 2016, and others are in the works in Portland, Oregon, and in New York City.

Wooden construction has attracted political interest in part because of the economic benefits for rural communities surrounded by forests. But turning these pioneering projects into a global trend won't be easy. Building costs are often high, and the global construction industry is almost entirely focused on concrete and steel, particularly when it comes to big buildings. And the climate benefits of building with wood hinge on a questionable assumption: that the world's forests will be managed sustainably. Some researchers worry that harvesting more timber could harm forest ecosystems, particularly in developing countries that are already plagued by poor and often illegal logging practices. "If we're going to cut wood, we've got to do it in a way that not only sustains the forest but also sustains the biodiversity and everything else," says Oliver.

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## TIMBER TECHNOLOGY

Steel and concrete weren't an option when Buddhist monks set about building a 32-metre pagoda at the Learning Temple of the Flourishing Law in Ikaruga, Japan, 14 centuries ago. They put their faith in wood, as did the monks at the Sakyamuni Pagoda in Yingxian, China. Erected in 1056, that structure rises a staggering 67 metres towards the heavens.

These pagodas are still standing today, a testament to the strength and durability of wood. Kilogram for kilogram, wood is stronger than both steel and concrete, and wooden buildings are generally good at withstanding earthquakes. But wood has developed a bad reputation over the centuries, because of catastrophic blazes that levelled cities such as London, New York and Chicago before modern fire-suppression strategies emerged. In fact, in case of fire wood maintains its structurally integrity much better than the non-flammable alternatives favoured by modern building codes. It chars at a predictable rate, and doesn't melt like steel or weaken like concrete. "The fact that it actually can withstand fire better than steel took a long time for people to realize," says Guido Wimmers, who chairs a master's programme in wood engineering at UNBC.

By some accounts, the modern era of tall wooden buildings began 20 years ago, with a simple experiment at the Technical University of Graz in Austria. Researchers glued layers of standard planks perpendicular to each other, and discovered that alternating the direction of the grain effectively negated the imperfections and weaknesses in any given plank. The result, known as cross-laminated timber, is a strong and lightweight wood panel that puts conventional plywood to shame. It can be made as large as desired and cut with sub-millimetre precision at the factory, which speeds up construction and reduces waste. And given the strength of these panels, there's no theoretical limit to how high wooden buildings can grow. "It transforms wood from a suburban material to a very urban material," says Michael Green, the Vancouver-based architect behind UNBC's design centre, and a leading advocate for wooden construction.

Wimmers says the initial goal of the technology was to make better use of low-grade wood products. "The wood construction industry was slowly vanishing, so they started to reinvent themselves," he says. Then the market for advanced timber technologies — including beams that are either glued or nailed together to increase strength — expanded as European countries put strict regulations on energy efficiency and greenhouse-gas emissions, forcing architects to reduce the climate footprints of their buildings. Wimmers estimates that in Europe, wood is now used in about 25% of residential construction, up from 5–10% in the 1990s.

The science of safety and engineering has also advanced. Douglas fir — the exposed layer at the UNBC centre — chars at 39 millimetres per hour. The provincial building code requires that the structure be able to endure at least one hour of fire on any given storey, so Green's team opted for floors made of a 5-layer panel that could afford to sacrifice a portion without losing its structural integrity.

Meanwhile, Wimmers's team is collaborating on the Tall Wood Project, funded by the US National Science Foundation, to improve earthquake resistance for high wooden buildings. Work by the consortium has shown that the buildings can withstand earthquakes as well as or better than concrete and steel[2], and the researchers will begin testing a two-storey wooden structure on a quake-simulator table at the University of California, San Diego, in June. They aim to test a ten-storey building there by 2020.

Asif Iqbal, a civil engineer who is working on the project, came to UNBC from New Zealand, where he saw the damage from the 2011 earthquake in Christchurch at first hand. Most of the steel-reinforced concrete buildings in the city remained standing, but around 1,800 were irreparably damaged owing to cracked concrete and warped steel. Iqbal says that many of the replacement buildings are being constructed from wood, precisely because it is more likely to survive another major earthquake and the steel connectors can be replaced relatively easily if damaged.

The long-term performance and economic viability of these buildings remains an open question. Wood is susceptible to mould and water damage, for example, and there is a higher risk of fire during construction. In September 2014, a £20-million (US$26-million) wooden sustainable-chemistry building being built at the University of Nottingham, UK, was destroyed by an electrical fire — in part because fire doors and windows were not yet in place to contain the blaze. Still, advocates say the future looks bright. "We are still fine-tuning wood technologies, but so far we haven't found any major issues that we cannot solve," Iqbal says.

## TRACKING CARBON

One of the main attractions of wooden construction is its potential to help stave off global warming. Oliver's research[1] suggests that humans currently harvest only 20% or so of the global forest growth each year, and more timber could be extracted without reducing the overall amount of carbon locked up in forests. The eventual climate impact of this harvest depends on the end use.

If the wood were simply burned for energy, the $CO_2$ that the tree had absorbed years earlier would immediately return to the atmosphere. Regrowing forests eventually pull that $CO_2$ back out of the air, so the idea of carbon-neutral wood energy is a function of time. It is also controversial: some argue that current policies in Europe overstate the climate benefits of wood fuel and create perverse incentives to cut down trees. But this debate doesn't apply to wooden buildings. "Just the fact that you have solid wood means that you are keeping $CO_2$ out of the atmosphere," says Oliver.

ED WHITE

**The centre's exterior was inspired by bark peeling from a tree trunk.**

Aside from the carbon sequestered in the wood itself, wooden construction offers further emissions savings. When researchers tallied the environmental impact of UNBC's building, they accounted for the manufacture and transport of every material — right down to the fossil-fuel-derived glue that binds the plywood together. Overall, the emissions related to construction were 12% of those for an equivalent concrete building[3], largely owing to differences in fossil-fuel use. "When you compare a wood building with a concrete building, wood wins every time," says Jim Bowyer, an emeritus engineer at the University of Minnesota in St Paul.

The UNBC building might have a uniquely low carbon footprint at the outset, but over time its environmental impact will grow as its heating, cooling and lighting requirements generate greenhouse-gas emissions. Day-to-day energy use and maintenance account for 80–90% of lifetime emissions for a typical building, and unfortunately the UNBC centre is no different. The consequence is that its long-term climate benefits are relatively modest.

But the most advanced buildings today, which combine energy-efficient designs and technologies with on-site renewable energy generation, can eliminate emissions over the life of the structure. In such scenarios, construction and materials — the building's 'embodied emissions' — account for 100% of a building's climate impact, giving wood an increasingly important advantage.

"We're moving towards really low-energy buildings," says Jennifer O'Connor, president of the Athena Sustainable Materials Institute, a non-profit research organization in Ottawa. "Quite frankly, if we are going to make a difference, then we had better start looking at those embodied emissions."

## THE LONG GAME

The wooden-building movement is, for now, focused mostly on Europe and North America. In the United States, more than 80% of houses are already wood-based, says Bowyer. Yet with the nation's timber industry currently extracting roughly one-third of annual forest growth, there is capacity to expand wood construction in mid-rise commercial and industrial structures without reducing the volume of carbon that is locked up in forests. Bowyer is leading an expert assessment convened by the American Wood Council, an industry body in Leesburg, Virginia; the team has found that the United States could roughly double the amount of carbon that it sequesters in buildings each year, offsetting the emissions from nine additional coal-fired power plants. By contrast, builders in Europe still rely mostly on concrete and steel: a 2010 Finnish government report[4] estimated that a mere 4% increase in annual wood use in construction throughout Europe would avoid 150 million tonnes of carbon emissions, almost as much as the Netherlands emits each year.

But to have a truly global impact, the movement must expand to developing countries, where forest management remains a challenge. Forests across the tropics are already being pillaged for timber and razed for agriculture. Indonesia, for example, has struggled to halt the palm-oil industry's destruction of rainforests. And although Brazil has made huge improvements in forest management over the past decade, demand for beef and soya beans is once again boosting land-clearing in the Amazon. Some fear that wooden construction would mean more trouble for some of the world's most precious ecosystems. "I've seen enough abuses of what you would call the wood-product sector that I'm leery of sweeping solutions that make big assumptions," says William Laurance, a tropical ecologist at James Cook University in Cairns, Australia.

Oliver argues that the push for wooden construction could help developing countries to establish sustainable industries that actually protect forests, if they are pursued in parallel with efforts to bolster governance. The challenge is to ensure that managed forests maintain the full suite of crucial ecosystems, including old-growth habitat and forest clearings. "It should all be preplanned and transparent," says Oliver. "That's kind of a utopia, but you've got to dream."

He is working with the United Nations Development Programme (UNDP) to design a comprehensive forest-management plan that would kick-start modern wooden construction in Turkey. Government figures indicate that the country erected 956 million square metres of building space between 2004 and 2014, and just 0.13% of that total was framed in wood. Yet 27% of the country is forested, and 7 million of Turkey's poorest citizens live in these areas, says Nuri Özbağdatlı, a forestry expert with the UNDP in Ankara. "We want to create a new value chain for wood," he says. "It will start with the forest villages and end up with the construction sector."

As wooden construction matures, it will face one final challenge: what happens when a building is decommissioned and torn down. Buddhist pagodas may last for centuries, but the general assumption for many modern buildings — including UNBC's centre in Prince George — is that they will outlive their usefulness and be replaced in several decades. If the wood is dumped into landfill and left to rot, its carbon will slowly leak back into the atmosphere. But if the wood is recycled — reused in future construction projects, for example — then the climate benefits are locked in.

Advocates of wood are pushing long-term strategies that promote recycling and other carbon-neutral options, but Green isn't too worried about the longevity of his building. Properly maintained, he says, there's no reason why it can't last as long as a Buddhist pagoda. Instead, he's focusing on getting this budding industry off the ground through a free online training course that will be translated into 30 languages, giving anybody with an interest — from architects and engineers to builders, developers and government officials — a more technical understanding of wooden construction. "We need to globalize the conversation," Green says. "This is the only hope of accelerating this to be competitive with concrete and steel, which have a 150-year head start." ■

**Jeff Tollefson** *writes for* Nature *from New York.*

1. Oliver, C. D., Nassar, N. T., Lippke, B. R. & McCarter, J. B. *J. Sustain. Forest.* **33,** 248–275 (2014).
2. Pei, S. *et al. J. Struct. Eng.* http://dx.doi.org/10.1061/(ASCE)ST.1943-541X.0001192 (2016).
3. Grann, B. *Wood Innovation and Design Centre Whole Building Life Cycle Assessment* (FPInnovations, 2014); available at go.nature.com/2pk4y7a
4. *The International Promotion of Wood Construction as Part of Climate Policy* (Ministry for Foreign Affairs of Finland, 2010); available at go.nature.com/2phy6rk