WHAT CAN WE DO ABOUT EMBODIED CARBON?

TEXT Jennifer O'Connor

THE ARCHITECTURE COMMUNITY IS ABUZZ WITH TALK ABOUT REDUCING EMBODIED CARBON IN BUILDINGS. WE ASKED JENNIFER O'CONNOR, PRESIDENT OF THE ATHENA SUSTAINABLE MATERIALS INSTITUTE, TO GIVE US A PRIMER.

PIXABAY

Embodied carbon explained

"Embodied carbon" is an imperfect term. The word "embodied" sounds like we're talking about carbon encapsulated in a material. Instead, it's shorthand for all the lifetime indirect greenhouse gas (GHG) emissions due to a building—in other words, everything other than emissions from building operations. For example, the GHGs emitted from diesel combustion in transporting a product to the building site are part of the embodied carbon in the product.

Embodied carbon is also known as value chain emissions, upstream/downstream emissions, or Scope 3 emissions.[1] The complete carbon footprint of a building includes all of these GHG emissions. A true zero-carbon building would account for and offset its operational carbon as well as its embodied carbon.

Most embodied carbon emissions are upstream or "upfront" of building occupancy—they are primarily related to the manufacturing of materials. This includes the extraction of raw resources, manufacturing of building products, and transportation of those products.

GHG emissions due to material manufacturing, use and disposal are more significant than many people realize. First, these emissions are a big upfront GHG pulse in the life of a building, which makes them a good near-term target for climate change mitigation. Second, as buildings approach net-zero carbon operation, embodied impacts will make up most of the carbon footprint in the built environment.

Embodied carbon has a lot of buzz lately, and that's inspiring to some design professionals. Kevin Welsh, Senior Sustainability Advisor at Integral Group, is one of them: "It's great to see the accelerating interest in embodied carbon. It's the next evolution of our industry's enthusiasm and dedication towards reducing the impacts of projects."

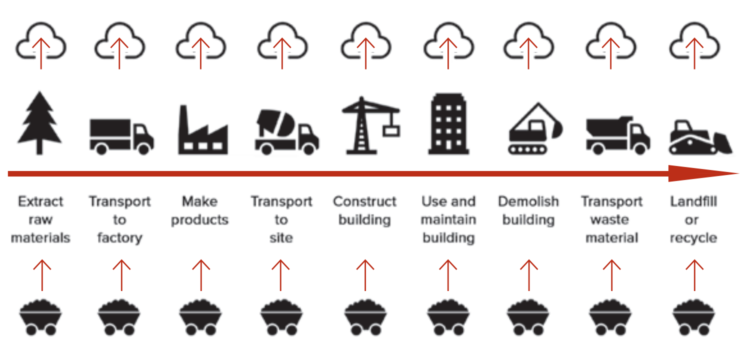
How to measure embodied carbon

Embodied carbon reduction begins with data. Without data, we're just guessing about where to look for improvements, and what decisions are actually beneficial. To bring in data, we need life-cycle assessment (LCA).

LCA is a holistic environmental impact assessment method. A cradle-to-grave LCA for a building accounts for all the lifetime flows between the building and nature, and then estimates the impact of those flows on the planet. An LCA provides multiple results having to do with damage to air, land and water.

Embodied carbon is one of these results—the global warming potential (GWP), expressed in equivalent tonnes of CO_2. To calculate

CRADLE-TO-GRAVE FOR A BUILDING



ABOVE The cradle-to-grave picture for a building. At every life phase, resources are consumed and emissions or wastes are created.

embodied carbon requires a full LCA study, although only one result from the study—the GWP—will be used.

Assessing embodied carbon impacts of design and material decisions is always a case-by-case situation involving cradle-to-grave LCA in the context of the whole building. There is no shortcut for this. And whole-building LCA is tricky. But two well-respected North American software tools make it easier for design teams: the Athena Impact Estimator for Buildings (a free standalone tool, produced by the Canada-based non-profit research group that I head) and Tally (a Revit plugin, developed by architecture firm Kieran Timberlake).

One word of caution: embodied carbon calculations are estimates, not absolutes. While LCA is a well-established, rigorous science guided by international standards, it is inexact. There are many variables and assumptions in LCA, and some data gaps and methodology question marks. The uncertainty in results increases with long-lived and complicated products like buildings.

Tactics to reduce embodied carbon

Consumption of anything has environmental impact, and making a building consumes a lot of resources. The easiest way to reduce embodied carbon is to consume fewer resources. That can mean less new construction, smaller new construction, less materials in new construction, and less frequent material replacements.

Another easy win is to be mindful in the use of products with high embodied carbon, such that their use is optimized. For example, cement is commonly over-specified (i.e. wasted) through practices like blanket specifications for 28-day strength concrete. If strength isn't needed so quickly, the cement content in the concrete can be reduced, thereby reducing embodied emissions.

But otherwise, there are no silver bullets. Looking for prescriptive answers is oversimplifying the problem and risking an unintentionally bad result. It's very difficult to justify the generic benefit of specific materials, building elements or tactics. Reducing embodied carbon usually requires an iterative process and a balancing of trade-offs. That requires a project-specific, whole-building, cradle-to-grave LCA study.

Getting the most bang for the buck usually means starting with the structural materials, which typically comprise most of a building's mass. Structural engineers are important partners to engage early for reaching sustainability goals.

What about wood and other bio-based products? These materials store carbon that was removed from the atmosphere by living plants, which makes for an interesting and complicated life-cycle carbon story. On the surface, bio-based products like mass timber from sustainably managed forests might be carbon winners. But there are methodology questions and data gaps in cradle-to-grave carbon accounting for wood products. This creates some uncertainty in embodied carbon calculation results. The bottom line: no single material will solve the embodied carbon problem, and designers need to choose all materials carefully.

Reducing embodied carbon will require a suite of tactics. Mark Lucuik, Director of Sustainability at Morrison Hershfield, has a great example from a recent project: a large bus storage facility in Calgary. With an integrated design process, the team designed a more efficient mechanical system that enabled a lower roof, reducing the height (and therefore material use) of the walls. The team also eliminated some finish materials, customized the concrete mixes, and brought a carbon perspective to the selection of insulation, roofing membrane and other materials. "In the end, we achieved an 18 percent reduction in embodied carbon and, equally important, big reductions in five other LCA measures," says Lucuik. "We achieved this reduction with decreases in capital cost and improvements in energy efficiency. A triple win."

PETER FRITZ. PHOTO COURTESY CHRISTOPHER SIMMONDS ARCHITECT AND MORRISON HERSHFIELD

ABOVE For the Rideau Valley Conservation Authority headquarters near Ottawa, architect Christopher Simmonds and consultant Morrison Hershfield used LCA to achieve 96 metric tonnes of savings in GHG emissions, through structural material optimization and the elimination of some finish materials.

This kind of work takes effort and commitment, which is why it doesn't happen very often. There are a lot of hurdles to be cleared before embodied carbon becomes a common focus in mainstream design and construction.

A case for keeping buildings around a lot longer

Existing buildings represent embodied carbon already in the atmosphere. Choosing to keep buildings in service for as long as possible helps amortize that carbon debt, by avoiding the new emissions that would be caused from demolition and replacement. There are many factors that support the case for building replacement. Can architects create longer-lasting buildings by designing for adaptability? Can architects help make the case for the adaptive reuse of existing assets? Consider the perspective of the University of British Columbia, a large building owner with many aging assets. "UBC Renew" is a program that aims

ABOVE The UBC Biosciences complex, an outdated 1957 building, was a candidate for replacement. Instead, it got an upgrade in 2011, led by Acton Ostry Architects. It will be used for at least another 40 years, avoiding the embodied carbon from a new building.

to minimize the financial and environmental impact of construction on campus, by supporting the rehabilitation of existing buildings.

Who owns this problem?

Pledges and calls to action on embodied carbon are easy. But who's going to actually get this job done? As Richard Hammond, principal at London, Ontario-based Cornerstone Architecture, puts it, "There is no single solution, and progress needs to come from a confluence of economic, social and technical initiatives. Every sector of our society has a role to play."

Most embodied carbon stems from material manufacturing, so we might look to industry for solutions. And industry is certainly stepping up, with gains especially evident in cement and concrete. "As a significant GHG emitter, our industry has been working hard on improvements for a long time," says Adam Auer of the Cement Association of Canada. An example is the development of Portland limestone cement (PLC), a replacement for general-use cement that cuts embodied carbon by 10 percent.

Steel is another product associated with high carbon impacts. Mark Thimons, from the American Iron and Steel Institute, says that "since 1990, the North American steel industry has reduced its average energy intensity and greenhouse gas (GHG) emissions intensity by 35 and 37 percent, respectively." He says the industry is also working to develop an entirely new process for the production of iron. The objective of Flash Ironmaking Technology is to significantly decrease energy use and reduce environmental impacts, especially CO_2 emissions.

Industry can come up with innovative, low carbon products, but it can't force the market to use them. Bob Larocque at the Forest Products Association of Canada notes that building codes are inhibiting the use of new products like cross-laminated timber, which has demonstrated embodied carbon benefits in tall buildings. Adam Auer identifies specification and procurement policies as a big barrier. "For example, government is the biggest customer of concrete," he says. "If carbon isn't part of government procurement policy, then PLC doesn't get specified—and there is insufficient demand for concrete manufacturers to even have PLC on hand."

Innovation from industry is only part of the solution—this is the supply side of the issue. If embodied carbon is fundamentally about resource consumption, then the demand side of the problem is equally important. Decisions about how to design, what to build, how big to build, and even whether to build at all have a huge impact on embodied carbon.

Material sourcing can be a big deal, particularly given the competitive pressure on domestic industry from imports. For example, Mark Thimons notes that "the embodied carbon of steel produced in North America is considerably lower than the embodied carbon of steel imported from many other countries, especially when transportation is considered."

Embodied carbon action will be most strongly affected by policy and financial market drivers. Currently, it's difficult to make a business case for reducing embodied carbon, as noted by architect and Athena Institute chairman Stephen Pope: "Life-cycle accounting for the built environment has been talked about for decades, but there is never money in the budget to do the analysis. With no monetization of carbon emissions, there is little to lure the business community to better behaviour through the use of carbon accounting."

What if embodied carbon had a price? The Living Building Challenge requires purchase of an offset for embodied carbon. If that approach was widely adopted in policy, then a clear financial driver would be in place to reduce embodied carbon, assuming the market rate for offsets is high enough. Consider the new Joyce Centre for Partnership & Innovation at Mohawk College, which was certified under the CaGBC Zero Carbon Building program and therefore had to declare its embodied carbon. The design focused on achieving a very low operational energy consumption of 73 eKWh/m^2/year. However, an offset for the 4,330 tonnes of embodied CO_2 in this building would have cost roughly $104,000 at today's low carbon price of $24 per tonne. As carbon prices rise, the incentive to reduce embodied carbon would get stronger.

Policy requiring embodied carbon disclosure can be a big help in raising awareness and motivating LCA skill development. It's a great first step in embodied carbon policy and is consistent with the spirit of transparent reporting so evident in other aspects of sustainable design. Disclosure can also support development of embodied carbon baselines and benchmarks. Without those in hand, it's hard to rationalize performance targets.

We will likely see growing ownership of this problem in the policy sphere, but it will be important that policy does not get ahead of available materials, building systems and the underlying LCA infrastructure. The technical underpinning is crucial to the reliability and comparability of embodied carbon assessments. Materials data, LCA methodology, and benchmarking need some work. A major Canadian initiative[2] led by the National Research Council is addressing some of this and will really help move the ball forward.

In the absence of a policy "stick," maybe a market "carrot" for disclosure will emerge. Kevin Welsh likes the idea of "a new niche certification scheme for buildings, for embodied carbon."

How low can we go?

There are ambitious calls to action out there for embodied carbon reductions. For example, the 2030 Challenge[3] and a new report from the World Green Building Council[4] call for zero embodied carbon by 2050. How realistic is that target?

Richard Hammond thinks deep cuts are feasible today, but "getting all new buildings to net zero by 2050 is a very big leap that will depend on a number of factors coming together, including broadly accepted carbon pricing and widely available new technologies."

With materials and processes available today, embodied carbon reductions in the range of 10 to 25 percent are easily achievable for many projects. But finding significant savings requires an unusually committed client and "a strong integrated design process, with everyone on board from the beginning," says Kathy Wardle, Director of Sustainability at Perkins and Will Vancouver.

The technical challenge in achieving zero embodied carbon is partly illustrated by looking at one corner of the story: what's possible with concrete. Adam Auer of the Cement Association thinks a 40 percent GHG emissions reduction for concrete is realistic, but will take collaboration across the construction value chain as well as with policy makers. Switching to Portland limestone cement reduces GHGs by 10 percent. Fuel switching in manufacturing might yield another 20 percent. Optimizing the amount of cement in a mix could yield further reductions of 20 percent or more. Getting to carbon neutrality will require carbon capture at manufacturing facilities, a technology that still faces a number of technological and economic hurdles. But Auer says the cement industry is recognised as an ideal candidate for carbon capture, and is very active in Canada and globally in its pursuit of the technology.

Let's extend these thoughts to the entire value chain for buildings and consider a few of the things that will need to happen in order to achieve zero embodied carbon without the purchase of offsets. All equipment used in resource extraction and the manufacturing and transportation of construction products would operate without fossil fuel. All structural wood products would be harvested from sustainably managed forests. All manufacturing facilities would have zero carbon emissions by using carbon capture and/or fuel switching to 100 percent non-fossil energy. All equipment on a construction site—as well as equipment used for demolition and the transportation of waste—would operate without fossil fuel.

Or perhaps technologies will emerge that enable carbon-capturing buildings: that is, buildings that actively remove GHGs from the atmosphere during their lifetime, to offset some of their embodied carbon. Exposed concrete already does this somewhat as it ages in place—a process called carbonation, which is not typically accounted for in embodied carbon calculations, and could be optimized by greater exposure to air of concrete in service and at its end of life. Maybe new building technologies will be developed that similarly absorb carbon dioxide.

In the short term, achieving zero embodied carbon will require the purchase of offsets. An innovative carbon trading system would use the revenue from offsets purchased for new construction to create financial incentives for retaining existing buildings and upgrading them for energy efficiency.

But is "how low can we go" the wrong question? In a race to zero, we may lose sight of the bigger picture. For example, building operations is still the biggest piece of the lifetime carbon pie, and needs to be balanced against embodied impacts. Many high-performance buildings have relatively high embodied impacts. "We don't want to encourage poor operating performance to achieve an embodied reduction—we need to take a life-cycle perspective," says Mark Lucuik.

In addition, we "don't have enough benchmark data to know whether the levels of performance proposed by the challenges are appropriate," says Stephen Pope. In fact, the whole carbon question is even more complex and nuanced than that. Says Pope: "Rather than looking at carbon use as an absolute, we have to look at carbon as a loop cycle. Some of it is always in use, but the use needs to be balanced."

Current hurdles aside, the enthusiasm for this topic is exciting and encouraging. Kathy Wardle is among those embracing the challenge: "It's nice to see this momentum building for embodied carbon, because we need to address all of the complex issues around materials—including life-cycle ecosystem and human health impacts."

Jennifer O'Connor is President of the Athena Sustainable Materials Institute. The Athena Institute is a non-profit research group that advocates for environmental performance measurement and accountability in the built environment and provides free life-cycle assessment resources.

i Carbon accounting practice widely follows the GHG Protocol and its language (https://ghgprotocol.org). Scope 1 is direct emissions from sources controlled by an entity (site emissions, in the context of a building). Scope 2 is indirect emissions from the generation of purchased energy (source emissions, in the context of a building). Scope 3 is other indirect emissions in the value chain (in the context of a building, this would include embodied carbon, occupant commute travel, and so forth).

2 To learn more, see https://nrc.canada.ca/en/research-development/research-collaboration/programs/low-carbon-assets-through-life-cycle-assessment-initiative.

3 "The embodied carbon emissions from all buildings, infrastructure, and associated materials shall immediately meet a maximum global warming potential (GWP) of 40% below the industry average today. The GWP reduction shall be increased to: 45% or better in 2025, 50% or better in 2030, and Zero GWP by 2050." https://architecture2030.org/2030_challenges/embodied/ - Accessed Oct 1, 2019.

4 M. Adams et al, *Bringing embodied carbon upfront: Coordinated action for the building and construction sector to tackle embodied carbon.* 2019. World Green Building Council.

REDUCING THE EMBODIED CARBON OF CONSTRUCTION MATERIALS

Operational carbon—the energy used to operate all existing buildings—is responsible for 28 percent of global CO_2 emissions each year. But embodied carbon is a blind spot that's only recently coming to light.

At least 11 percent of annual global CO_2 emissions are attributable to the carbon associated with materials such as concrete, steel, wood, glass, and insulation used for new construction just in the past 12 months. Between now and 2050, the operational and embodied carbon associated with new construction will be responsible for equal shares of global carbon emissions from buildings—making them both major concerns in the climate crisis.

***Canadian Architect*'s attention turned towards embodied carbon last year with an article by Life Cycle Assessment specialist Anthony Pak (*CA*, July 2019) and continued with a primer on embodied carbon accounting by Athena Sustainable Materials Institute president Jennifer O'Connor (*CA*, February 2020). Our series continues with two articles offering practical advice on design strategies for reducing embodied carbon.**

KEY CONSIDERATIONS FOR KEY MATERIALS

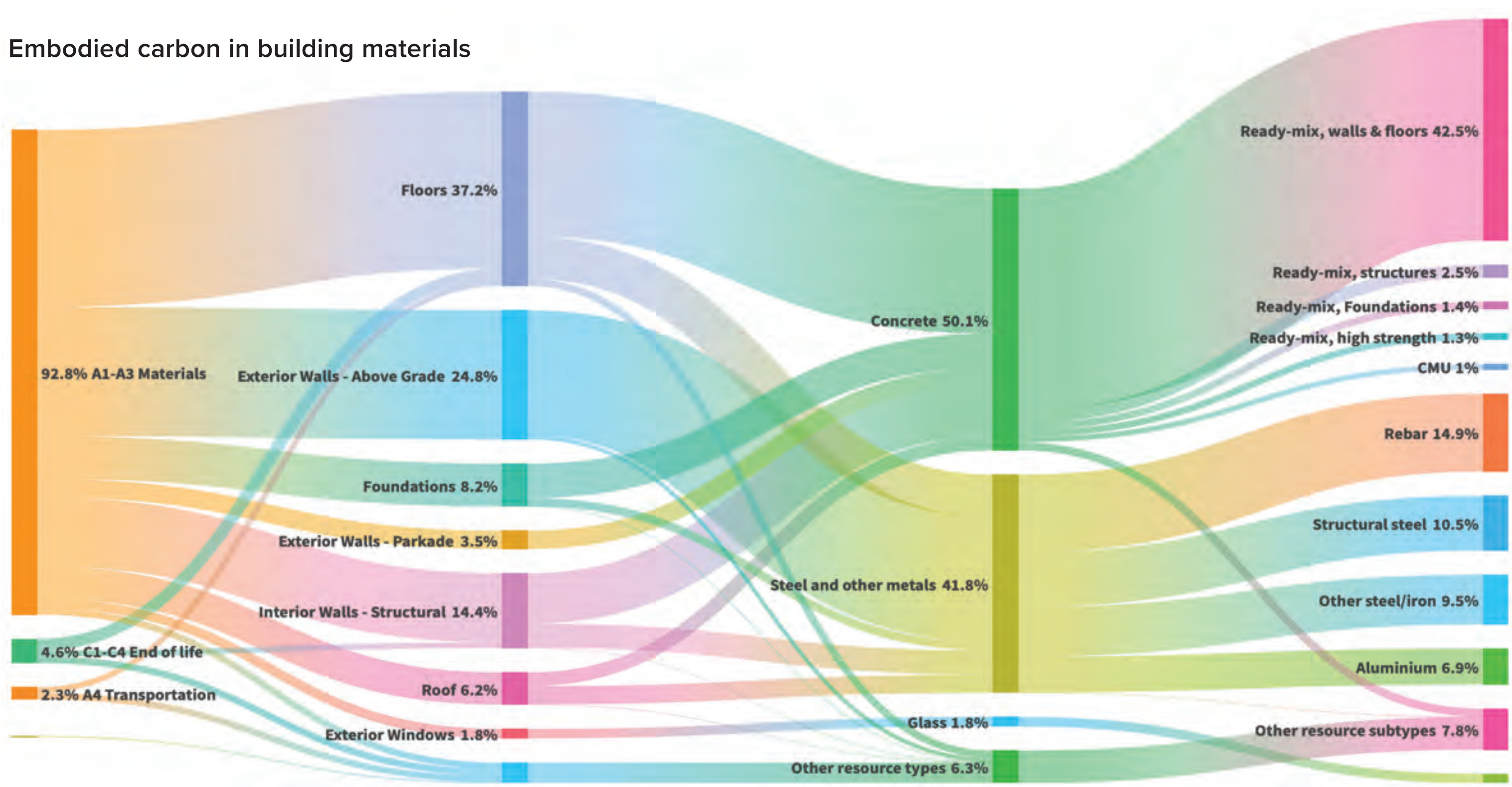
TEXT Anthony Pak

The challenge we face is overwhelming and complex. Our industry's emissions currently account for 40 percent of total global annual CO_2 emissions. Of that, a third is attributable to embodied carbon. The attention we have paid to energy efficiency—via improved insulation properties, renewable energies, and passive systems—has led to significant operational improvements in the last two decades. But over that same period of time, we've put half of all historical CO_2 into the atmosphere. This is in part due to the fact that we've been largely focused on only part of the problem.

To meet the 2030 Challenge, we need to not only achieve net zero operational carbon, but also radically reduce embodied carbon. We need to face new questions: How do we now choose between two different window options, two wall assemblies, two concrete mixes, two structural systems? Assuming both options perform and cost the same, does either contain materials that were sustainably sourced, processed and transported? Does either option have half the carbon footprint of the industry norm? What is the norm?

There are many facets to the carbon profile of materials—the Carbon Smart Materials Palette website by Architecture 2030 is among the best resources for further research. But architects often ask me for a basic primer on the main materials used in building structures and envelopes. Here's a material-by-material assessment, focusing on the biggest carbon considerations for each material.

Embodied carbon in building materials



An LCA evaluation by Priopta looks at the embodied carbon, or Global Warming Potential (GWP), of the materials used in a building.

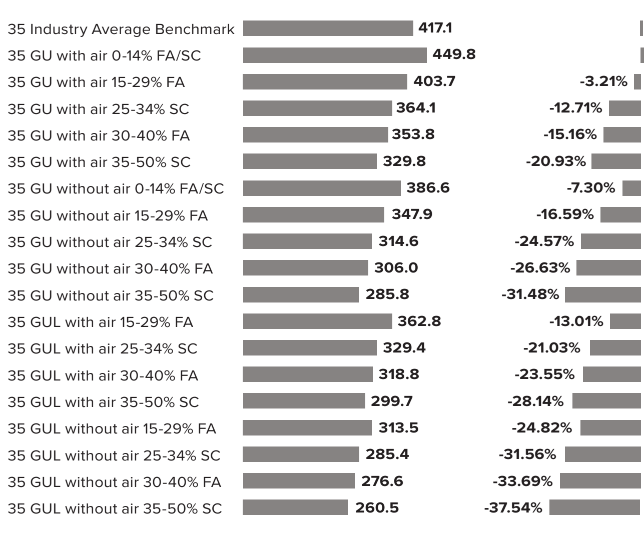
CONCRETE

The main environmental impact associated with concrete stems from its cement. Although cement makes up only 10 percent of the concrete mix, it is responsible for over 80 to 90 percent of concrete's embodied carbon. Cement production involves heating a mixture of limestone, silica, alumina and gypsum to 1,400-2,000 degrees Celsius. The heat-intensive process often uses fossil fuels, but also, the chemical reaction itself generates CO_2. Anything you can do to reduce the amount of cement in your concrete mix will have a significant impact on the overall embodied carbon of the concrete.

One suggestion is to use Portland Limestone Cement (sometimes called general-use limestone cement) in place of regular Portland Cement. In this type of mix, limestone displaces some of the cement. This substitution has no major structural implications, and can lead to a 10 percent reduction in Global Warming Potential (GWP). Supplementary Cementitious Materials, such as fly ash or slag, can also be substituted for cement. Strategies such as using post-tensioned slabs or voided concrete—such as hollow-core slabs, waffle slabs, or bubble-deck systems—may also help reduce the overall amount of concrete in a structural system.

Performance-based specifications can also be a useful tool to choose instead of prescriptive specifications. This may require testing or other procedures. Prescriptive requirements may prevent ready-mix suppliers from delivering the lowest embodied carbon concrete for a particular application.

Global Warming Potential of different concrete mixes



A chart based on data from the CRMCA Industry Average EPD (2017) compares the Global Warming Potential (GWP) of different concrete mixes, including differences between general use (GU) and general use limestone (GUL) mixes, and different levels of inclusion of fly ash (FA) and slag (SC).

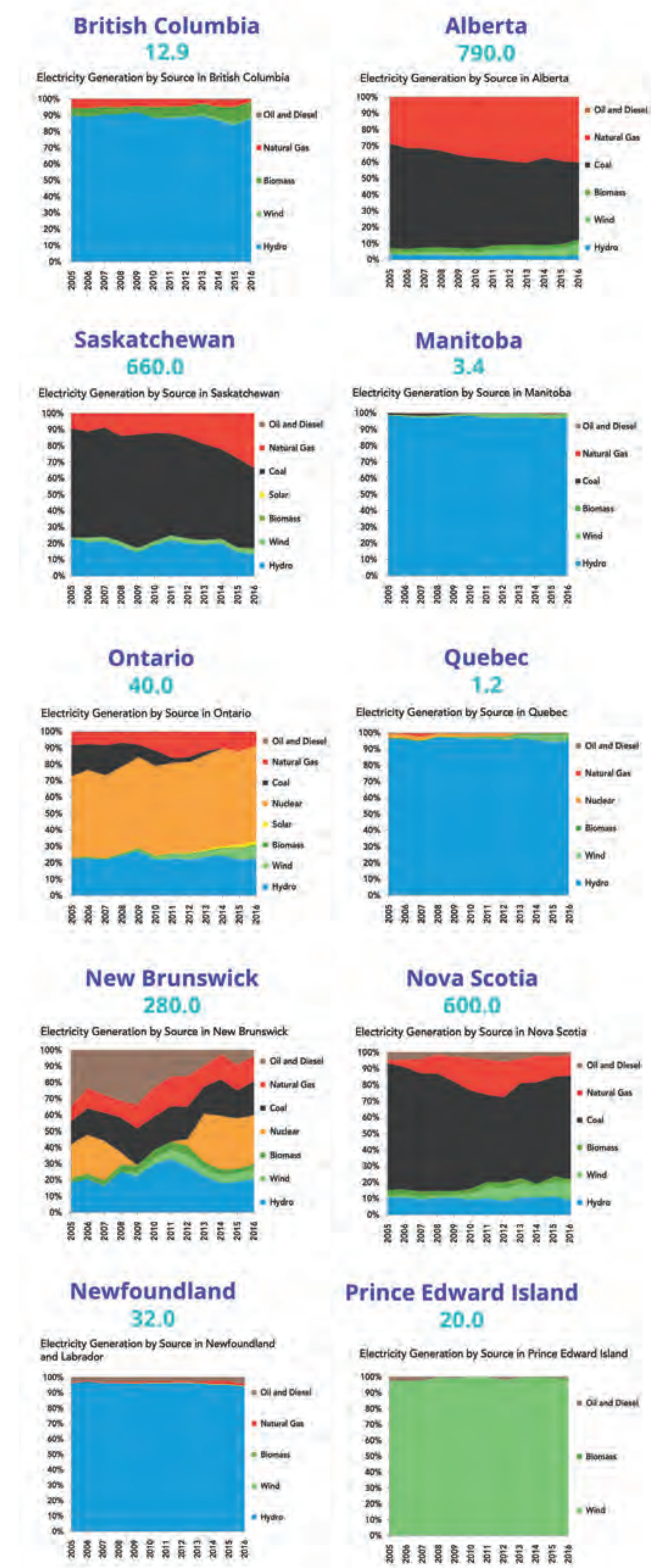
STEEL

There are two ways of producing steel: using a basic oxygen furnace or an electric arc furnace. The steel made with basic oxygen furnaces is much more emissions-intensive. These furnaces burn coal or natural gas, and the feedstock is largely virgin iron ore, with 25 to 37 percent recycled material. This type of steel makes up 71 percent of global steel production and is the predominant type produced in Asian steel plants.

Some 68 percent of steel produced in the United States, and 40 percent of Canadian steel, is made using electric arc furnaces. This lower-

Electricity Grid Carbon Intensity by province

(gCO_2e / kWh)



A comparison of the carbon intensity of electricity grid mixes in provinces across Canada. Source: National Energy Board, *Canada's Renewable Power Landscape, Energy Market Analysis*, 2017.

emissions method uses more recycled steel scraps—up to 100 percent, with an average recycled content of 93 percent for hot rolled shapes. Because it's an electricity-driven process, the carbon-intensity of the local electricity grid impacts the carbon-intensity of the resulting steel.

For most materials, transportation is only a small slice of the carbon impact—production technology and the electricity grid (in the case of electricity-driven processes) tend to matter more. This holds true for steel, where typically over 90 percent of carbon emissions come from steel production, and less than 10 percent from transportation and fabrication.

In a steel structure, consider using steel that comes from electric arc furnaces in areas with a low-carbon electricity grid, and specify high-recycled content steel whenever possible. Look for shapes that come from electric arc furnaces. In North America, these typically include hot rolled shapes such as wide-flange members, angles, channel shapes and rebar. Hollow structural shapes and metal deck are typically made at mills with basic oxygen furnaces.

WOOD

In Life Cycle Assessment (LCA) calculations, wood structures generally show lower emissions compared to concrete and steel, although this is not always the case. Using wood in buildings is one of the best uses of the material, as it locks in its captured carbon for a long period of time.

We suggest specifying wood that comes from sustainably managed forests and avoiding wood harvested from primary old growth forests. Forest management practices can significantly impact the carbon footprint of wood. However, there are still many questions around the forest-related impacts on biogenic carbon that aren't fully captured in LCA studies. For instance, what's the impact on soil carbon of increased wood harvesting? What would the carbon sequestration have been if you left the forest alone?

On a landscape level, BC's wildfires in 2017 and 2018 generated three times the province's emissions from all other sources. Climate change is making our forests more prone to large wildfires; consideration and additional research is needed as to whether the forestry sector plays a role in increasing or decreasing wildfire risk, as there are arguments on both sides.

What happens in the forest sector will have a huge impact on global emissions. Our forests can be one of our biggest carbon solutions, but also one of our biggest emitters if we don't treat them the right way. It's on a whole different scale than trying to distill how much carbon is stored in a cubic metre of wood.

ALUMINUM, GLAZING AND ENVELOPE DESIGN

Primary aluminum production is energy-intensive, using about ten times as much electricity as steel and accounting for four to five percent of global electricity demand. As such, the key factor that impacts the embodied carbon of aluminum is the carbon intensity of the electricity used. Canada is the world's fourth largest producer of aluminum and has the lowest carbon footprint of the large producers, since it uses mostly hydroelectricity and the latest generation of technologies. For example, primary aluminum production from Asia emits around 17 $kgCO_2e/kg$ aluminum, while the same material produced in Canada emits around 2 $kgCO_2e/kg$ aluminum.

Using recycled aluminum has even lower emissions, as it uses 95 percent less energy than primary aluminum production and is infinitely recyclable. However, recycled aluminum can only satisfy less than 30 percent of global demand, so low-carbon primary aluminum production remains essential.

Ideally, building envelope design should consider impacts on both operational and embodied carbon. For instance, triple-paned windows will be higher-performing on the operational side, but the extra layer of glazing will have impacts on the embodied side. Glass itself is not particularly carbon-intensive, but the materials used for framing it can drive emissions up. Curtain wall assemblies, for example, can have high carbon emissions because of the aluminum content of mullions.

Aluminum should be treated as a high-value material and should be used sparingly, where possible. Specify aluminum from regions with low-carbon electricity mixes. Timber-framed glazing is a great low-carbon option for residential construction, as timber has low embodied carbon and better thermal performance than steel or aluminum.

INSULATION

XPS and spray foam insulation can have extremely high embodied carbon due to the hydrofluorocarbon (HFC) blowing agents used. All XPS and most spray foam in North America currently uses HFC blowing agents. This gas has a greenhouse impact over a thousand times greater than the equivalent amount of CO_2, so small traces released during installation and through off-gassing carry a huge Global Warming Potential. Through my research, I realized that some building LCA tools have significantly underestimated the embodied carbon of XPS and spray foam insulation, as they did not properly account for the HFC blowing agent impacts.

In Europe, HFC blowing agents are banned, and in Canada, they are due to be banned starting in 2021. Some US States will also have legislation in place to limit the use of HFC. New XPS and spray foam products using lower GWP blowing agents will be coming to market next year, so be sure to specify them—particularly in projects outside of Canada that will not have HFC regulations in place.

Where possible, consider using insulation materials that naturally sequester carbon, such as cellulose, wood fibre, and straw. However, it is important to consider the impact on both embodied and operational carbon when comparing insulation options.

BEYOND LIFE CYCLE ASSESSMENTS

Embodied carbon, as a field, is a blind spot. But there are blind spots within the blind spot—such as the forestry side of wood production and the blowing agents used for insulation.

Life Cycle Assessment studies typically only look at structure and the envelope, but the materials used in HVAC systems and cyclical tenant improvements can also tally up in carbon impact.

Another major blind spot is refrigerants. The near-term impact of refrigerants released into the atmosphere has an outsized role in global warming, compared to other greenhouse gases. We typically quantify the operational carbon savings from using a mechanical system such as Variable Refrigerant Flow, but neglect to account for the global warming impacts of refrigerant leaks.

With Life Cycle Assessments, we are generally focused on finding lower-carbon material options. A bigger lever is choosing to retrofit existing buildings, where the structure and envelope are repurposed, taking advantage of the carbon already expended.

Efficient space planning is also important. In the UK, the housing demand is 34 m^2/person, whereas in the United States, it's 68 m^2/person. In Canada, residential floor area per capita varies from city to city—it's 34 m^2/person in Toronto and 63 m^2/person in Calgary. How can we make more effective use of space?

When we think about problems worth solving, we're looking for problems that are big, solvable and ignored. Operational carbon is a very big, solvable problem, but one where there is already significant focus. Embodied carbon is a place where we have significant potential for mitigating carbon. It's a problem that merits our attention—and action—as an industry.

LEARNING FROM KIGALI: LESSONS FOR CLIMATE-POSITIVE DESIGN

TEXT Kelly Alvarez Doran

When presenting our work on reducing embodied carbon in our projects in Kigali, we're often asked some version of the question: "You can do that in Rwanda, but how can this translate to a developed context?"

The simple answer is that at this point in time, all places around the globe have much in common. COVID-19 has revealed just how much our industry—from developed markets in North America to land-locked emerging markets in Africa—depends on a global network of material and labour exchanges. Our projects in Rwanda have faced the same delays and material shortages as those in Boston, most notably with specialty items related to electrical and water infrastructure, manufactured in Southeast Asia.

Fortunately, construction on our Kigali-based projects resumed largely unimpeded after an initial eight-week shutdown. This was a direct result of actions taken by the Government of Rwanda to manage the pandemic, along with early design decisions to source the vast majority of materials and labour for our projects in-country. After a decade of working in this manner, our Kigali office has become deeply familiar with the materials, processes, and people that it engages. As a result, our projects have become more resilient and impactful—and our practice more sustainable.

The more nuanced answer to this question is contingent upon one's willingness to challenge the status quo. Our initial unfamiliarity with Rwanda was somewhat of a blessing, as we had no preconceived notions of what was normative construction practice. The opportunity to work in Rwanda has fundamentally changed our understanding of how to practice architecture and engineering.

Conversations like those held over the window schedule for Munini Hospital with Bruce Nizeye, our long-time mentor and quantity surveyor, have lifted our eyes past the pages of the catalogue to see the actual materials, labour, and supply chains that are activated by specifications. In responding to a sketched window, Nizeye asked us: "What glass do you want? If you want this kind, it comes from this supplier in Tanzania, along this road, and can't exceed this size, because of the type of trucks that make that journey."

Similarly, the dimensions specified for the window's frame would dictate whether it could be manufactured on site in rural Rwanda, or would come from a metal shop in Kigali, or Nairobi, or India. The specifics of how our team drew that opening quickly began to have significant, direct impacts on the project's supply chain. By drawing with certain dimensions—ones that were not necessarily the "norm"—we could direct the enormous capital associated with the project towards Rwandan labour, specifically in the underserved rural area immediately around the project.

TOWARDS HALF

A year ago, we wrote a letter to the editor of this magazine outlining the urgent need for Canadian architects to undertake a "radical refocusing towards embodied energy." MASS has been working hard to ensure this conversation is front and centre for all of our projects—whether in Santa Fe, Boston, or Mombassa—at all stages. We're doing Life Cycle Assessments and material research early on to ensure projects track towards the 2030 emissions targets.

From the outset of designing the Rwanda Institute for Conservation Agriculture (RICA), we've been focused on finding ways to halve the project's embodied footprint. We've dug test-pits, conducted structural analysis of soils and timber, visited timber mills in Rwanda, Uganda, and Tanzania, inspected steel sections in Nairobi, and worked with a ceramic tile manufacturer to establish the country's first Environmental Product Declaration (EPD). These efforts have allowed us to confidently specify low-carbon materials and assemblies that are certainly not the regional norm. The structure is largely made of earth blocks harvested from the project's site, while the overall design minimizes the use of cement and steel, optimizes passive systems, and embodies only 58 percent of the emissions of "business as usual."

We're actively exploring the advantages and limitations of existing Life Cycle Assessment tools in the various contexts we operate, and have developed our own accounting systems to fill the gaps. We're collaborating with industry leaders like Arup, Transsolar, Atelier 10, Bionova, and Priopta to improve and expand how we're accounting for emissions across the life of a project—including strategies for on-site sequestration through landscape. Through engaging and acting to address this challenge, we have learned some basic lessons that we're now bringing to all our projects, in North America and Africa alike.

LEAN

The big ticket in emissions reductions is a project's structure. We are achieving lighter, less carbon-intensive structures by working with structural engineers early to reduce spans, introduce columns, and reduce reliance on steel and concrete to transfer loads.

At RICA, we established structural grids and constrained window and door dimensions to allow compressed earth blocks and rammed earth walling to take the majority of the loading. This led to a dramatic reduction of reinforced concrete across the project, resulting in a 48 percent embodied carbon reduction in that aspect of the assembly.

CLEAN

Simple changes to the materials being specified in a project's assembly can result in big Global Warming Potential reductions. Spending time to become familiar with EPDs and the databases and tools used to compare them (EC3, One Click, and Athena) often reveals significant differences between material choices.

At JJ Carroll, a seniors' housing project in Boston, we switched our under-slab insulation from XPS—a material that uses harmful HFC blowing agents—to EPS. We also changed our above-grade insulation from glass-wool to cellulose. We see these as low-hanging-fruit from an emissions standpoint.

OLD SCHOOL

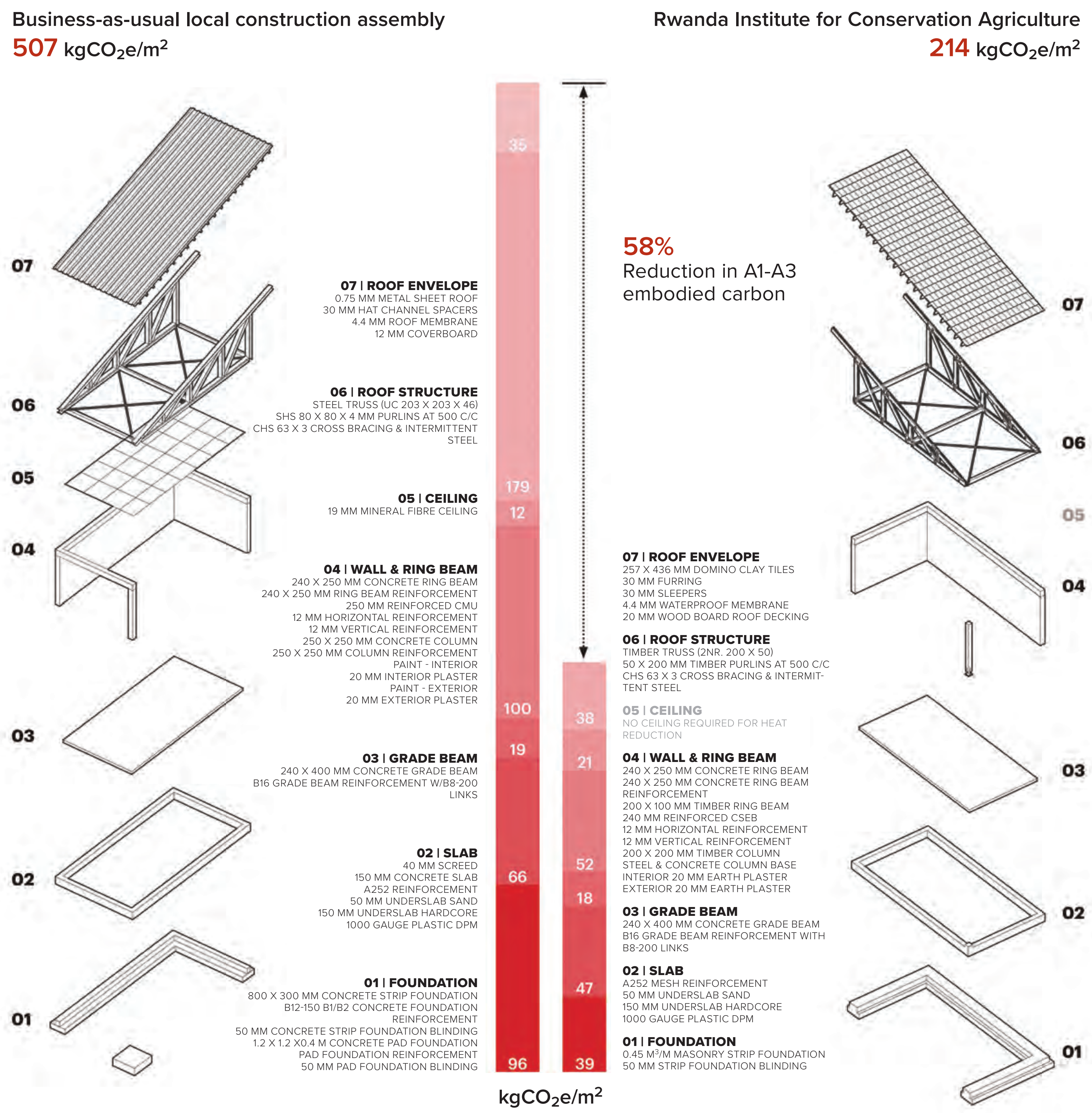
Looking at how buildings in a certain region were constructed a century ago can bring up options for emission reductions. What systems were employed? Where were the materials sourced and manufactured? How have they performed? What locally abundant materials have fallen out of fashion, and might we look to engage them in new ways?

At RICA, we discovered that a huge proportion of the project's carbon footprint was hidden in the reinforced concrete foundations we had initially designed. We had worked with stone foundations on other smaller-scale projects to save costs, so we began evaluating the feasibility of using stone foundations at RICA. Rolling back the clock to employ stone reduced the emissions of the foundations by 250 percent.

QUESTION THE STATUS QUO

We often come across statements like "We don't have access to these products," or "That isn't how things are done here." We see these as opportunities to help make the dramatic changes required of our system. We can encourage new materials and suppliers into the market by specifying them now. We'll spend the additional time needed to advocate for why importing something or supporting an upstart is the right move from a climate perspective. We often question standard practices, and work with engineers and contractors to find lower-emitting solutions.

At JJ Carroll, we are working with the project's structural engineer to fine-tune the use of concrete and achieve reductions. We're asking basic questions: How are we specifying concrete mix proportions? Have strengths been specified based on what is needed in different parts of the building, and at different times in the construction process? What prescriptive requirements are placed on the concrete? How many mixes are being used? Do we require EPDs?



How do mixes compare to NRMCA benchmarks?

Over the past year, Canada has taken globally recognized actions to address the embodied emissions of construction. The leadership displayed by Vancouver's City Council, the National Research Council, Builders for Climate Action, and local chapters of the Carbon Leadership Forum illustrates what is possible if we place emphasis on this issue. I'm hopeful that Canadian architects and engineers can learn from the experiences of colleagues—including our work in Kigali—to inform projects across the country, taking full advantage of each region's constraints and opportunities. ◖▲

Canadian ex-pat architect Kelly Alvarez Doran is a Senior Principal at MASS Design Group. He leads the practice's office in London, UK, and oversees its work in Europe and East Africa.

JJ Carroll residence
Boston, Massachusetts

Exterior wall assemblies
CO_2e/m^2 per material

WALL TYPE A
CMU VENEER ON CMUS

1 4" NOMINAL GROUND-FACE CMU (4" X 8" X 8")

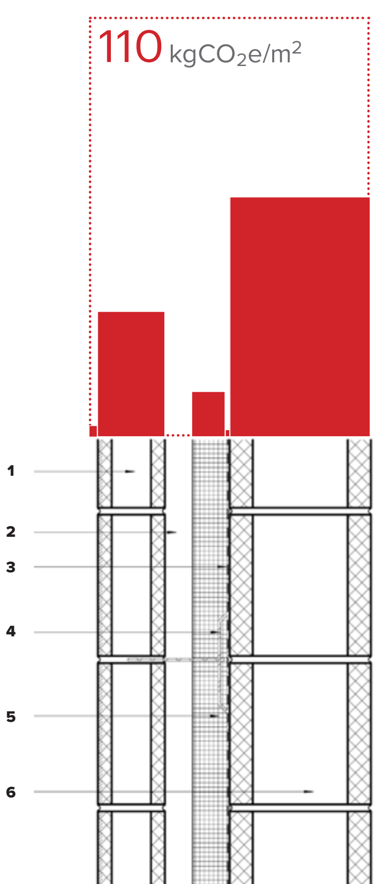
2 1-1/2" AIR CAVITY

3 THERMALLY BROKEN METAL MASONRY TIES AS SPECIFIED, SPACED VERTICALLY EVERY 6 BRICK COURSES MAX.

4 2" R 11.4 POLYISO RIGID BOARD INSULATION

5 1/2" FRT PLYWOOD SHEATHING

6 CMU



WALL TYPE B
TERRACOTTA SHINGLE
ON METAL STUDS

1 TERRACOTTA SHINGLE (7/8"X 14"X 9"). BASIS OF DESIGN: TERREAL NEXCLAD 14

2 3/16" RAINSCREEN DRAINAGE MAT PERFORATED AND CORRUGATED PLASTIC MADE OF PRE-CONSUMER RECYCLED HIGH-IMPACT POLYSTYRENE WITH AN ADHERED SPUN-BOND POLYPROPYLENE FABRIC

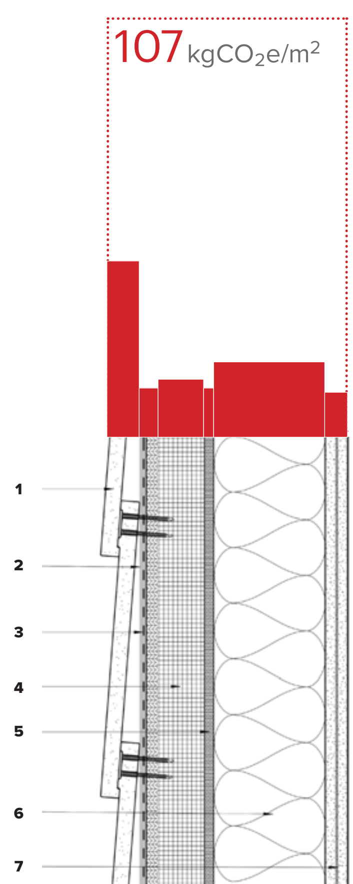
3 SELF-ADHERED WEATHER BARRIER

4 3-1/8" R 15.9 PANEL WITH 5/8" FRT PLYWOOD, NAILABLE SHEATHING AND 2-1/2" CLOSED-CELL POLYISOCYANURATE FOAM INSULATION

5 1/2" FRT PLYWOOD SHEATHING

6 6" LGM STUD FRAMING 16" O.C. MAX. AND BLOWN-IN CELLULOSE INSULATION

7 (2) 5/8" GWB



WALL TYPE C
FIBRE CEMENT PANEL
ON WOOD STUDS

1 FIBRE-REINFORCED CEMENTITIOUS PANEL

2 1-1/2" HCI RAINSCREEN ATTACHMENT SYSTEM. BASIS OF DESIGN: KNIGHT WALL SYSTEM

3 STAINLESS STEEL SCREW BY ATTACHMENT SYSTEM MANUFACTURER

4 2-1/2"MINERAL WOOL INSULATION

5 SELF-ADHERED WEATHER BARRIER

6 1/2" FRT PLYWOOD SHEATHING

7 2X6 WOOD FRAME AND BLOWN-IN CELLULOSE INSULATION

8 (2) 5/8" GWB

9 EXPOSED FASTENER WITH LOCK WASHER BY FAÇADE MANUFACTURER

10 JOINT