ZERO HOUSE

ZERO CARBON, ZERO NET ENERGY, ZERO TOXIN, ZERO WASTE PREFAB HOME

Zero House was a collaboration between The Endeavour Centre and Ryerson University's Architectural Science department. The Ryerson team contributed the conceptual design and provided energy modelling and rendering. The Endeavour team assembled the materials and systems and panelized the design, and the Endeavour class of 2017 built the home.

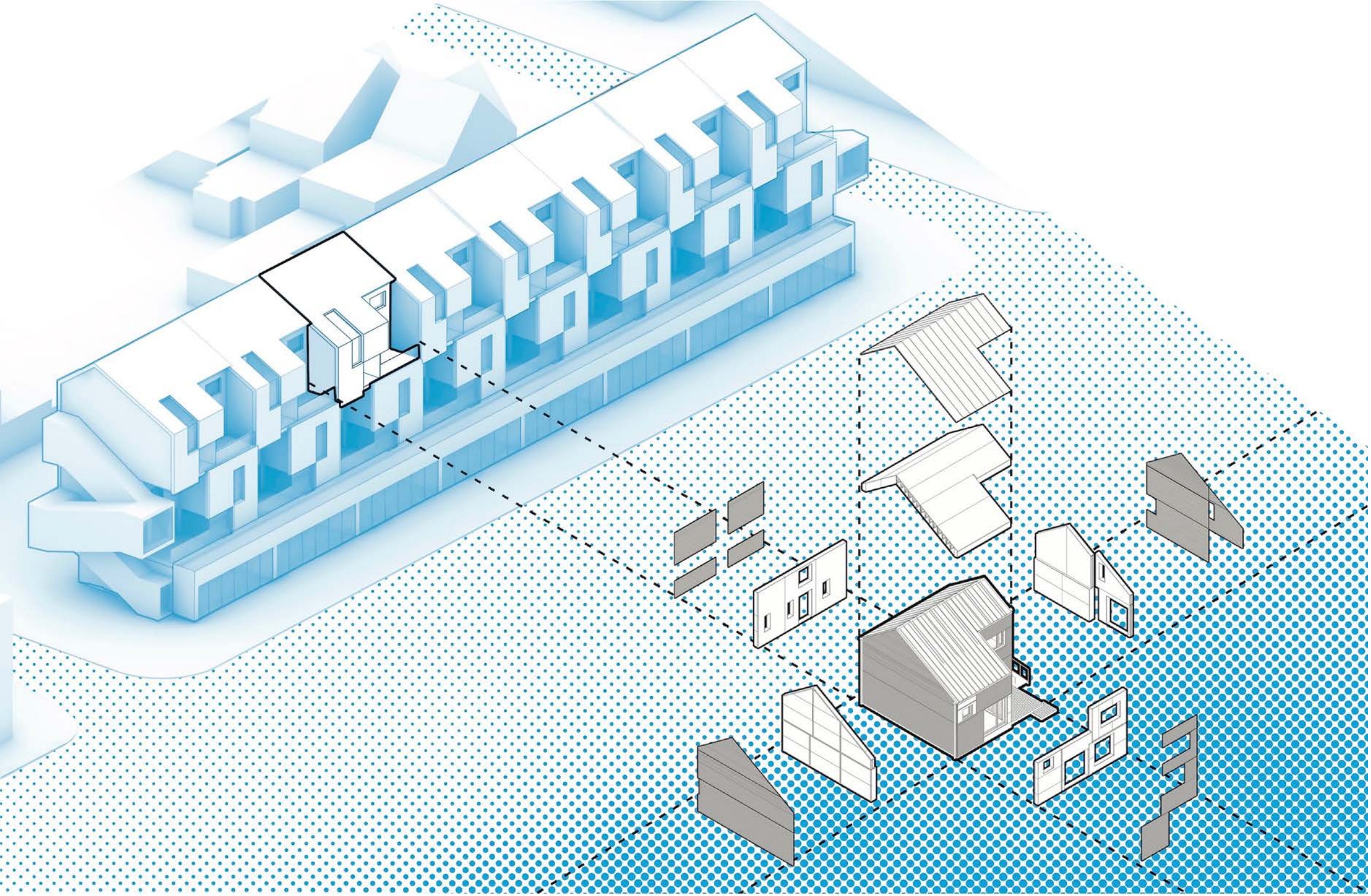
The team had some simple but important goals for the project: net zero energy, net zero (or better) carbon footprint, zero toxins or questionable chemicals and zero construction waste. In addition, we wanted it to be architecturally appealing and affordable. And completed prefabricated.

We succeeded on all of these goals, making Zero House an important demonstration of what's possible right now. We worked with many innovative suppliers who sponsored the project, and we were honoured to work with them.

The two schools worked together to bring Zero House to the EDIT exhibition in downtown Toronto in the fall of 2017, where it was seen by over 30,000 shower goers.

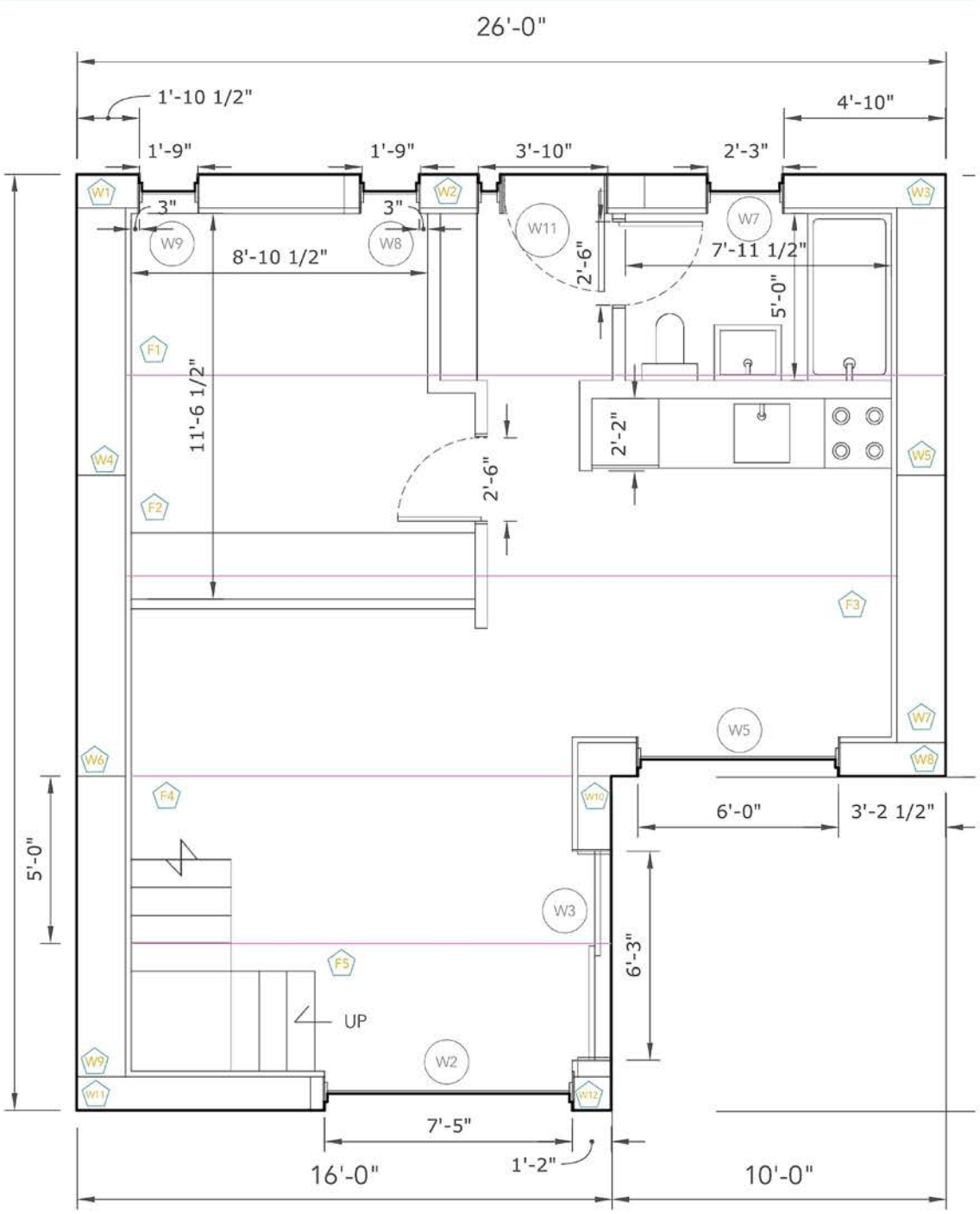
EDIT Expo at Unilever factory in downtown Toronto

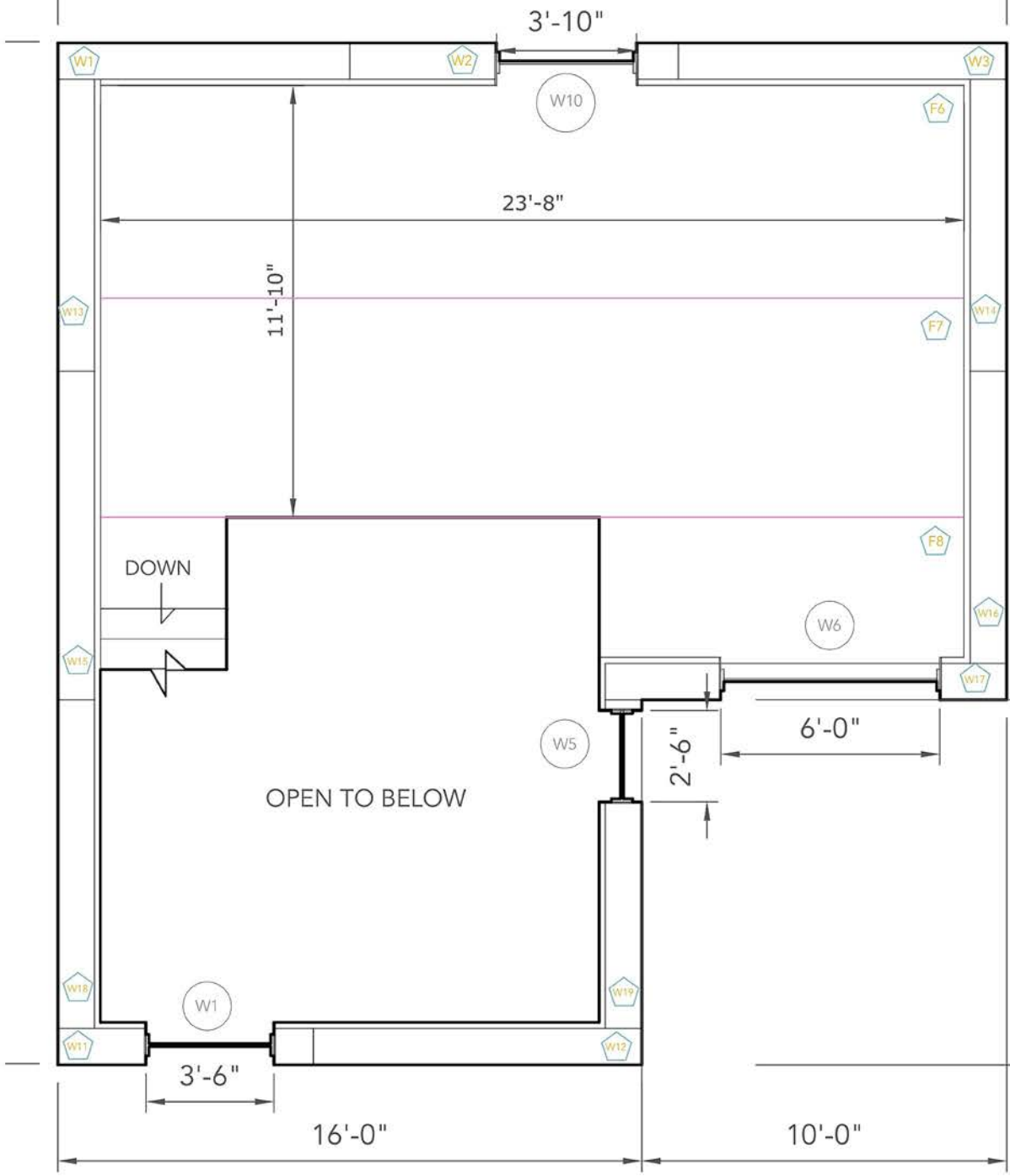
The site of the EDIT exhibition, before it was transformed into a 10-day festival of innovation (above), and with Zero House erected front and centre to greet show-goers.



One piece of a larger design

Zero House was built as a small, single family dwelling (1,100 square feet). But the design team sees Zero House as one unit in a stackable row house design intended to address urban rebuilding at a reasonable density.





Floor plan

The Ryerson team provided the overall design and floor plan

Criteria matrix

CRITERION	1	2	3	4
Ecosystem impacts				✓
Embodied carbon				✓
Energy efficiency				✓
Indoor environment				✓
Waste				✓
Resilience	✓			
Maintenance & durability	✓			
Code compliance			✓	
Material costs			✓	
Labour cost/sources				✓
Additional criteria….	Completely prefab, including finishes			

Defining our sustainability goals

Every project at Endeavour begins with a goal-setting exercise, and this results in a criteria matrix that defines our goals in 10 different categories.
These project parameters are then used to make decisions about materials and systems throughout the project.
We feel that having a well-defined set of goals is critical to a successful project.
Zero House had highly ambitious goals, reflecting our desire to make it an exceptional building.

Getting some early practice

Endeavour's class of 2017 started their six-month course with some learning projects, including a scale model of Zero House (above) and building a cob oven (left).

The class of 10 participants spanned a wide range of ages and backgrounds. The team coalesced quickly and put in an incredible effort to build a house, deconstruct it, rebuild it at the EDIT show, staff the show, and then dismantle the building again. About half the class stayed on to rebuild it on its final site.

Solar powered job site

The class built a solar power station on a trailer bed that powered the entire construction process for Zero House. some early hands-on experience with assembling a renewable energy system.

Making mycofoam

One of the first projects was to make some samples of mycofoam, using the Grow-It-Yourself kits from Ecovative. The mycofoam would be used as an exterior insulation sheathing on a Zero House wall.

Mycofoam samples

The mycofoam process begins with a package of chopped straw that has been inoculated with Ecovative's strain of mycelium. We add flour and water and leave it in the bag for about 5 days. Then we break up what's in the bag and put it in our forms, adding a bit more flour. The form is covered, leaving a few small air holes. In 5 more days, a remarkably rigid and durable insulation has grown. At R-4 per inch and naturally fire- and moisture-resistant, this is a material that could transform the building industry.

A “flying factory” space

Zero House needed a home-base for initial construction, and The Mount Community Centre generously allowed us to build on their front lawn. This gave us lots of space and high visibility in the middle of Peterborough.

We used a temporary “flying factory” set up in a large tent to assemble the floor, wall and roof panels for the building. The tent gave us a dry place to build and store all the panel sections.

Floor panel construction

The first prefab elements to be created were the floor panels. Using wood trusses from Peterborough Truss & Floor, we created the floor as five panels.

A strip of 1/2-inch MSL Fiberboard was used on each truss to provide a thermal break, and the floor "boxes" were clad in plywood on the top, bottom and ends (above).

The 16-inch deep trusses plus the fibreboard gave the floor assembly approximately R-60.

Making prefab elements

It was critical that all the panels for Zero House were built accurately. We used the large, stable surface of a pair of floor panels as a base on which to build all the wall panels.

Wall panel construction

ReWall (above) is a structural sheathing panel made from recycled drinking boxes. The wax-impregnated paper is shredded, heated and compressed to form the sheets, which are coated in kraft paper.

SonoClimat Eco4 fiberboard (right) is a 1-1/2-inch insulated sheathing panel rated at R-4. It provides an excellent thermal break over the framing on each panel.

Both products are affordable, non-toxic, recyclable or compostable, and store a lot of carbon.

Different panel types

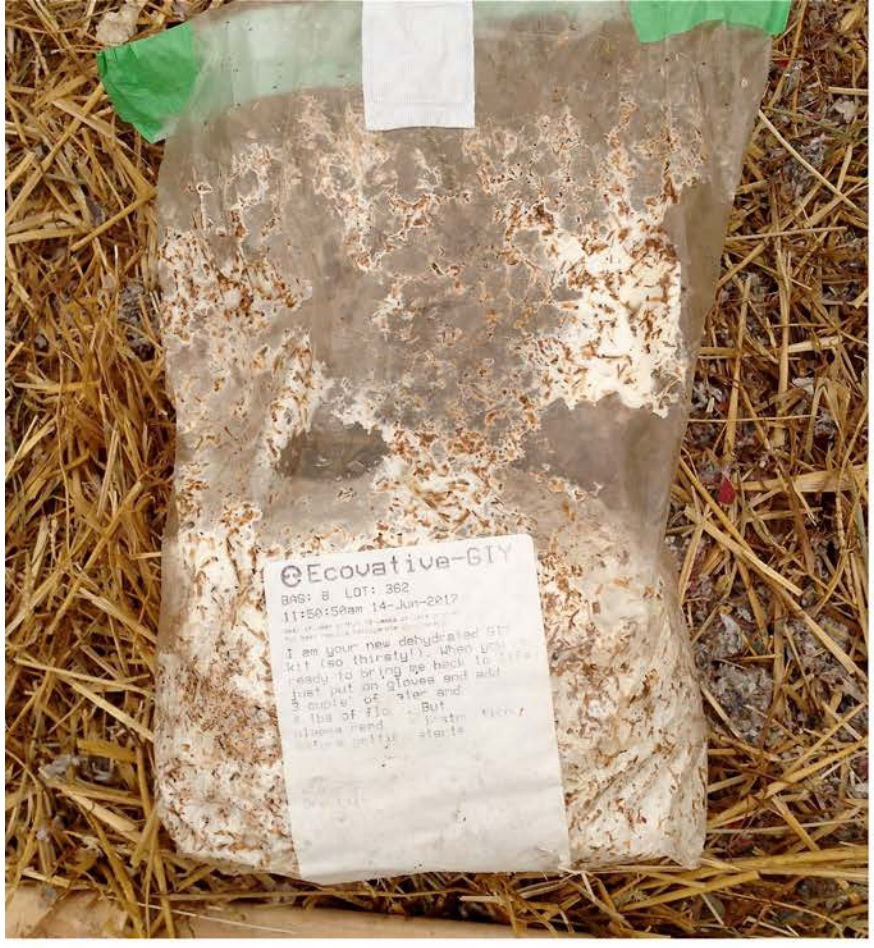
Cork sheathing from Jelinek Cork www.jelinek.com was used on two of the wall panels. These 2-inch panels provide an R-7.2 thermal break on the exterior of the building. The cork is not affected by water, is non-toxic, carbon-storing and recyclable or compostable.

Straw bale panels

The straw bale panels were our first effort at creating a version of a straw SIP that does not use a plaster finish.

Horizontal strapping is integrated into the panel, providing additional fastening for the sheathing and creating a 3/4” space that we filled with loose cellulose insulation. This insulation was compressed between the sheathing and the bales and fills in the highs and lows of the bale surface. This provides continuous insulation and prevents convection loops.

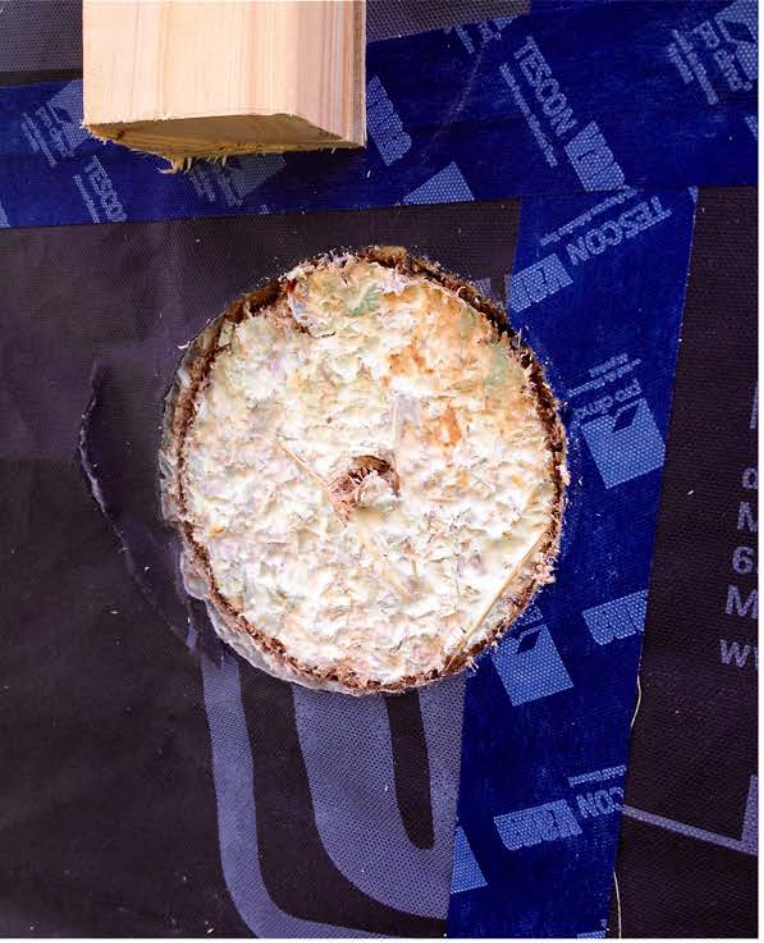
The bales are placed into the frame and tightly packed at the edges of the panel.



Growing mycofoam onto straw panels

One of the straw bale panels was "sheathed" in Mycofoam. We started the culture in the bags (top left) and then placed the material directly on the straw bales in the panel (top right), to a depth of 1-1/2 inches to match the fiberboard sheathing on the other half of the panel. In five days, we exposed the culture to the light and allowed it to dry.

The finished Mycofoam (left) had bonded well with the straw surface, and provided R-6 as a thermal break on the exterior face of the panel.



Mycofoam & straw bond

The Mycofoam panel needed a 6-inch hole cut in it for a ventilation pipe. Using a hole saw, we removed the Mycofoam from the straw. This gave us a chance to see how well the Mycofoam had bonded with the straw bale.

The Mycofoam mimicked the bond that typically exists between straw and plaster in a typical bale wall. These are two materials that work together extremely well!

Angled roof panels

Roof panels were constructed with the trusses running horizontally across the building by building parallelogram boxes. This allowed us to avoid the need for a ridge beam, greatly expediting the construction process. This format also minimizes settling of the cellulose insulation.

A temporary foundation

With all the panels constructed, we set up a temporary platform foundation for the building using steel beams. The beams mimic the location of the foundation walls on the final construction site.

Assembling the floor panels

The floor panels were moved into place manually, using rollers and the power of the whole team to move from the tent and onto the foundation beams.

The floor is ready. The five panels come together quite quickly.

Assembly day

With all the panels complete, we are ready for assembly!

Zoom boom lifting

A “Zoom-Boom” arrives to start moving the panels out of the tent and onto the floor assembly.

Each wall panel is suspended using a D-ring and GRK structural screws on the four top corners.

Wall assembly

Each of the wall panels is lifted into place with the zoom boom.

The panels are braced with temporary bracing on the interior of the building and fastened to the floor assembly and adjoining panels using GRK structural screws.

All the hard work that went into making the panels so accurately paid off with a quick and hassle-free assembly.

Final wall panel

It all fit together remarkably well, a testament to the accuracy of the plans and the work of the construction team. All the walls were assembled in a single day.

Craning the roof

A crane replaces the zoom-boom to install the roof panels. The crane was so much faster that we decided to use a crane for the full assembly on the next round.

Air control layer

As soon as the panels are assembled, we wrap the building in Mento 1000 from ProClima, supplied by 475 High Performance Building Supply www.foursevenfive.com, and tape the seams with ProClima's Vanna tape. These products are much more durable than any of the typical North American house wraps and tapes, with great performance spec's. Once wrapped, the building is rain-ready and cladding can begin.

Interior vapour control layer

Intello is a vapour control layer from ProClima, and we affixed it to the interior face of all the panels. Intello is a “smart” vapour control, able to vary its permeability depending on conditions. If it is moist behind the Intello it will “open” its pores and allow drying to occur.

The wall system for Zero House is “vapour open” or “vapour permeable,” meaning that moisture is able to dry to either side of the assembly. We like this strategy, as it offers a great deal of resilience to the building, which can recover from wetting incidents without trapping moisture that can cause mold.

Air tightness details

AFM Safecoat caulking is non-toxic and no-VOC, and is used to seal the interior strapping to the Intello layer. Taking care to seal all the penetrations in the barrier will pay off in exceptional air tightness and energy efficiency over the life of the building.

The interior strapping provides a service cavity for electrical wiring. By keeping all the wiring and boxes on the interior side of the barrier, we minimize the number of penetrations and possible leaks.

A service cavity also means that changes can be made to the wiring in the future without having to open up the wall assembly.

A non-toxic interior space

Our attempt to use only products with no Red List or even questionable chemical content was almost entirely successful. The only exception was the plywood subfloor, which has formaldehyde in the glue that binds the plies together.

We used AFM Safecoat's Safe Seal to coat the plywood in the building. The Safe Seal locks VOCs in and prevents them from off gassing into the building. It would be ideal to find a formaldehyde free plywood, but this product is a great option when VOCs can't be avoided.

FSC-certified ash flooring with a natural oil finish was applied over the sub flooring. It was an unusual step to lay the finished flooring at this early stage, but we knew there wouldn't be time at the EDIT show to lay all the flooring, so it went down at this stage.

To ensure that we could still disassemble the panels, we used a removable strip of flooring at the panel seams (above).

A plywood interior

We chose a prefinished plywood from Columbia Forest Products www.columbiaforestproducts.com as the interior wall and ceiling finish. The wood is FSC certified, and the glues and finish are both formaldehyde free. The panels are durable and able to be removed and reinstalled

Panelized interior for easy dismantling

Columbia Plywood panels are mounted with an intentional gap that reveals a galvanized metal strip. This system looks good, and gives us some "wiggle room" when the building is rebuilt.

Tadelakt plaster hightlights

A few highlight panels were finished with a polished lime plaster known as tadelakt. The plaster is polished with olive oil soap as it cures, creating a beautiful, shiny and highly water-resistant finish.

One panel in the entryway and the ceiling of the shower area are finished with tadelakt.

Ventilated rain screen

The strapping for the exterior cladding looks complicated!

First layer of strapping is vertical, and provides a ventilated channel behind the siding, and connects with the ventilation channel under the roofing.

Horizontal strapping provides a plane for the white plywood panels. Another layer of vertical strapping creates the plane for the corrugated metal panels.

Both siding types lend themselves well to our requirement for materials that can be installed, removed, shipped and re-installed again with minimal effort.

Inline windows and doors are installed with triple pane glazing and fiberglass frames.

High quality windows and doors

The performance of the Inline windows and doors helps us reach our energy efficiency target of being a net zero energy building. The window extensions allow us to place the windows in the insulation plane for best performance.

ROOF INTEGRATED PHOTOVOLTAICS

BiPVCo www.bipvco.com provided their unique adhesive Flextron photovoltaic modules. Each 120 Watt module is adhered directly to the standing seam metal roof from Havelock Metal www.havelockmetal.com.

This type of PV panel provides a simple, easy mounting system with no additional hardware or roof penetrations. It greatly reduces the cost of installation.

Open house!

Peterborough phase of construction is complete, and we invite the public to see.

The team is assembled to reflect on their remarkable achievement… the complete construction of a prefab house in less than 3-months!

The team knows the building inside-out, and are ready to take it all apart…

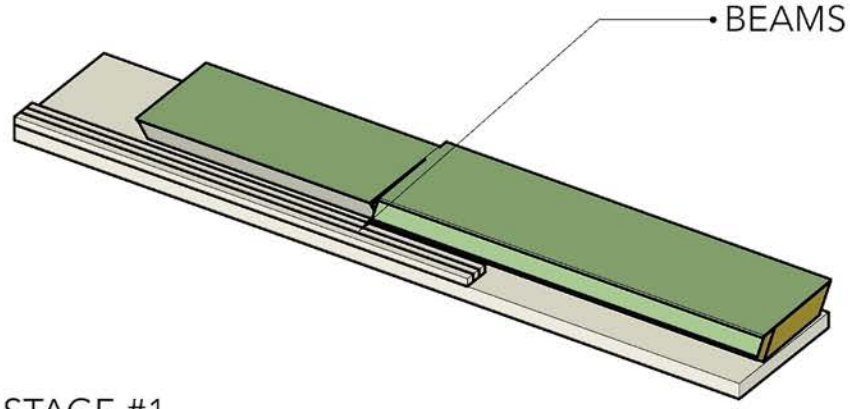
Garbage champion

The building produces just three bags - about 20 pounds - of landfill waste!

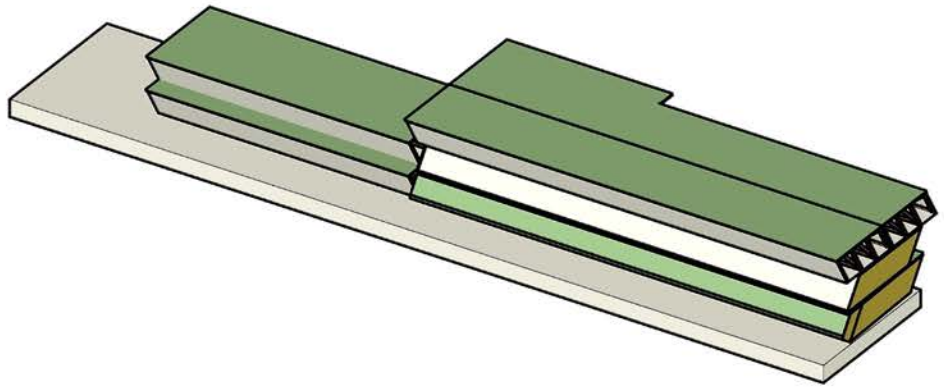
Taking it apart

Down it comes! The crane arrives to begin the disassembly process. The building's panels will fill two flatbed trucks.

TRUCK #1
LONG FLAT TRUCK



STAGE #1



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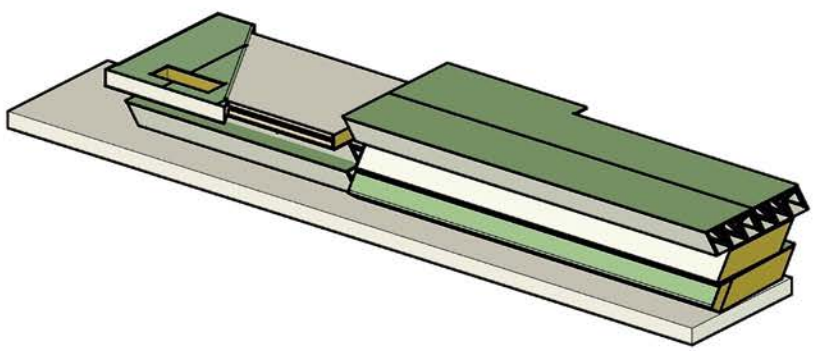
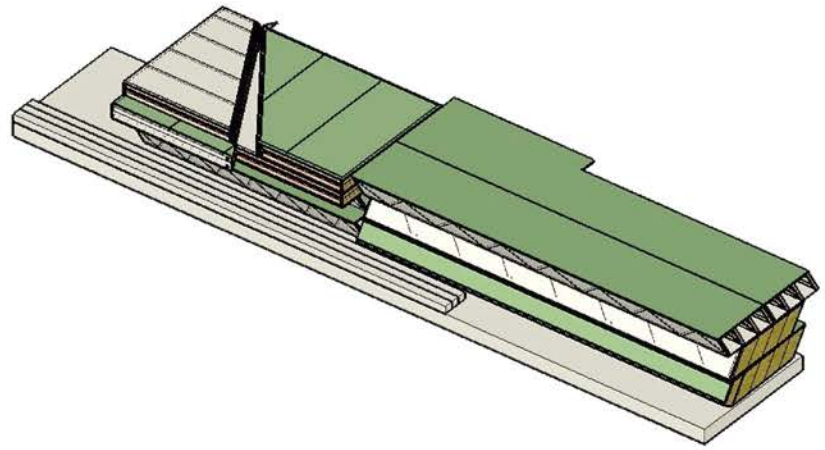


STAGE #3



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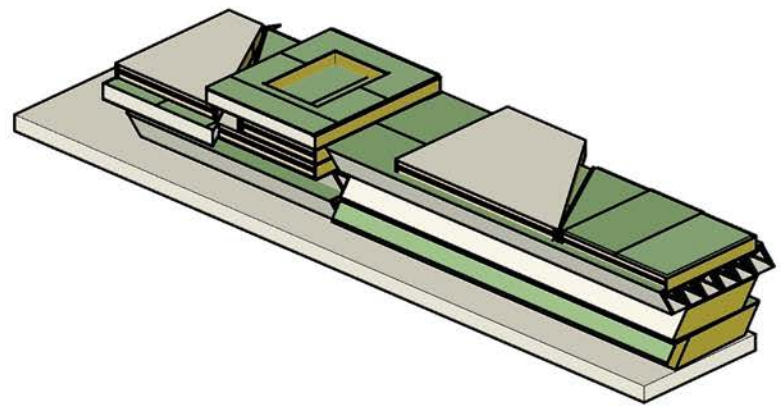


STAGE #5

Careful planning for prefab shipping

Making sure that all the panels fit onto the trucks and are in the right order for reassembling the building takes a lot of planning!

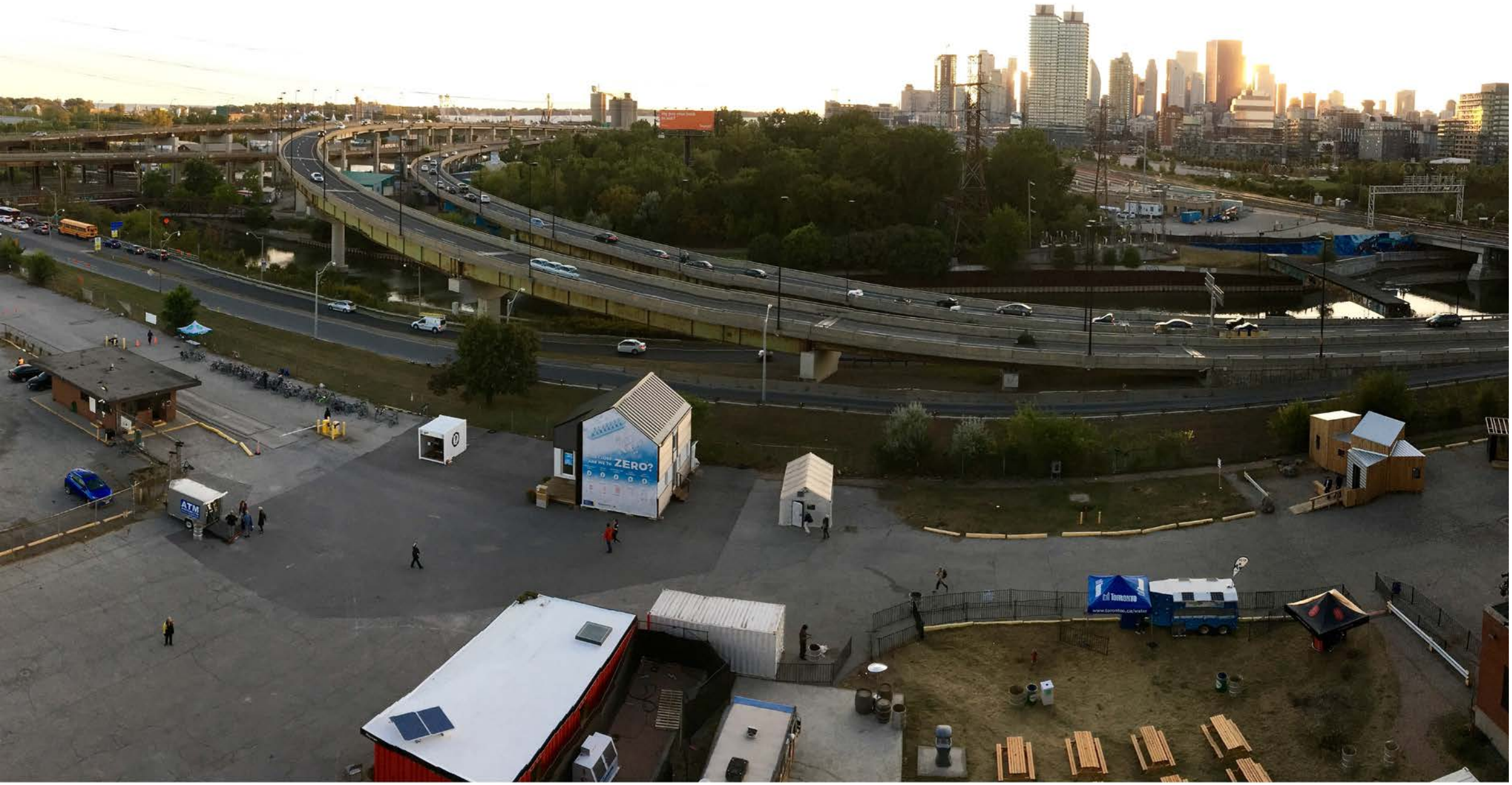
Toronto assembly

The EDIT show is in downtown Toronto, right at the base of the Don Valley Parkway.

The trucks are unloaded and the panels re-assembled in just one day.

A good fit the second time!

We weren't sure that the panels would fit back together as accurately the second time, but were pleasantly surprised at how well it all went together.



Ready for the public!

It’s only six days from the time the trucks rolled on the EDIT site until the building is assembled and largely finished.

A deck and signage

A deck is built, using thermally modified ash from Cherry Forest Products www.thermallymodifiedwood.com. This heat-treated wood becomes very stable and rot-resistant, as well as taking on a beautiful colour. Thermally treated wood avoids any kind of chemical treatment and in keeping with our non-toxic goals.

A building-sized sign informs show attendees of our sustainability targets and how we measured up.

ZERO HOUSE TO ZERO HOUSING

BY RYERSON UNIVERSITY + ENDEAVOUR CENTRE PETERBOROUGH

Toronto, Canada

ryerson.ca

endeavourcentre.org

ØA

How do we scale-up solar-powered, single family–oriented Passive House design to address the lack of urban housing alternatives? There is emerging demand for the "Missing Middle" in live-work urban housing as a substitute for high-cost, high carbon–footprint, high-rise condo towers. Can we intensify existing low-rise urban neighbourhoods with high performance, zero carbon footprint stacked townhousing? This one-to-one scale model demonstrates Net Zero Energy (NZE) performance using an air-tight and highly insulated enclosure and state of the art passive and active systems, including building integrated photo-voltaics (BIPV) for facades and roofs. Its all-natural and/or recycled material palette sequesters carbon. Using custom

Show ready…

Interpretive signage was important to the Zero House message at the EDIT show. The sustainable features of the home don't necessarily call attention to themselves, so we tried to make sure that people could understand what was so special about the house.

Showing off our sponsors' products

The upstairs of Zero House is used to display the materials we used to achieve our goals. Attendees at EDIT can find out all about how to meet our Zero House goals using materials that are currently available on the market.

Our sponsors

We appreciated the generosity of all our Zero House sponsors, and were proud to share their products with the 30,000 people who attended the EDIT expo over the 10 day run of the show.

With the EDIT show over, it's time for Zero House to be taken apart again…

A permanent home…

At the building's final site, a Nexcem foundation with a crawl space is prepared to receive the Zero House panels.

Dense packing cellulose insulation

The cellulose insulation from Applegate was added into the floor, roof and the non-straw bale wall panels.

The roof received R-70, the floor R-60 and the walls R-40. As soon as the cellulose was added, the house was warm despite the frigid temperatures.

Sheep's wool insulation is stuffed into the gaps around windows and doors.

Blower door test

An important part of our energy efficiency strategy was to make the building as air tight as possible.

A blower door test after assembly showed that we were at 1.05 air exchanges per hour at a 50 Pascal pressure difference between inside and outside (ACH50), far beyond what our codes require and approaching the value of 0.6 ACH50 required for Passive House certification.

We were proud of this achievement, especially considering all of the assembly and disassembly the panels had experienced.

Daikin air source heat pump

Daikin provided an air source heat pump, a highly efficient way to provide both heating and cooling for Zero House. The heat pump provides an average of 2.5 units of heat for every unit of electricity used to power it. The PV system on the roof will generate as much electricity over the year as is used for heating and cooling the building. The tempered air is delivered via two wall mounted units in the house, one upstairs and one down. Each works on its own remote control and provides quiet, effective temperature control.

Lunos ventilation system

The ventilation for Zero House is provided by two pairs of Lunos www.lunoscanada.com ductless energy recovery ventilators (ERVs). These simple, effective units bring air into the building through a ceramic core. Each pair cycles so that one unit is exhausting air while the other is drawing in fresh air. The exhaust unit is transferring heat and moisture to the ceramic core, then when the pair reverse direction, the outdoor air is warmed as it comes through the ceramic core. Heat exchange averages over 90%.

Grid tied photovoltaics

The PV modules are run through a Fronius Primo inverter www.fronius.com/en, converting the direct current electricity from the PV modules to alternating current to be sent to the local utility grid.

The building was among the last in Ontario to receive a MicroFIT contract, under which the home owner is paid for all the power the PV modules generate.

The 30 BiPVCo modules have a peak output of 3.6 kilowatts. Under sunny conditions the actual output averages between 3-3.3 kW.

Grid tie gear

The setup for a grid-tied PV system requires a double meter base, DC and AC disconnects and the inverter. One meter records all outgoing electricity, the other records all incoming power. The owner receives a cheque for the first and a bill for the other.

On demand hot water

Hot water is provided by a tankless, electric unit from EcoSmart. This is a 24 kW unit, capable of bringing cold well water up to 115-125F as it passes through the unit. While conventional tank heaters lose a fair bit of heat while keeping water hot during idle times, the tankless unit only uses power when required.

Nearing completion

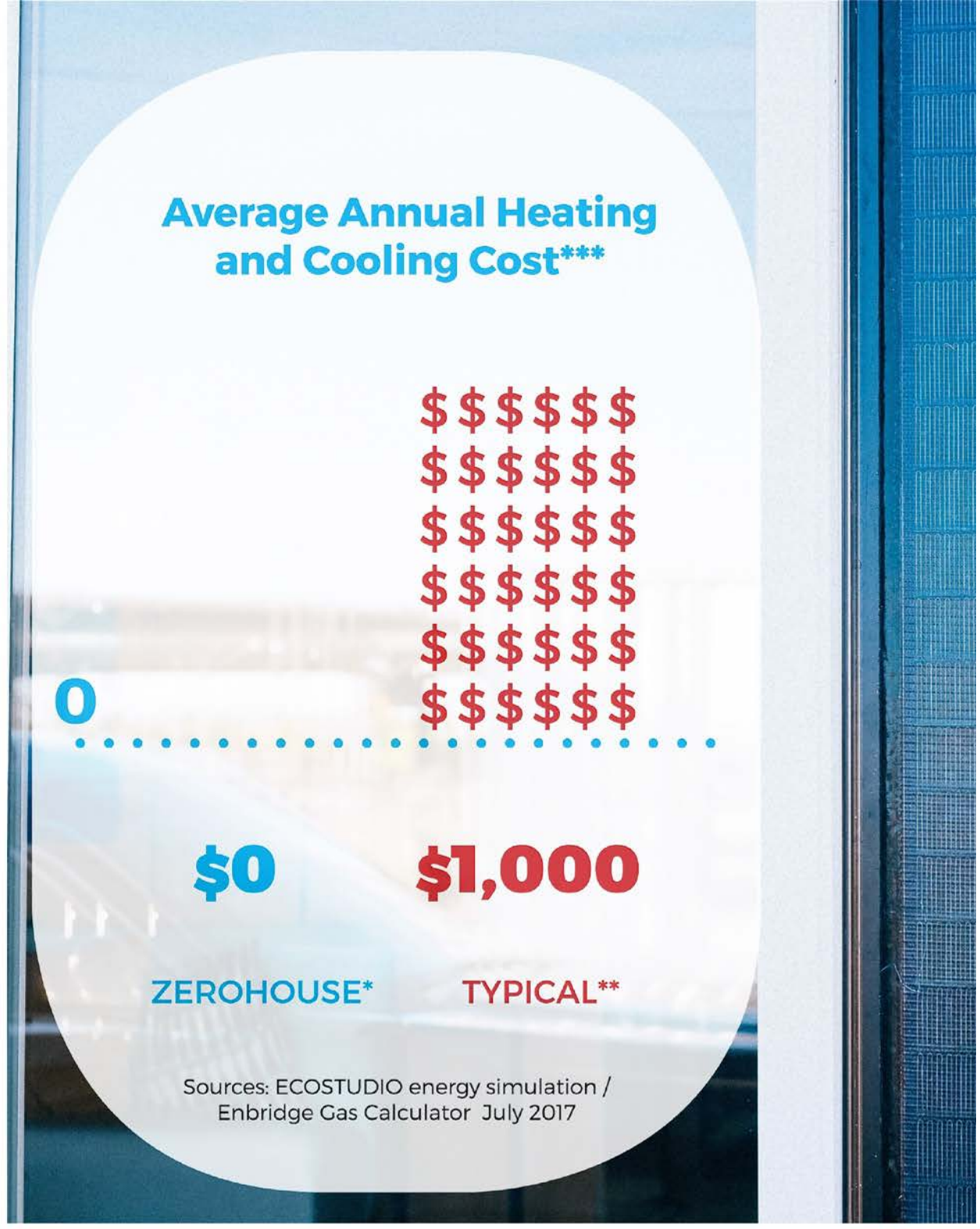
Wood dominates the interior finish, with Columbia Plywood walls and ceiling and Nadurra ash floor.

The open spaces and vaulted ceiling create a sense of space much greater than the home's small footprint.

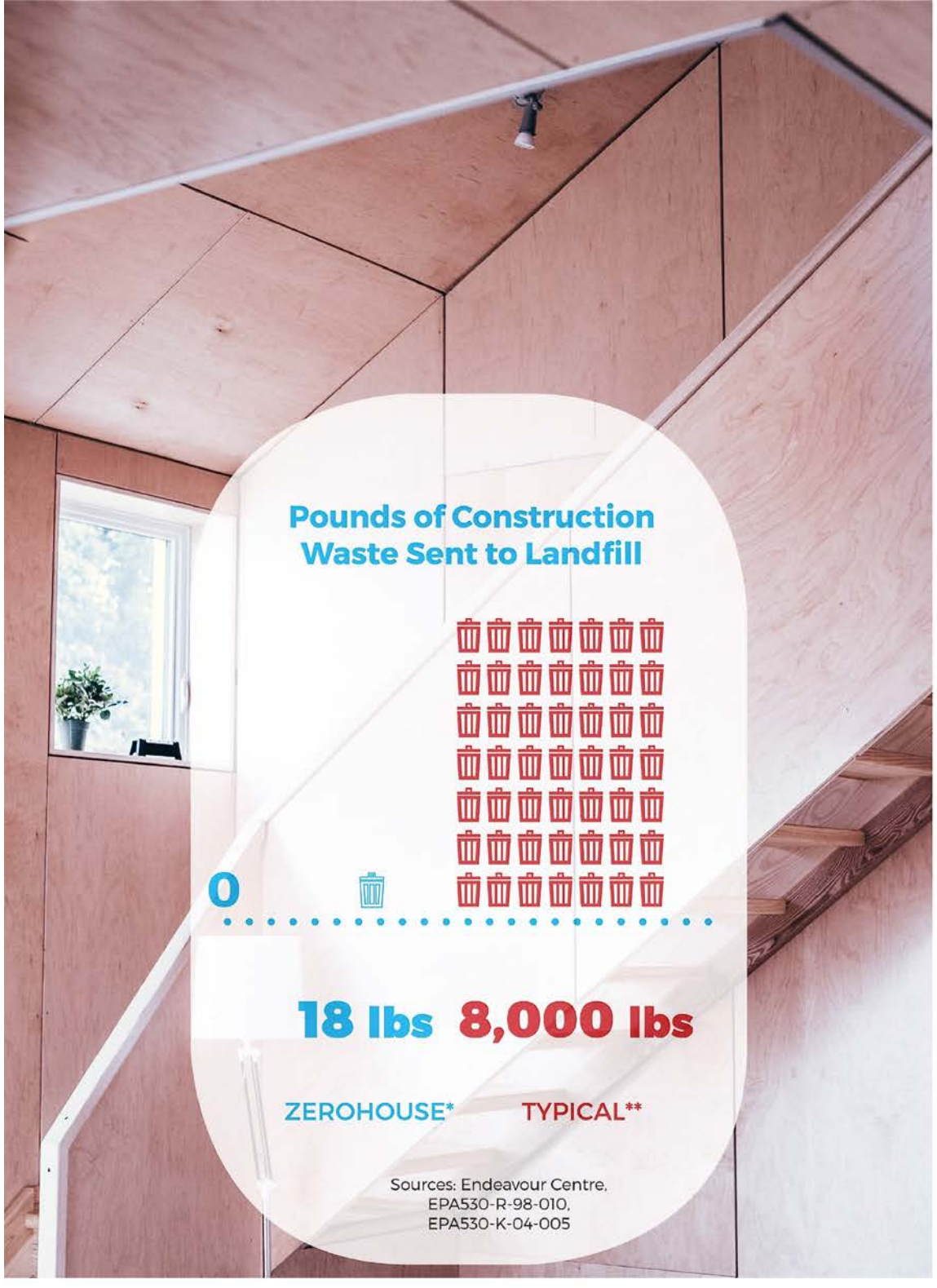
Finishing touches

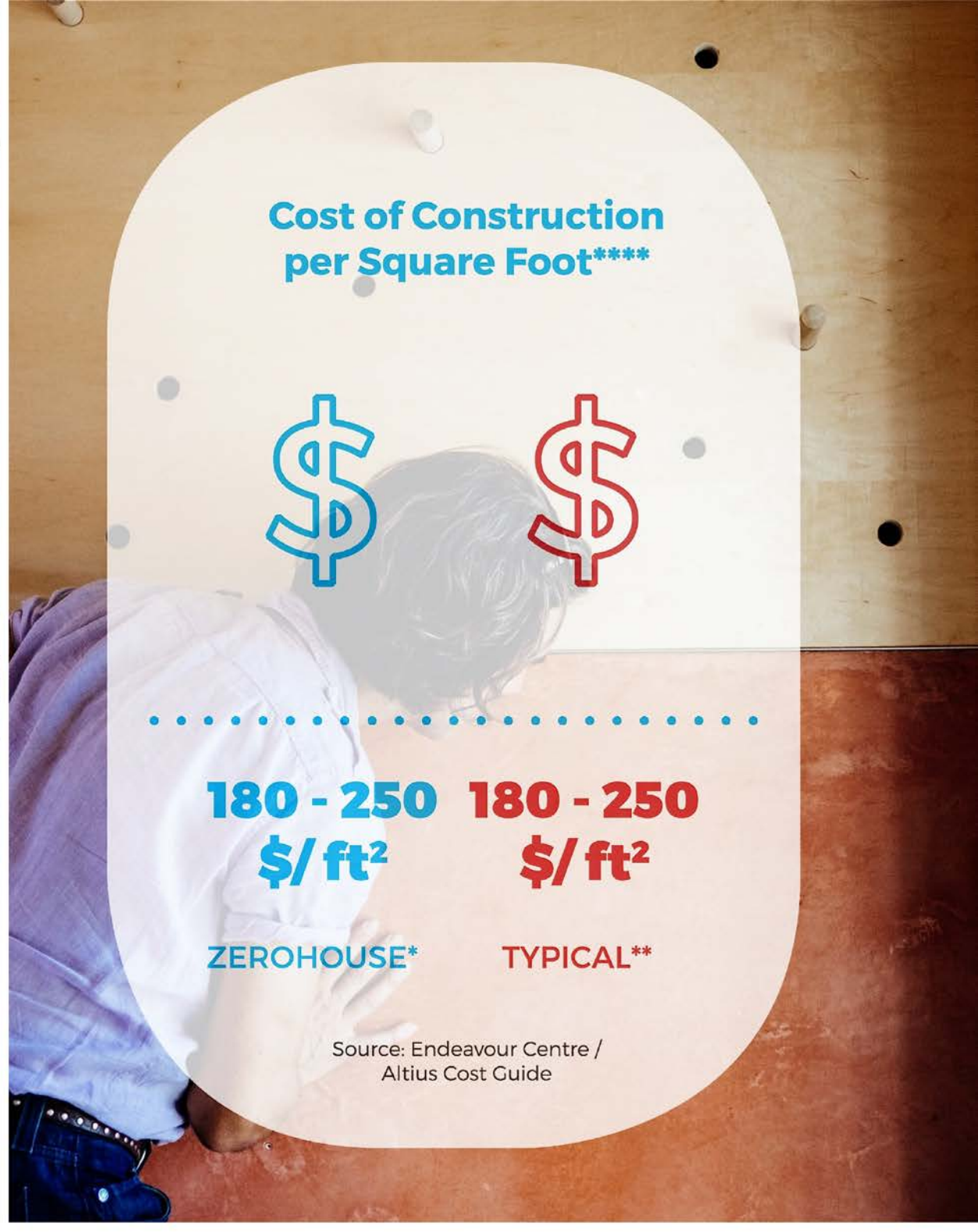
Tadelakt panels in the entryway (left) and shower ceiling (right) break up the wood. Cork flooring from Duro Designs www.duro-design.com is non-toxic and carbon-storing.


BOSCH

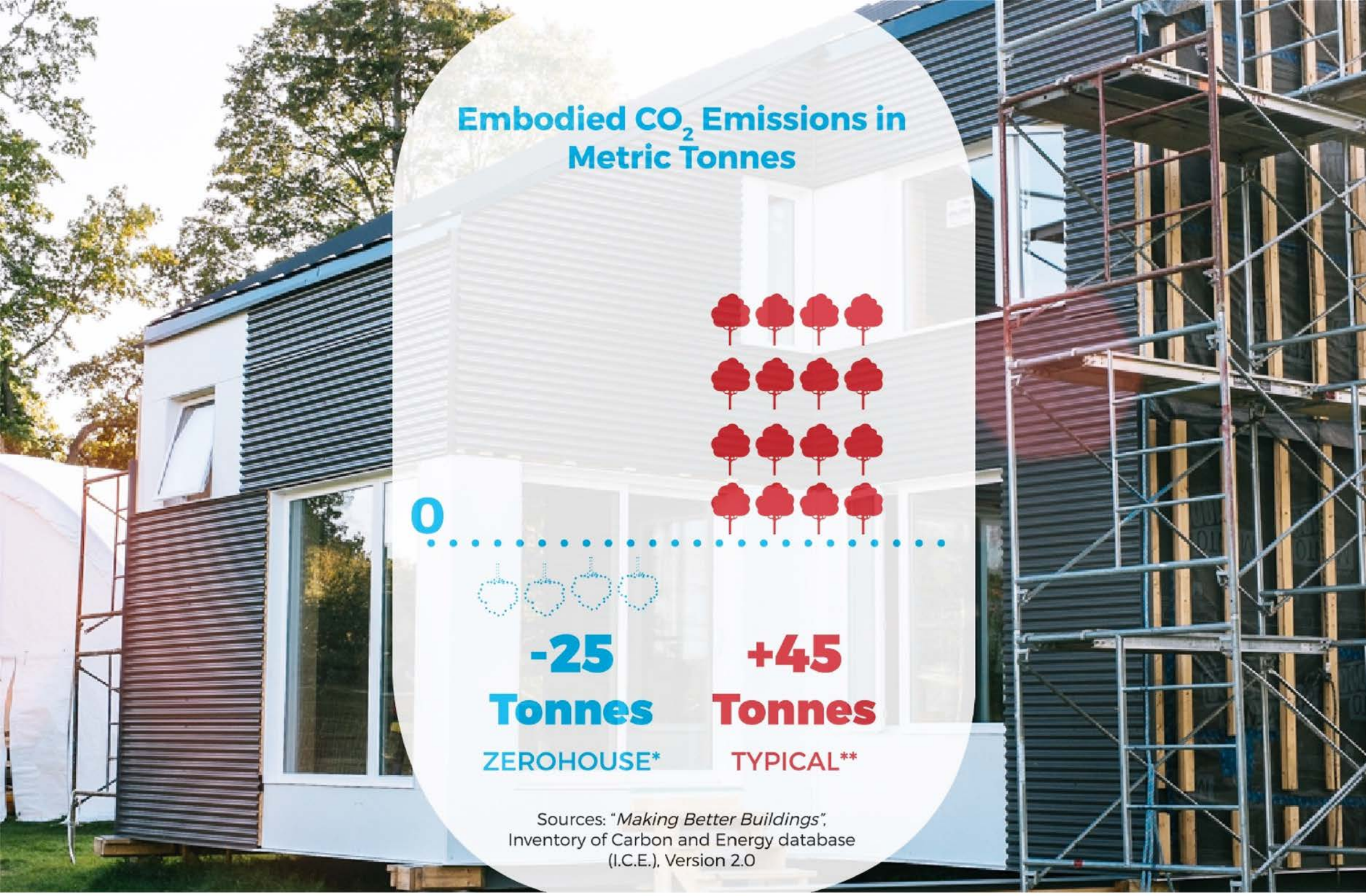


We carefully measured and vetted all our initial goals for the project, and were proud to have met all of them. No emitting materials were used inside the building, and our energy model predicted zero costs for the homeowner.





We sent a tiny fraction of the waste that is typical for residential construction to the landfill, and we managed to build the project for a very reasonable cost.



A climate change draw-down

Perhaps most exciting of our achievements was creating a building that has a net carbon-storage of nearly 25 tonnes, rather than the emissions of 45 tonnes associated with conventional construction.

Endeavour is proud of the achievements we made with the Zero House project.

We were able to demonstrate how it is possible to meet the highest possible goals for human health and environmental performance without incurring a cost penalty.

The prefabricated panels allowed us to use very affordable structural materials and reduce labour costs. This, in turn, allowed us to use some more costly non-toxic finishes.

Zero House

ENDEAVOUR
novative learning, building & living

ECOSTUDIO

he Zero House innovative green building project is based on three mple concepts:

ERO NET ENERGY USE
ERO CARBON FOOTPRINT
ERO TOXINS

his joint project between **The Endeavour Centre** and **Ryerson's ECOSTUDIO** is being ilt for display at the EDITdx Expo for Design, Innovation and Technology in Toronto this ll, where show goers will be able to visit the home, meet the designers and builders and perience the Zero House innovative green building project for themselves.

Climate Defender Sponsors

applegate insulation
ReWall
GRK FASTENERS
The MOUNT COMMUNITY CENTRE
Merrett Home hardware building centre
HAVELOCK METAL ROOFING & SIDING
HANES COMPANIES
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FLEXTRON Flexible Photovoltaic Roofing Solution

BiPVco

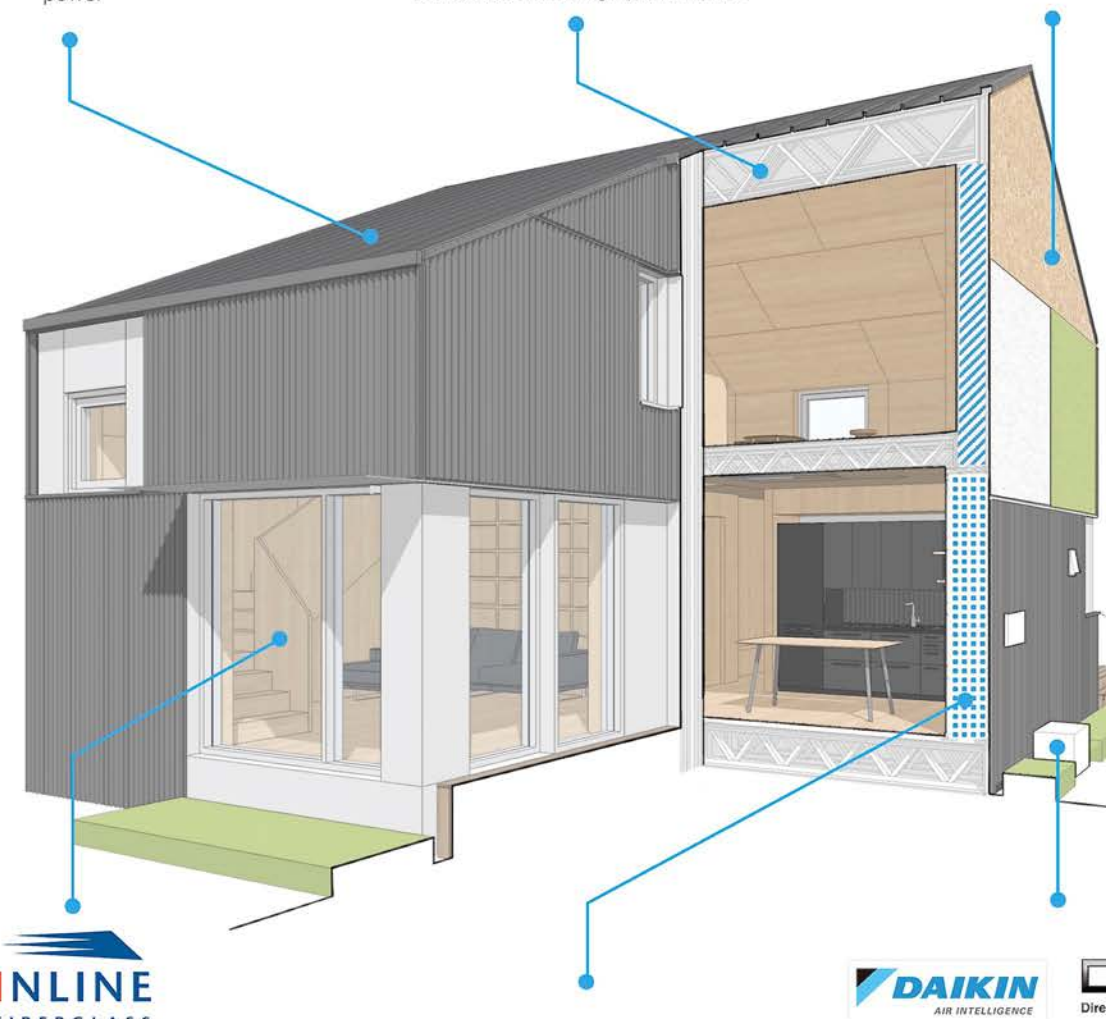
Flextron building integrated photovoltaic modules provides 3,840 watts of solar power

Highly Insulated and Modular

The R60 insulated roof and floor assemblies as well as the walls are designed for ease of construction and high performance

Wood Fibreboard, Mycofoam, Co

All-organic insulated sheathing options whic eliminate thermal bridges with zero-toxins.



INLINE FIBERGLASS

Inline Windows

Fiberglass framed, triple pane windows and exterior doors provides energy efficiency

Straw Bale Insulation

Efficient, Non-Toxic, and sustainable.

DAIKIN AIR INTELLIGENCE
DXS Direct Expansion Solutions

Daikin | DXS

Mini-split air source heat pump provides high efficiency heating & cooling

Zero House wouldn't have been possible without the participation of all our sponsors. These are companies that share our goals of energy efficiency, carbon reductions and non-toxicity. All the materials needed to make Zero House are available now!

www.endeavourcentre.org

Find out more about our sponsors:

Climate Champion Sponsors:
Inline windows www.inlinefiberglass.com, BiPVCo solar panels bipvco.com, Daikin heat pump www.daikincomfort.com, ProClima air tightness system www.foursevenfive.com

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