BUILDERS FOR CLIMATE ACTION

Low-Rise Buildings as a **Climate Change Solution**

2019

EXECUTIVE SUMMARY

WHY

- Buildings are a leading contributor to greenhouse gas emissions, and no climate action plan can succeed without adequately addressing this key sector
- The response to building-related emissions has been to focus solely on energy efficiency, but this may result in initiatives and policies that will raise emissions rather than lower them
- We can feasibly and affordably capture and store vast amounts of carbon in buildings, transforming the sector from a major emitter to a major carbon sink

Buildings contribute to climate change in three distinct ways:

1. **Up-front embodied carbon:** the emissions arising from the harvesting, manufacturing and transportation of building materials
2. **Energy efficiency:** the amount of energy consumed by buildings expressed as energy use intensity or EUI
3. **Fuel source emissions:** the emissions profile of the fuel used to heat, cool and power appliances in buildings

All three factors must be considered in order to address emissions from the building sector.

HOW

- Two sample buildings are modeled with a wide array of conventional and alternative building materials to determine the GHG impact on “up-front” embodied carbon emissions
- The sample buildings are modeled at two levels of energy efficiency using two different fuel sources to determine effects on operational emissions
- Results from embodied and operational emissions are combined to determine best practice to reduce or eliminate building emissions between 2020 and 2050
- Up-front embodied carbon, fuel source emissions and energy efficiency measures are ranked by their impact on overall carbon footprint

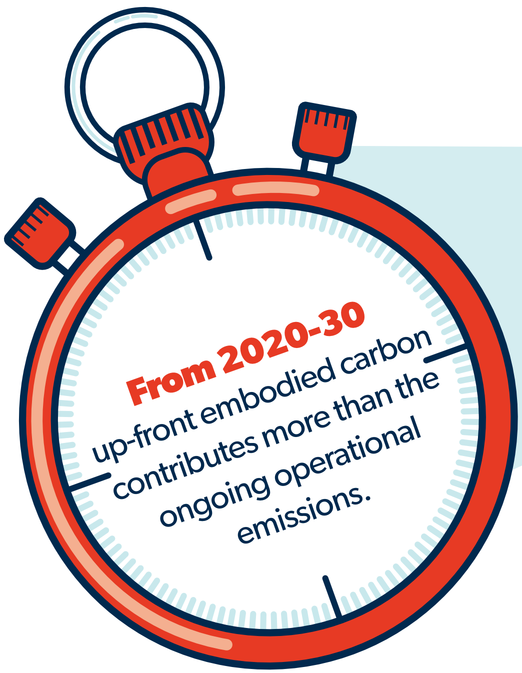
What We Found

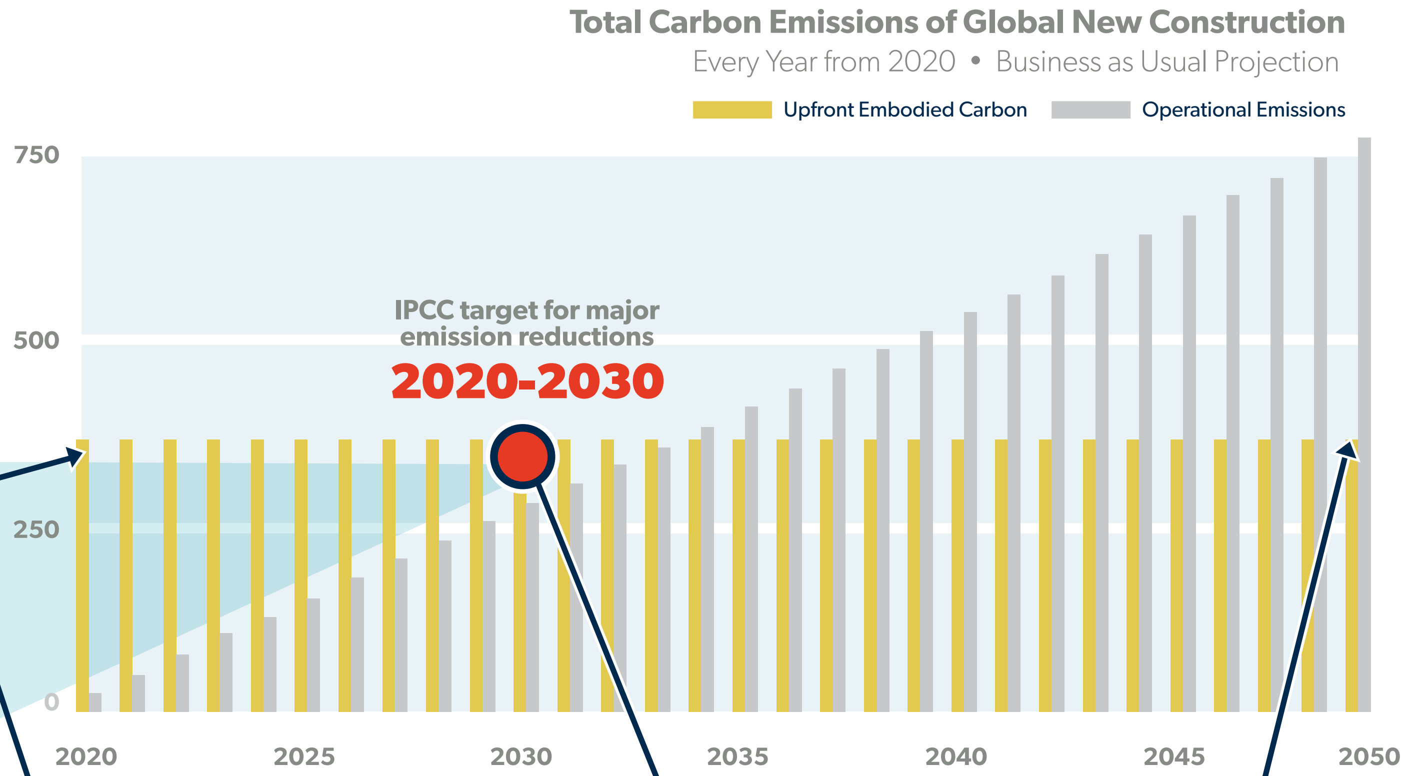
WHAT WE FOUND	SO WHAT	NOW WHAT
Typical low rise buildings have high up-front embodied carbon emissions, ranging from 90-420 $kgCO_2e$ per square meter of building area	Up-front embodied emissions are a much larger issue than previously considered, and must be reduced to address overall sector emissions	Up-front embodied emissions for buildings materials must be measured and policies enforcing caps developed for fast reductions
Available, affordable material options can reduce net up-front carbon to zero, eliminating this large source of emissions	Zero up-front emissions is a realistic option for the sector requiring no changes in codes or construction methodology and creating vast emission reductions across the sector	Building sector leaders should be ambitiously move to make buildings with zero up-front emissions.
Feasible, affordable material options can be used to achieve net carbon storage in buildings, with up to 170 $kgCO_2e/m^2$ of net storage demonstrated	Carbon-storing buildings are an exciting and practical way to transform buildings from a leading driver of climate change to a leading means of CO_2 drawdown	Opportunities to develop building materials from widely available agricultural residues, waste fibers and forestry by-products should be actively encouraged
Fuel switching to clean, renewable electricity provides the largest overall emission reductions, with annual savings of 70-75% compared to natural gas	The most meaningful investments in emission reductions are at the grid level, where clean energy will greatly reduce the carbon footprint of buildings	Clean energy is critical for the building sector to meaningfully reduce its carbon footprint and policy efforts must be focused on this goal
Material selection is the most impactful intervention at the individual building level, with reductions of up-front emissions of 150%	Designers and builders can completely transform the carbon footprint of their buildings through carbon-smart material choices	Collective action is required to understand and promote carbon-smart material choice
Energy efficiency beyond current code minimum in Ontario is the least effective and most costly means of reducing building emissions	Net zero energy building codes will not adequately address emissions from the building sector within a meaningful time frame	Policy makers and regulators must aim for true net zero carbon buildings, not net zero energy buildings

Time is a Critical Factor

TIME is a critical factor

Emissions averted today contribute more to slowing climate change than emissions averted in the future





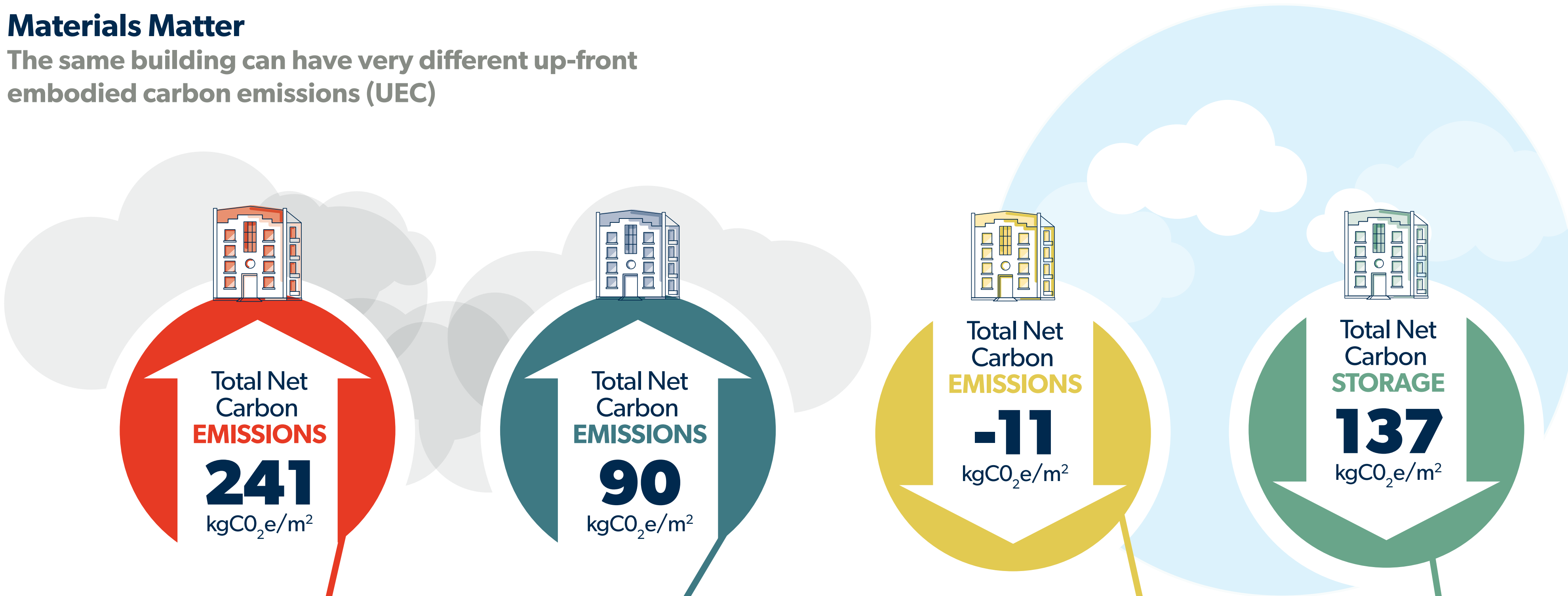
DAY 1
A building will have emitted 100% of its embodied carbon the day it is built

TODAY to 2030
Embodied carbon is the largest contributor of GHGs

BY 2050
Embodied carbon can still be the majority of emissions

Materials Matter

The same building can have very different up-front embodied carbon emissions (UEC)



High UEC

Assembly includes:

- High carbon concrete
- XPS & closed cell spray foam
- Brick cladding
- Steel interior framing
- Drywall
- Vinyl windows
- Tile & carpet flooring
- Clay tile roofing

Typical UEC

Assembly includes:

- Average carbon concrete
- Mineral wool insulation
- Fiber cement cladding
- Wood & TJI interior framing
- Drywall
- Vinyl windows
- Engineered wood & vinyl flooring
- Asphalt shingle roofing

Best Conventional UEC

Assembly includes:

- High SCM concrete
- Cellulose & wood fiberboard insulation
- Wood cladding
- Wood interior framing
- Drywall & wood walls
- Aluminum clad wood windows
- Engineered wood & FSC hardwood flooring
- Steel roofing

Best UEC

Assembly includes:

- Iso-Span ICF with high SCM concrete
- Expanded glass sub-grade insulation
- Straw & wood fiberboard insulation
- Wood cladding
- Compressed straw panel interior walls
- ReWall interior cladding
- Wood windows
- Linoleum & FSC softwood flooring
- Cedar shake roofing

This result indicates a whole new paradigm: buildings with net carbon storage. **Drawdown buildings can radically alter the carbon footprint of the low-rise building sector.**

Total Net Carbon
STORAGE
137
kgC0$_2$e/m^2

Total Net Carbon
EMISSIONS
241
kgC0$_2$e/m^2

This result indicates the seriousness of up-front carbon emissions from low-rise buildings. **At these rates of emissions, buildings cannot be part of a climate change solution.**

What This Means at Scale

CARBON
EMMITTING
BUILDING

Avg of
225 $kgCO_2e/m^2$
emissions

+ Adding emission equivalent of
15 coal plants

=

54 million tonnes
of carbon **emissions**

Total 2017 U.S.
Low-rise Construction:
241 million m^2 of new low-rise residential construction*

Business-as-usual will result in massive annual up-front emissions.

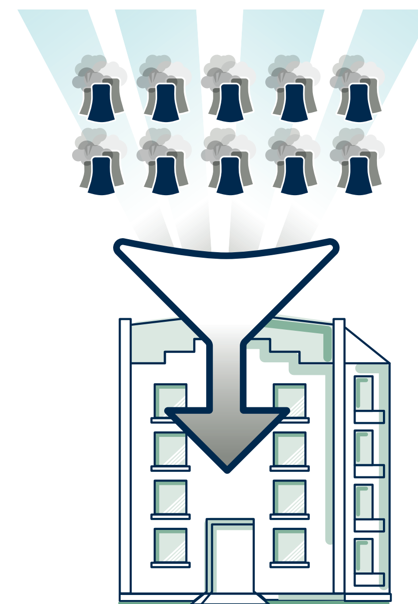
Carbon-storing buildings eliminate all up-front emissions and can result in meaningful carbon drawdown.

**U.S. Census Bureau/U.S. HUD, CB19-21*

36 million tonnes
of carbon **storage**

=

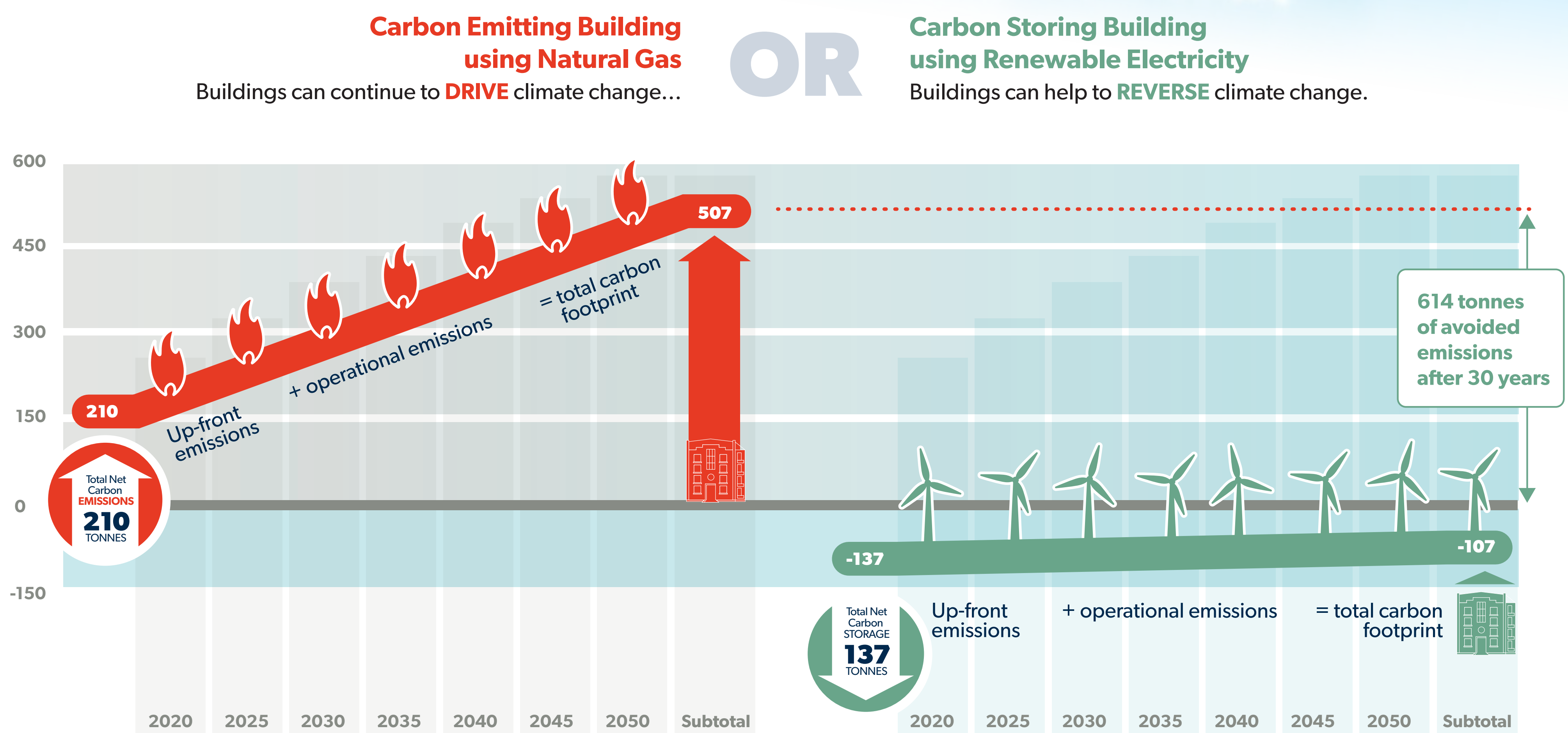
- Removing emission equivalent of
10 coal plants



CARBON
STORING
BUILDING

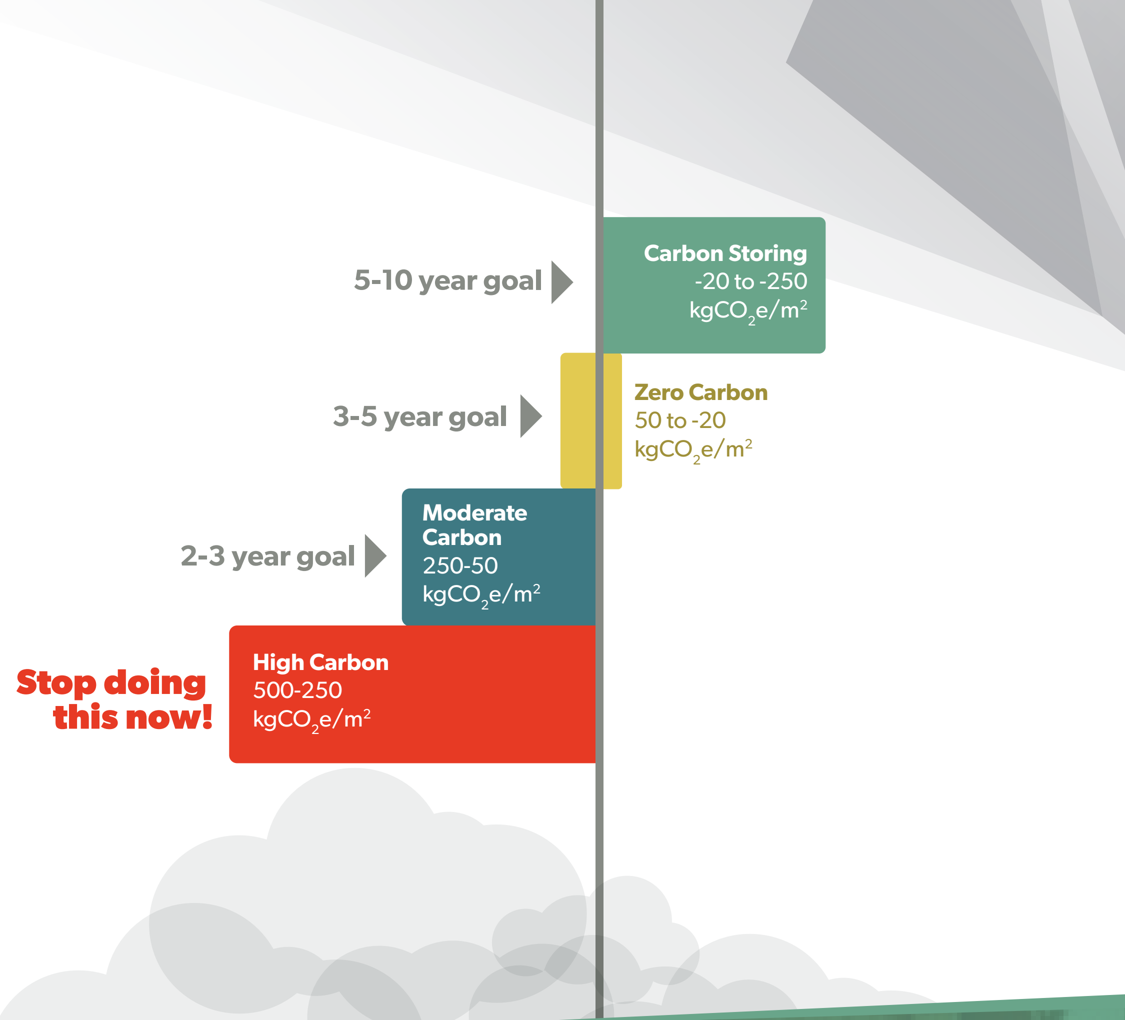
Avg of
150 $kgCO_2e/m^2$
net storage

Combining Up-front and Operational Emissions



A Clear Pathway to Zero Carbon or Carbon Storing Buildings

We can set realistic thresholds for combined up-front and operational emissions - **carbon use intensity** - to steer the low-rise building sector in a climate positive direction that is measurable and achievable.



KEY CONSIDERATIONS

Carbon Use Intensity

We should be examining all three aspects of GHG emissions from the low-rise building sector:

Up-front embodied carbon emissions

the emissions arising from the harvesting, manufacturing and transportation of materials

\+

Operational carbon emissions

Energy efficiency/Energy use intensity
the amount of energy consumed by buildings

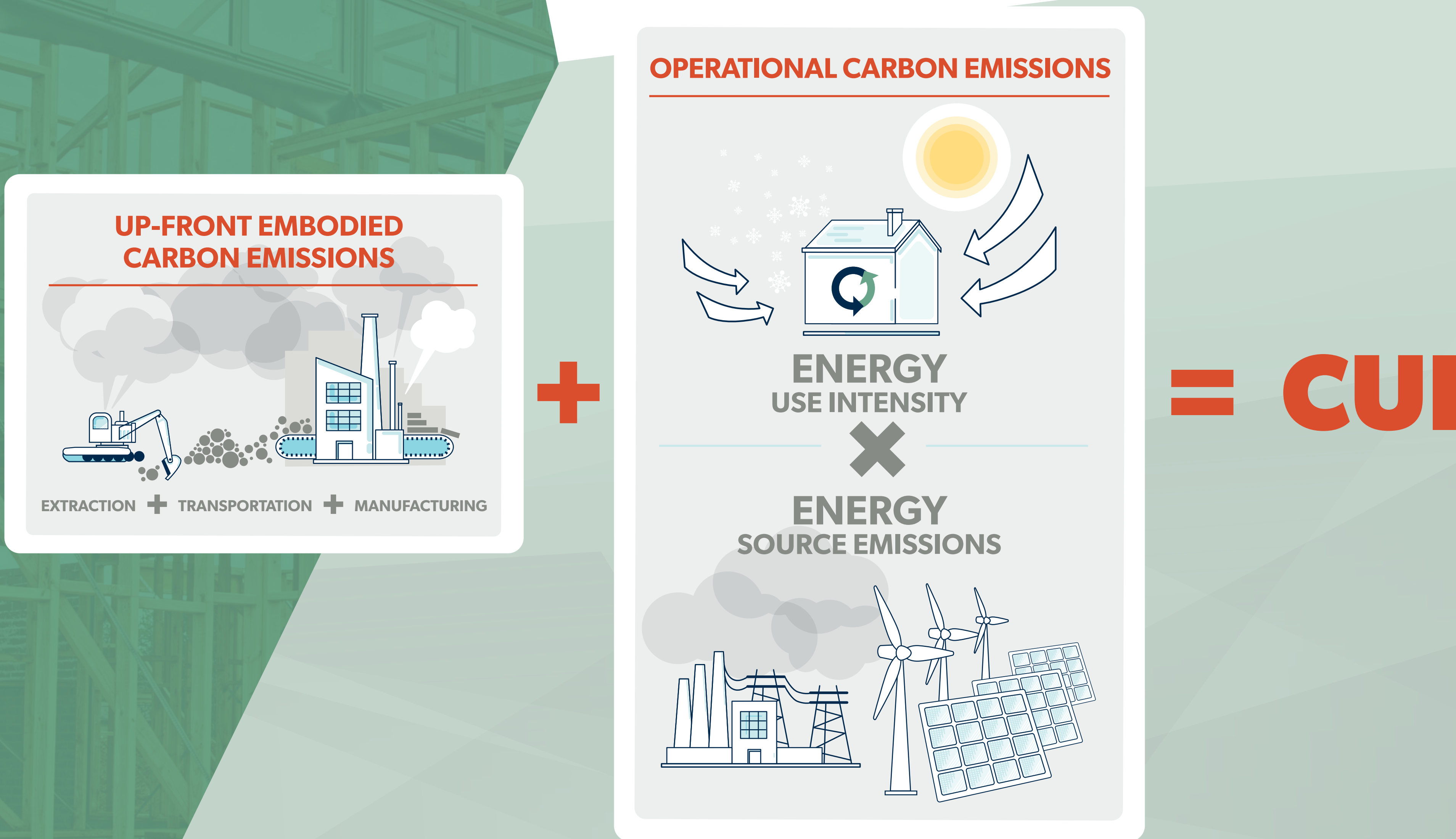
×

Energy source emissions
the emissions profile of the fuel used to power buildings

= **Carbon Use Intensity (CUI)**

Only by considering all three emission factors can we design truly “zero carbon” buildings. Ignoring any one of these aspects of building emissions raises the possibility that our efforts are, at best, incomplete and at worst, counterproductive.

A zero carbon building needs to have a CUI of zero.

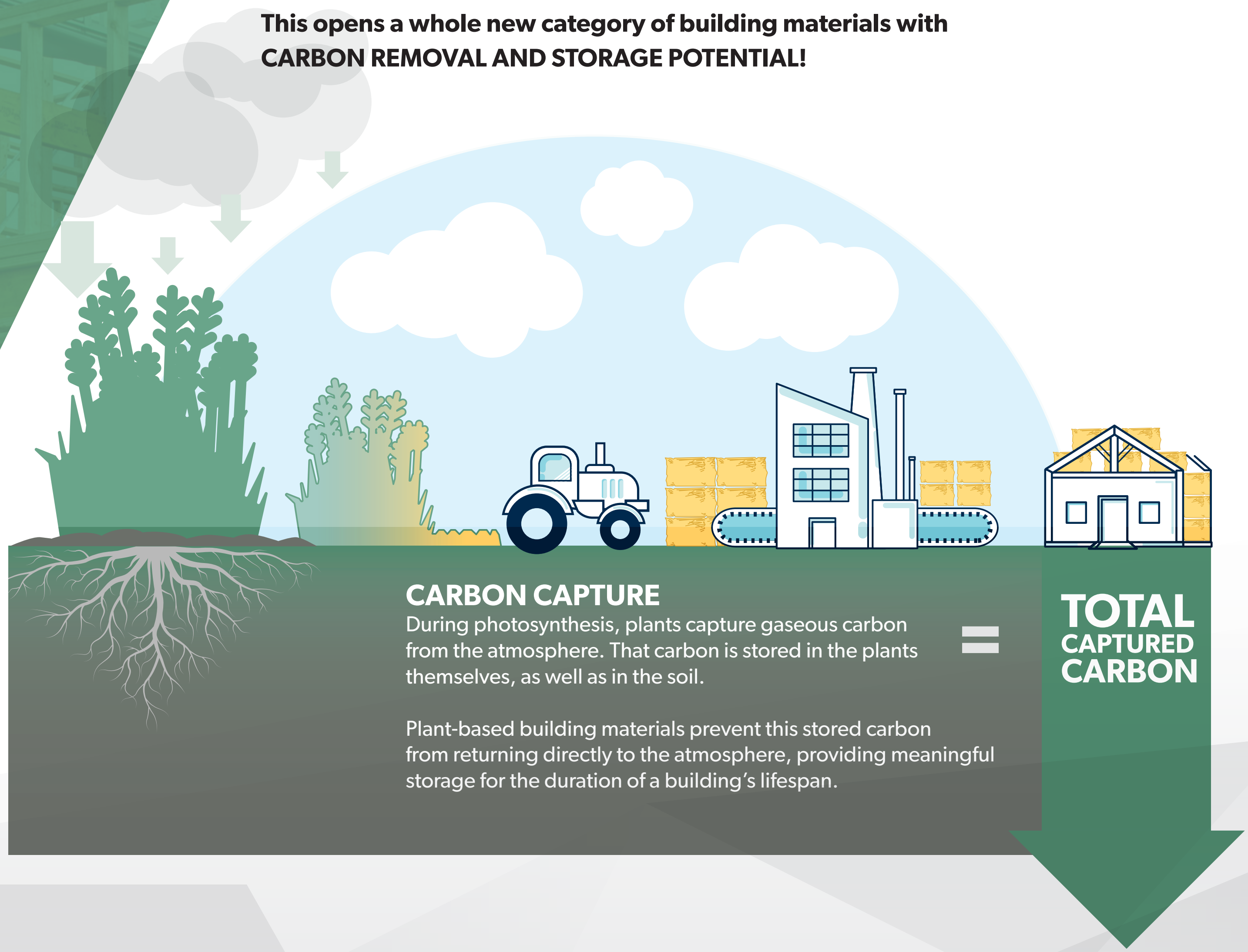

UP-FRONT EMBODIED CARBON EMISSIONS
EXTRACTION + TRANSPORTATION + MANUFACTURING
+
OPERATIONAL CARBON EMISSIONS
ENERGY USE INTENSITY
×
ENERGY SOURCE EMISSIONS
= CUI

A New Paradigm: Carbon Storing Materials

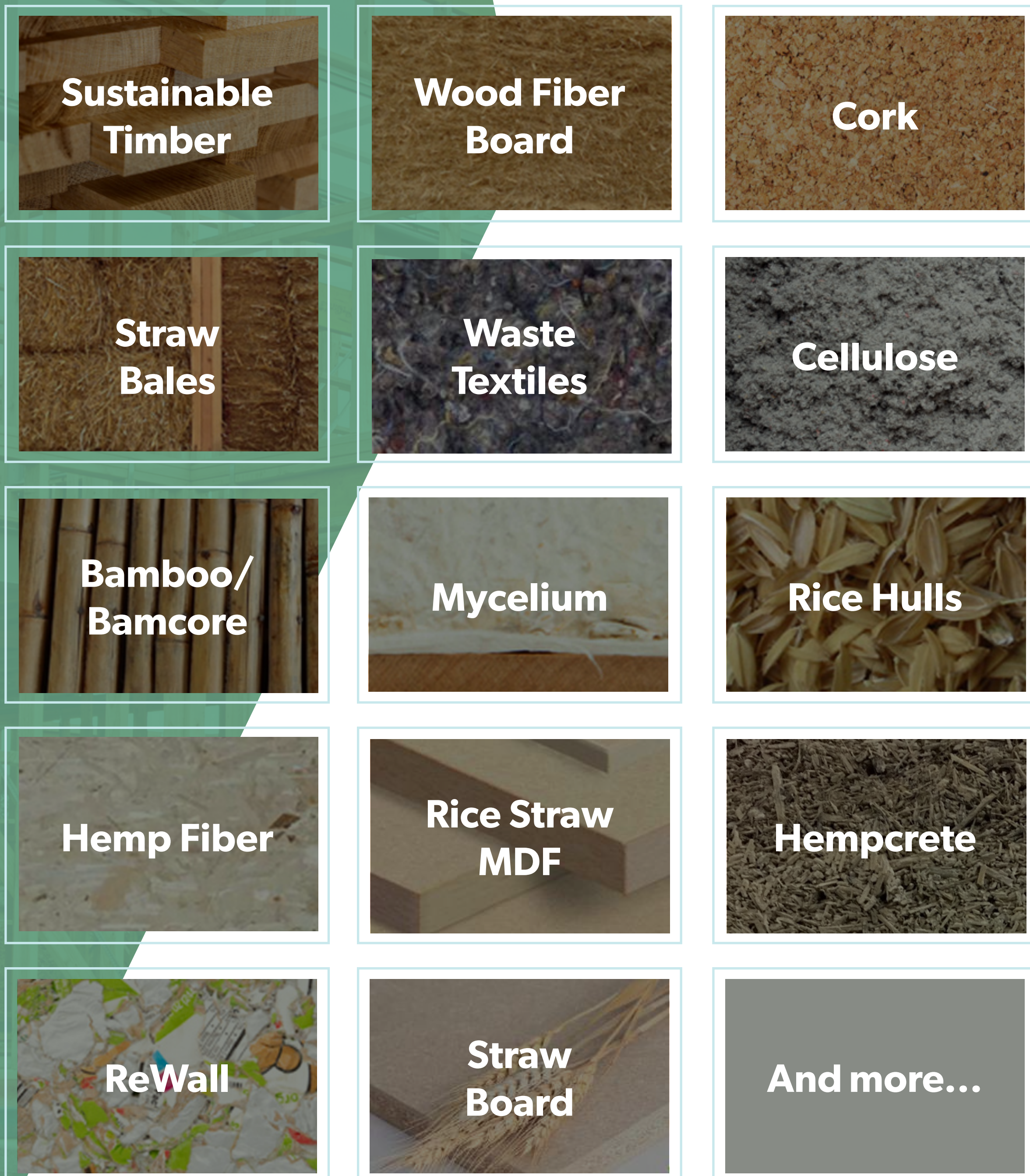
The results of this study demonstrate that we are capable of making low-rise residential buildings with a net zero embodied carbon footprint, and that we can even surpass this threshold and create buildings that actually have net carbon storage rather than net emissions.

Plant-based materials **STORE** more atmospheric carbon than was emitted in harvesting and manufacturing.

This opens a whole new category of building materials with CARBON REMOVAL AND STORAGE POTENTIAL!



Carbon Storing Materials



Plant-based building materials made from agricultural residues and waste fiber streams offer particularly high storage potential as we already produce these materials in vast quantities and do not need to create new sources of emissions in order to procure the source material.

The building industry already produces numerous plant-based materials, and many others could be scaled up to provide a potentially vast carbon sink within the built environment.

Straw-based Building Materials

2.16 billion tons of grain straw were grown globally in 2016 drawing down almost 8 billion tonnes of CO_2. That's enough carbon storage to offset all annual transportation GHG emissions and replace all current insulation materials.

There are many straw-based building products that are ready to become mainstream options.

UP-FRONT EMBODIED CARBON EMISSIONS

METHODOLOGY

Up-front Embodied Carbon Emissions

Eight examples of two types of common low-rise building are examined using the Global Warming Potential (GWP) figures from Environmental Product Declarations (EPDs).

Total up-front emissions are based on material takeoffs for code-compliant foundation, exterior walls, interior walls, floor & roof assemblies and windows.

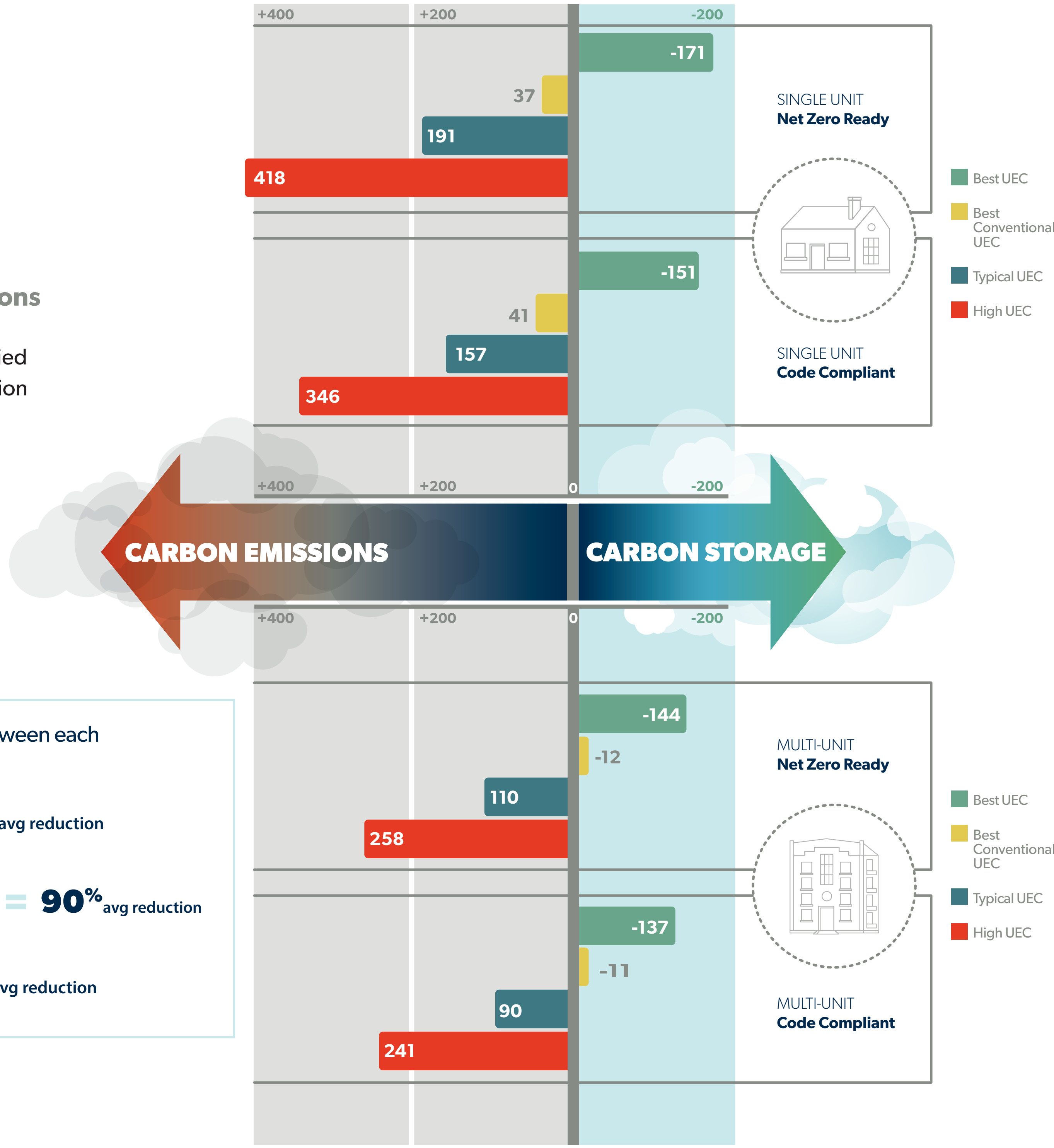
Over 350 materials were modelled, with four representative examples created that were typical of **high**, **typical**, **best conventional** and **best** up-front embodied carbon.

RESULTS

Up-front Embodied Carbon Emissions

There is an extremely wide range of embodied carbon results, showing that material selection can have a dramatic impact on up-front emissions.

Up-front embodied carbon emissions $kgCO_2e/m^2$



There are large reductions in emissions between each of the four building examples…

High UEC TO **Typical** UEC = **57%** avg reduction

Typical UEC TO **Best Convertional** UEC = **90%** avg reduction

High UEC TO **Best** UEC = **148%** avg reduction

OPERATIONAL CARBON EMISSIONS

METHODOLOGY

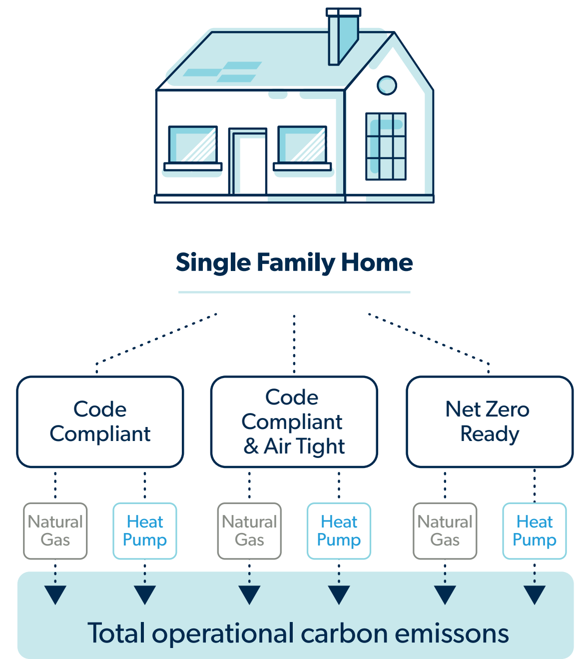
Operational Carbon Emissions

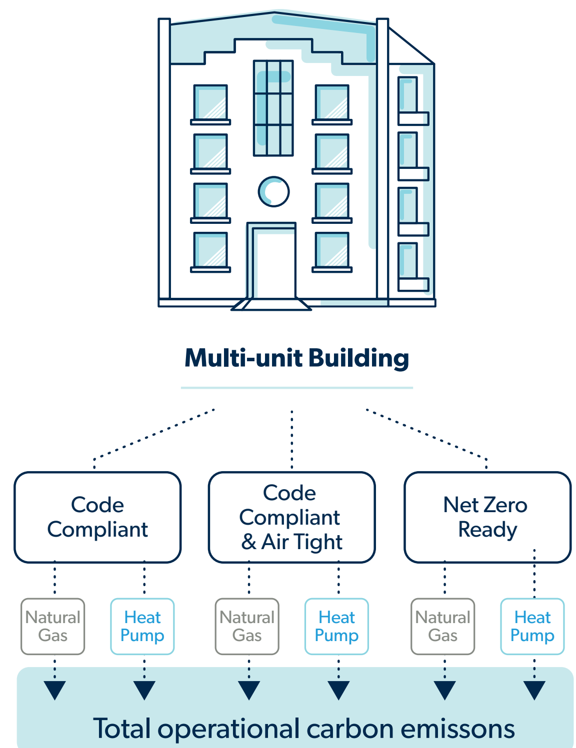
Energy models were generated using Energy-10 (E10), a US Department of Energy-developed dynamic hourly simulation energy modeling program, based on Toronto, Ontario climate data.

Thermal Performance Values for Model Buildings

	Single unit, code compliant[37]	Single unit, net zero ready	Mulit-unit, code compliant[38]	Mulit-unit, net zero ready
Roof	R-60	R-80	R-60	R-80
Walls	R-19 plus R-5 continuous	R-40	R-13 plus R-10 continuous	R-30
Basement walls	R-12 plus R-10 continuous	R-30	R-15 continuous	R-20
Slab	R-10	R-20	R-15	R-15
Windows	U-0.28	U-0.18	U-0.29	U-0.20
Doors	U-0.28	U-0.18	U-0.45	U-0.20
HRV efficiency	75%	89%	75%	89%
DHW min. efficiency	Electric 0.93 Gas 0.80	Electric 0.93 Gas 0.80	Electric 0.93 Gas 0.80	Electric 0.93 Gas 0.80

Jacob Deva Racusin, author of *Essential Building Science* and energy modeler for New Frameworks Natural Design/Build in Vermont, executed the energy models for this study using Energy-10 (E10), a US Department of Energy-developed dynamic hourly simulation energy modeling program, with Andrew M. Shapiro of Energy Balance, Inc. performing a technical review of the models.





RESULTS

Operational Carbon (OC) Emissions

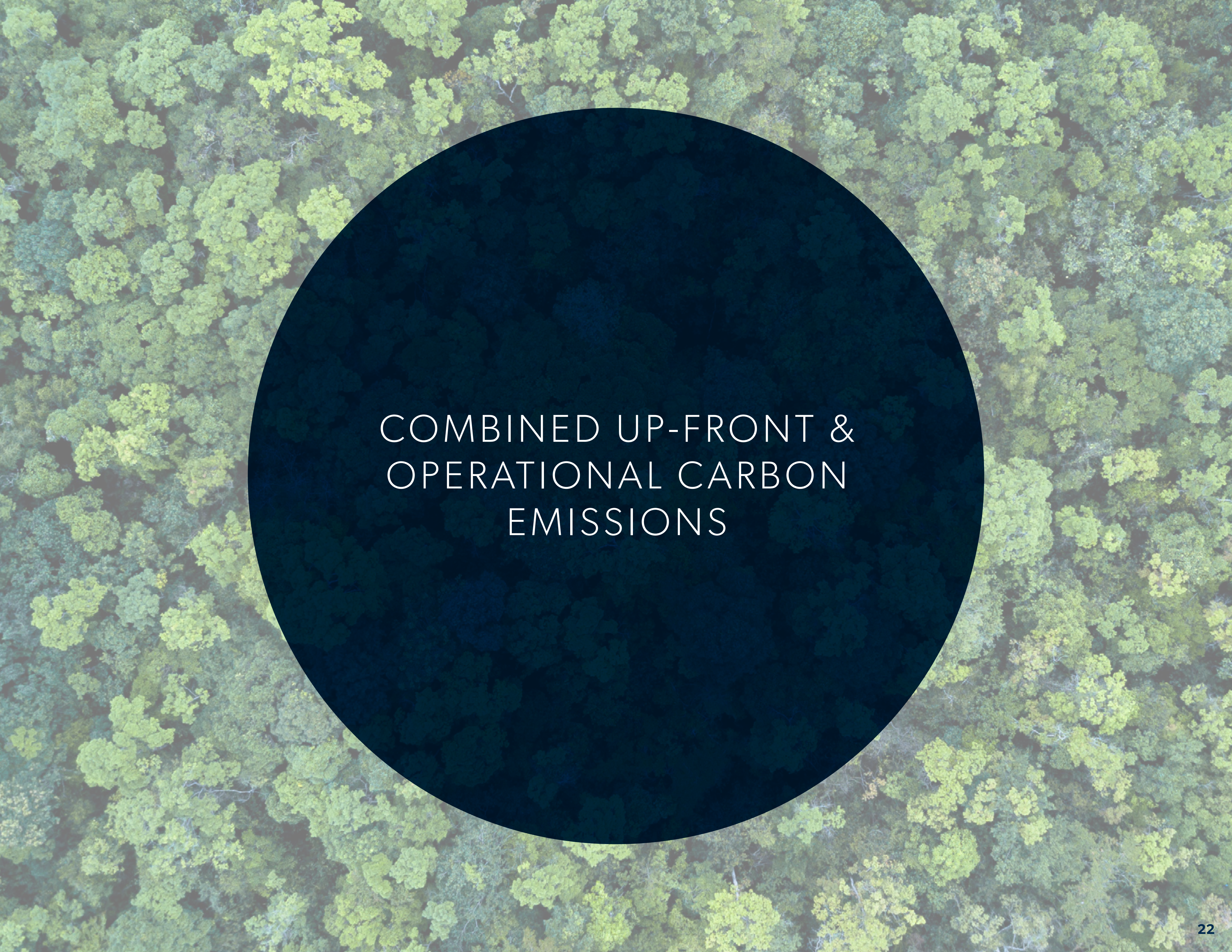
The difference in OC emissions for the two fuel sources is remarkable, averaging 96 percent lower for the **all-electric** versions compared to those heated with **natural gas**.

As expected, net zero ready buildings produce significantly less emissions, regardless of fuel type. The single-family building generates 69 percent less emissions in the **all-electric** version and 47 percent less when using natural gas. The multi-unit building reduces OC by 75 percent with electric heat and 53 percent with **natural gas**.

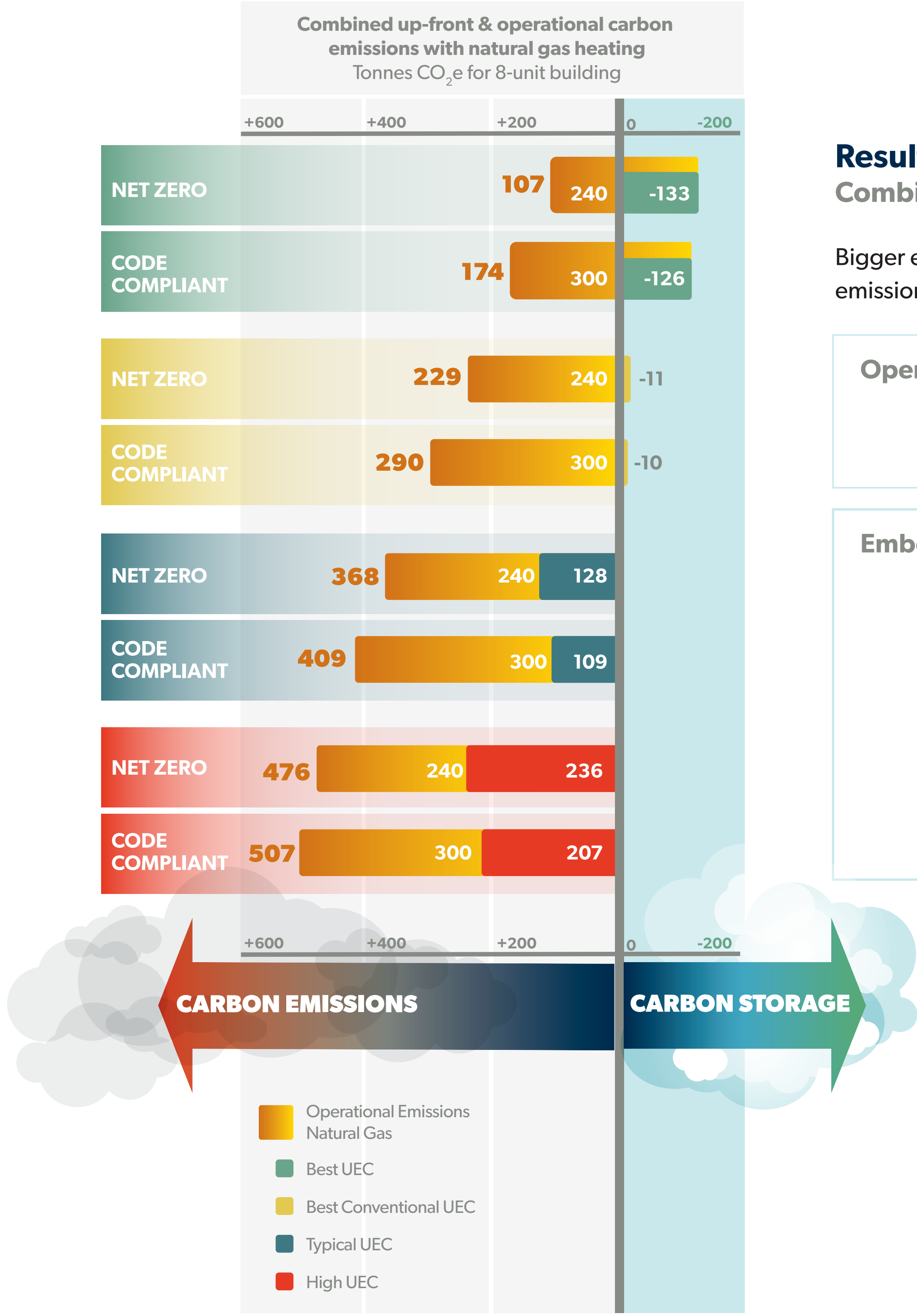
The effect of airtightness is significant. Modeled at 1.0 ACH/50 without any upgrades in insulation or window quality, the single-family building reduces OC by 38 percent (electric) and 23 percent (gas) while the multi unit sees OC reductions of 58 percent (electric) and 40 percent (gas).

Energy Model Results for Toronto, Ontario climate zone.

Description of Building	Heating CO2e, Electric ASHP, Ontario Grid	Heating CO2e, Natural Gas
	$kgCO_2e/yr$	**$kgCO_2e/yr$**
Single-unit, code compliant	160	3,000
Single-unit, code compliant, air-tight	100	2,300
Single-unit, net zero ready	50	1,600
Multi-unit, code compliant	750	15,000
Multi-unit, code compliant, air-tight	330	9,000
Multi-unit, net zero ready	190	7,100



COMBINED UP-FRONT & OPERATIONAL CARBON EMISSIONS



Results with natural gas heating

Combined up-front & operational carbon emissions

Bigger emission reductions can be made by addressing up-front embodied emissions than by moving to higher levels of energy efficiency.

Operational carbon reductions:

Code Minimum TO **NET ZERO** = **60** tonne avg reduction over 30 years

Embodied carbon reductions:

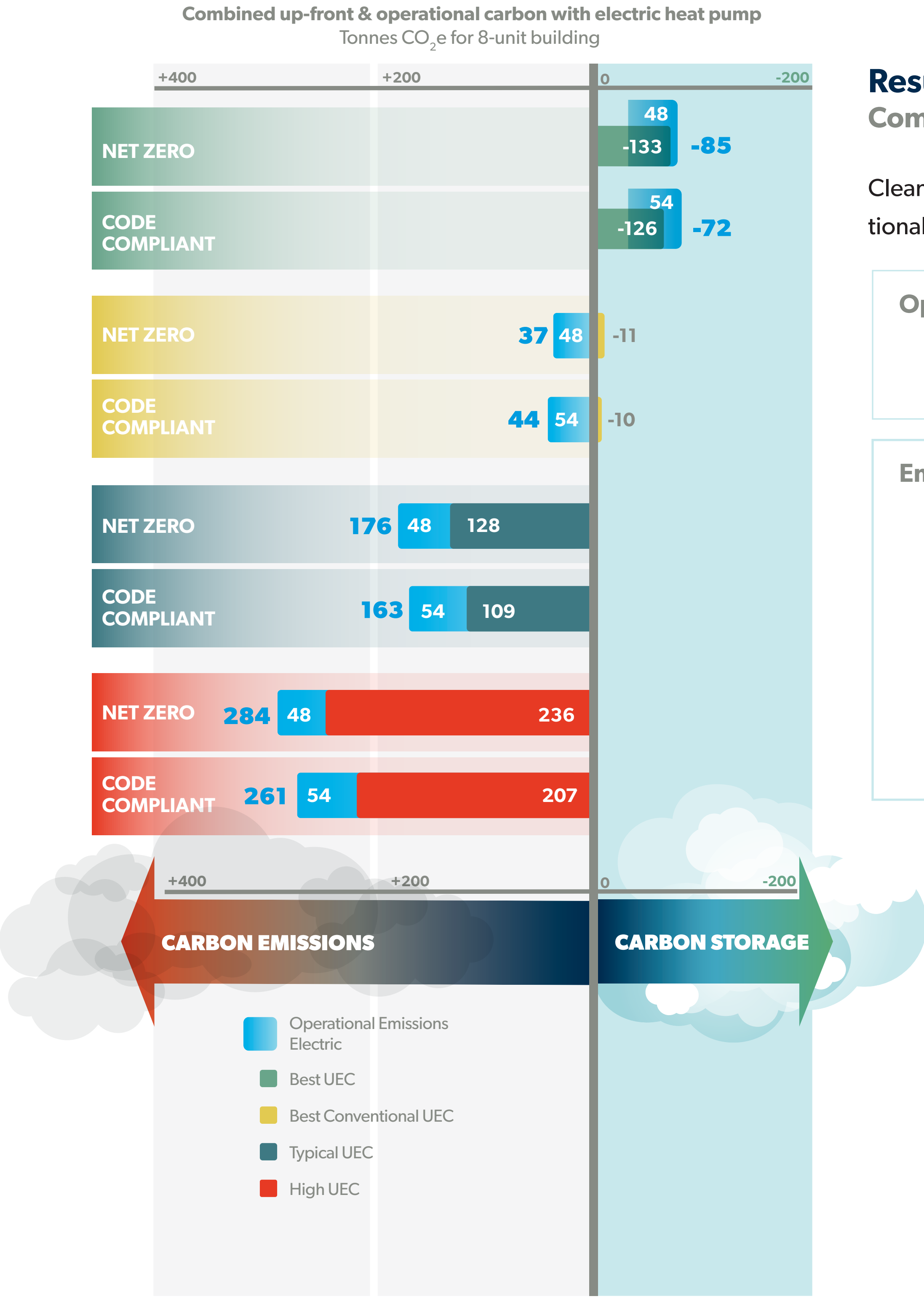
High UEC TO **Typical** UEC = **103** tonnes Immediate Reduction!

Typical UEC TO **Best Convertional** UEC = **129** tonnes Immediate Reduction!

Best Convertional UEC TO **Best** UEC = **119** tonnes Immediate Reduction!

We can build AND operate the **Best Conventional UEC** building for 30 years with fewer emissions than just the up-front embodied emissions of the **High UEC building**.

We can build AND operate the **Best UEC** building for 30 years with fewer emissions than just the up-front emssions of the **Typical UEC** builing.



Results with heat pump (using Ontario electrical grid)

Combined embodied and operational carbon

Clean electrification means that up-front embodied emissions from conventional buildings are the majority of overall emissions in 30 years.

Operational carbon reductions:

Code Minimum TO **NET ZERO** = **6tonne** avg reduction over 30 years

Embodied carbon reductions:

Up-front Emissions High UEC TO **Typical** UEC = **103tonnes** Immediate Reduction!

Typical UEC TO **Best Convertional** UEC = **129tonnes** Immediate Reduction!

Best Convertional UEC TO **Best** UEC = **119tonnes** Immediate Reduction!

Improvements in energy efficiency from Ontario code minimum to Net Zero ready standards do not result in meaningful carbon reductions when clean electricity is the fuel source. In fact, the additional insulation materials in the **High UEC** and **Typical UEC** examples result in a higher overall carbon footprint despite the energy savings.

The **Best UEC** model remains in a state of net storage of 72-85 tonnes by 2050, and will continue to be a site of net storage until the end of the century, a truly remarkable achievement and a great contribution to limiting climate change if we can achieve these results at a large scale.

KEY FINDINGS

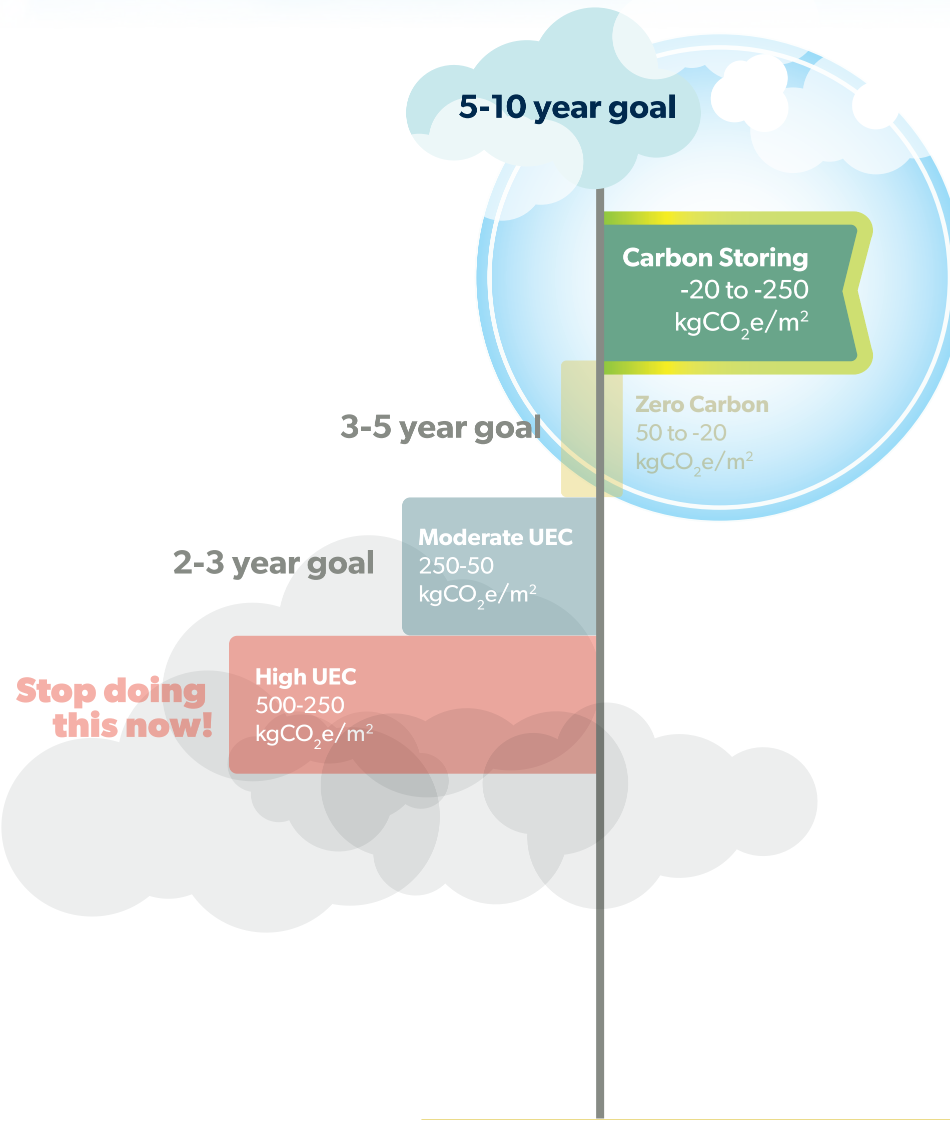
KEY FINDINGS 1

Low-rise buildings can store a significant amount of carbon

The results from the **Best UEC** examples for both the single- and multi-unit buildings indicate that this type of residential construction can provide net carbon dioxide removal and storage of **137-171 $kgCO_2e/m^2$** using a viable material palette.

Compared to expected net emissions of 90-191 $kgCO_2e/m^2$ from the **Typical EUC** and 241-418 $kgCO_2e/m^2$ for the **High UEC** examples, the volume of net storage capacity indicates a major paradigm shift from GHG emitting to carbon storing buildings.

We should not set our expectations at mere carbon reductions. We should aspire to this type of realistic net carbon storage in our buildings.



KEY FINDINGS 2

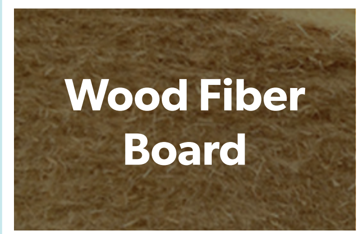
Buildings can feasibly reach zero up-front embodied emissions today

The **Best Conventional UEC** example exhibited an average of -12 $kgCO_2e/m^2$ for the multi-unit building and 39 $kgCO_2e/m^2$ for the single-unit, making this type of building carbon neutral.

The key materials selected to create this model represent options that are commercially available, competitively priced and code-compliant:

- Use of cellulose insulation in walls and attics. This product is widely manufactured and distributed in North America.
- Use of wood fiberboard exterior insulation. This product is widely available in Europe, and has limited production in North America.
- Specification of concrete mixes with high percentages of supplementary cementitious materials (SCM). These mixes can be specified from most concrete batching plants.

Designers and builders could realistically move to implement this type of zero up-front carbon building with few impediments, and in doing so dramatically alter the embodied carbon emissions of the building industry, bringing residential UEC climate impacts close to zero.



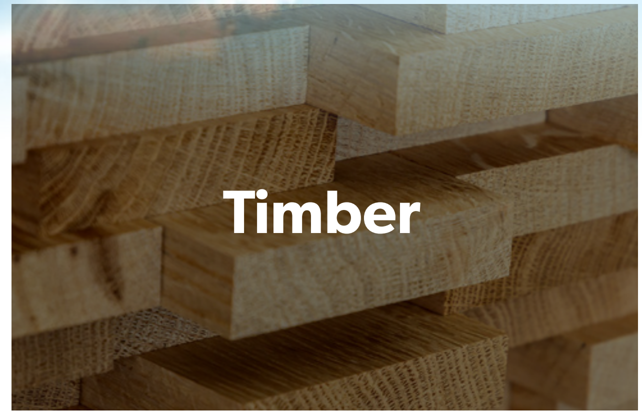
KEY FINDINGS

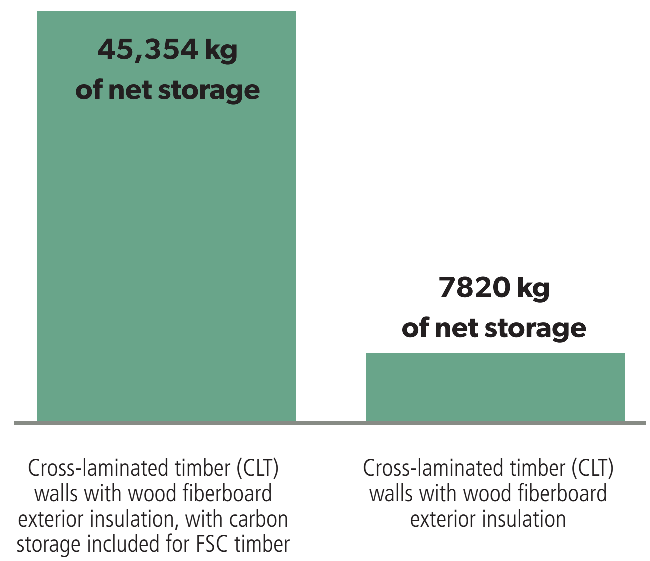
The carbon storage potential of wood is significant, but difficult to accurately quantify

Timber has a very important role to play in a low-carbon built environment. The replacement of high UEC materials like concrete and steel with a low UEC and renewable material is a key strategy for the building industry to adopt. However, the attribution of carbon storage in timber products must be carefully considered, and counted only when enough is understood about a specific product and its life cycle to correctly assume that meaningful net storage is occurring.

In this study, the sample building assembly with the highest up-front carbon storage has cross-laminated timber (CLT) walls with wood fibreboard insulation, resulting in 45 tonnes of storage. However, if carbon storage in the CLT is not counted, the same walls have just 7.8 tonnes of storage.

Sustainably harvested wood with quantifiable levels of carbon storage can provide a path to buildings with high amounts of up-front carbon storage. We need to undertake collective action to ensure that carbon-positive forestry practices quickly become the norm.





KEY FINDINGS

Carbon-storing materials have numerous co-benefits

This study focuses on the Global Warming Potential (GWP) of materials, but the Environmental Product Declarations used in this study show that the materials with the best carbon storage capabilities also tend to have the best results in the other impact categories, which include acidification, eutrophication, smog and ozone generation, fresh water use and hazardous waste generation. This is worthy of further study, but would indicate that, in most cases, overall environmental improvements would follow from replacing high GWP materials with alternatives with lower GWP.

Additionally, none of the carbon storing materials in this study contains ingredients found on the International Living Future Institute's chemical Red List*. An initial exploration of carbon storing materials using the Data Commons of the Healthy Building Network** does not indicate any content that falls in the High or Very High hazard levels. As the indoor environment quality of buildings is of growing concern, the move to a materials palette that includes more carbon-storing options appears likely to correspond with improvements in occupant health and safety. Materials with less potentially dangerous chemical content also have benefits at end of life, with fewer opportunities for environmental contamination through landfill, recycling or combustion.

* https://living-future.org/declare/declare-about/red-list/

** https://pharosproject.net/

ATMOSPHERE		
Global Warming Potential refers to long-term changes in global weather patterns — including temperature and precipitation — that are caused by increased concentrations of greenhouse gases in the atmosphere.	**Ozone Depletion Potential** is the destruction of the stratospheric ozone layer, which shields the earth from ultraviolet radiation that's harmful to life, caused by human-made air pollution.	**Photochemical Ozone Creation Potential** happens when sunlight reacts with hydrocarbons, nitrogen oxides, and volatile organic compounds, to produce a type of air pollution known as smog.

WATER	
Acidification Potential is the result of human-made emissions and refers to the decrease in pH and increase in acidity of oceans, lakes, rivers and streams – a phenomenon that pollutes groundwater and harms aquatic life.	**Eutrophication Potential** occurs when excessive nutrients cause increased algae growth in lakes, blocking the underwater penetration of sunlight needed to produce oxygen and resulting in the loss of aquatic life

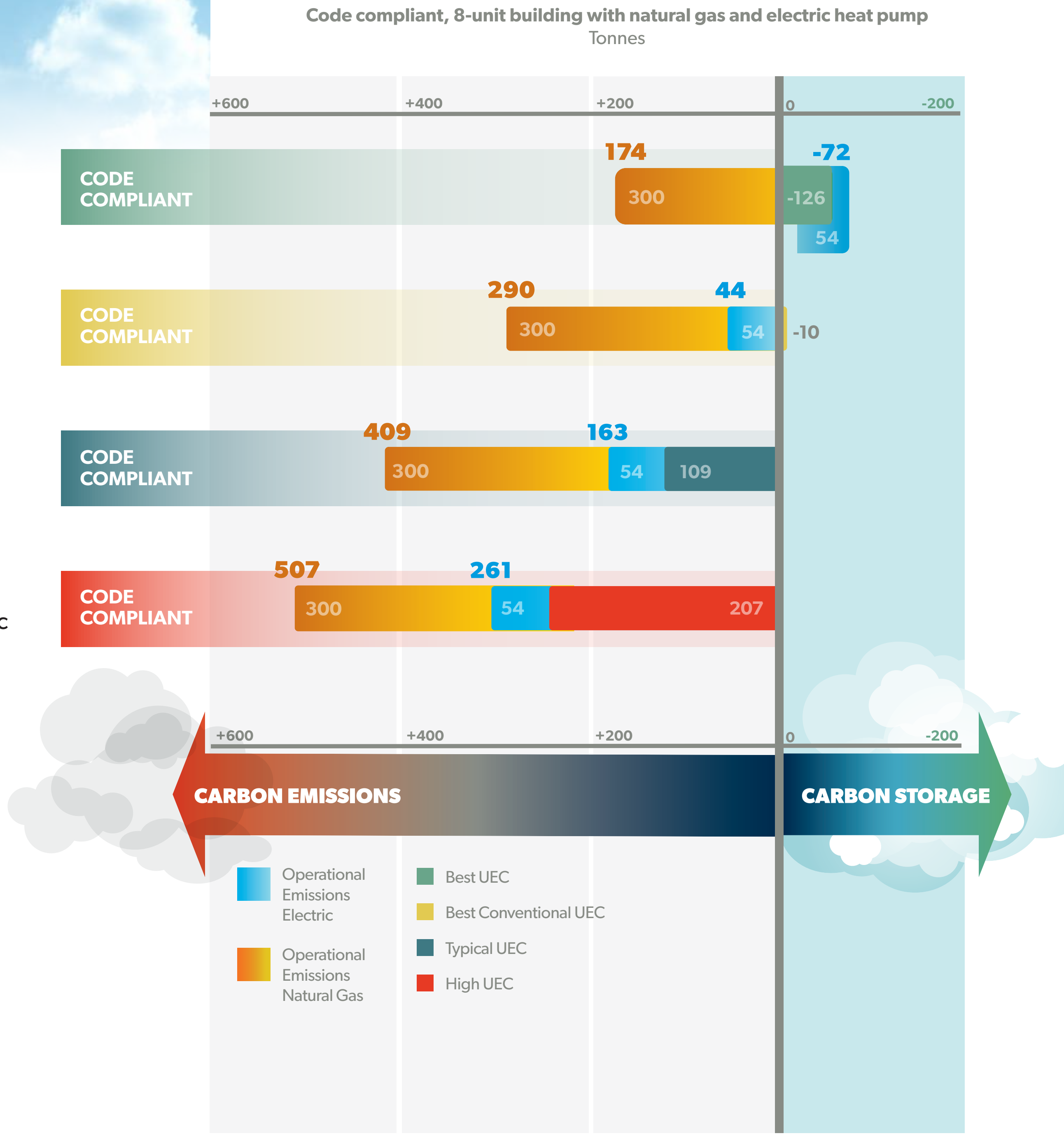
EARTH	
Depletion of Abiotic Resources (Elements) refers to the reduction of available non-renewable resources, such as metals and gases, that are found on the periodic table of elements, due to human activity.	**Depletion of Abiotic Resources (Fossil Fuels)** refers to the decreasing availability of non-renewable carbon-based compounds, such as oil and coal, due to human activity.

KEY FINDINGS

The emissions profile of the energy source has a greater impact than the energy efficiency of the building.

A switch from natural gas as the heating fuel to electric air source heat pumps using the Ontario, Canada electrical grid can reduce 246 tonnes of emission reductions between 2020 and 2050 (8.2 tonnes per year) in the code compliant versions, and 192 tonnes in the net zero examples (6.4 tonnes per year). This far outweighs the 60 tonne improvement from making the natural gas model more energy efficient, and the 6 tonnes from improving energy efficiency for the electric heat pump model.

This indicates that we can achieve greater emissions reductions from aggressively moving to clean energy grids than from improving the energy efficiency of individual buildings. The building industry can and should encourage the move to clean energy grids as a key part of its own emissions reduction efforts.



KEY FINDINGS

A narrow focus on operational emissions can be counterproductive and have unintended climate consequences

The term "energy efficiency" misses the point when it comes to climate change: energy and GHGs are not necessarily synonymous, and we need to think about Carbon Use Intensity (CUI) rather than Energy Use Intensity (EUI). Energy efficiency is just one consideration in an overall GHG reduction strategy, but not a stand-alone solution to GHG emissions.

Reducing up-front embodied carbon is a more effective intervention than improving energy efficiency from current code minimums in Ontario to net zero ready levels. Each "step" between the four levels of embodied carbon explored in this study represents a drop in emissions of 98-139 tonnes of UEC per building, while the energy efficiency improvements are 60 tonnes if fueled by natural gas and 6 tonnes with Ontario electricity.

The move to cleaner energy reduced emissions by 246 tonnes for the code compliant version and 192 tonnes for the net zero, compared to reductions of 60 and 6 tonnes for the code compliant and net zero versions. If the energy source produces low or no emissions, we won't achieve meaningful reductions by reducing the amount of clean energy we use. If we insist on increasing insulation using high UEC materials, we will actually cause overall emissions to increase rather than decrease.

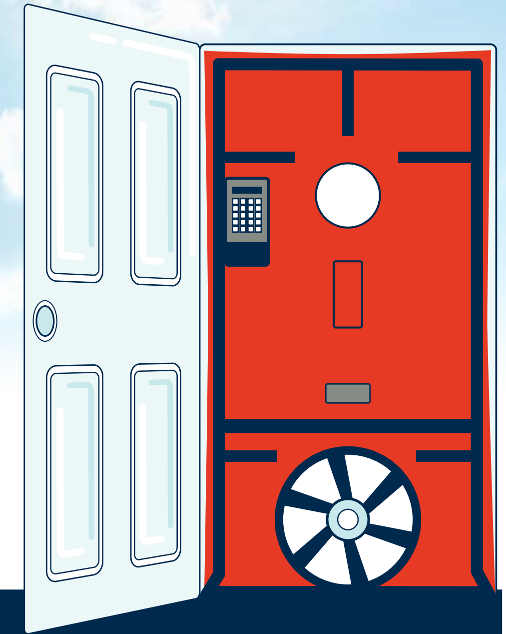
Operational Carbon Reductions

Natural Gas Code Compliant	**Net Zero**	**60 tonne** avg reduction over 30 years
Electric Code Compliant	**Net Zero**	**6 tonne** avg reduction over 30 years

Up-front Carbon Reductions

Up-front Emissions **High UEC**	Up-front Emissions **Typical UEC**	**98 tonne** avg reduction
Up-front Emissions **Typical UEC**	Up-front Emissions **Best Conventional UEC**	**119 tonne** avg reduction
Up-front Emissions **Best Conventional UEC**	Up-front Emissions **Best UEC**	**116 tonne** avg reduction

KEY FINDINGS



Air tightness is an easy intervention for reducing operational emissions

Buildings insulated to meet minimum code requirements in Ontario can improve energy efficiency from 23-56% by increasing air tightness from code minimum standards of 2.5-3.0 ACH/50 to 1.0 ACH/50.

These results suggest that air tightness alone is a highly effective GHG reduction strategy. All low-rise buildings in Ontario already incorporate the air control layers required for achieving 1.0 ACH/50, including exterior weather resistant membrane and interior vapour control layer. An improvement in the installation procedures for these materials and a greater emphasis on achieving and protecting air tightness can result in overall reductions in operational emissions that do not require investments in more insulation and better windows.

This is the easiest intervention for reducing operational emissions without requiring the use of more insulation materials.

Energy Model Results for Toronto, Ontario climate zone.

Description of Building	Heating CO2e, Electric ASHP, Ontario Grid	Heating CO2e, Natural Gas
	kgCO_2e/yr	**kgCO_2e/yr**
Single-unit, code compliant, 2.5ACH/50	160	3,000
Single-unit, code compliant, 1.0ACH/50	100	2,300
Single-unit, net zero ready, 1.0ACH/50	50	1,600
Multi-unit, code compliant, 3.0ACH/50	750	15,000
Multi-unit, code compliant, 1.0ACH/50	330	9,000
Multi-unit, net zero ready , 1.0ACH/50	190	7,100

RELATED FINDINGS

Renovations of existing buildings should consider embodied carbon in addition to energy efficiency

The high carbon footprint of many conventional insulation materials and windows – two of the main upgrades in efficiency renovations – indicates that climate policy for reducing GHGs from existing buildings must consider the up-front embodied carbon implications or the resulting renovations may be responsible for more emissions than will be saved over many decades of reduced operational emissions.

Renovations performed with carbon-storing insulation materials will have an immediate climate drawdown effect in addition to providing additional energy efficiency. The stored carbon in such renovations could buy time for the buildings to transition to cleaner energy sources.

Since existing foundations, structural walls and roof framing are typically preserved – and therefore don't require additional up-front emissions – the use of carbon-storing insulation materials is likely to make the net carbon storage per square meter of renovation projects much higher than for new buildings. Renovated buildings could become key sites of net carbon storage.

Opportunities exist for significant carbon storage in commercial, institutional and high-rise buildings

Although this study focuses on low-rise residential construction, many of the material options that provide the most significant up-front emissions reductions (high SCM concrete, cross laminated timber, rammed earth) and carbon storage (cellulose, compressed straw wall panels, ReWall, cement-bonded wood wool, cork) can be used in any building typology. Though it may be more difficult to get these types of buildings into net storage balance, this study indicates that mass timber structures with carbon-storing partition walls, ceiling panels, cladding and/or finishes could dramatically reduce the up-front emissions of larger buildings, and should be the focus of further study.

NEXT STEPS

NEXT STEPS - GENERAL:

Builders/designers — Understand the extent to which our activities are responsible for climate change and make firm commitments to intentionally reduce emissions at an aggressive pace.

Manufacturers — Understand the role that material emissions play in global climate change and make commitments to lower emissions immediately and aim to move toward low-carbon or carbon-storing materials.

Policy-makers — Signal an intention to require net carbon storage in buildings within a reasonable frame. Offer incentives to innovators and manufacturers to develop carbon-storing materials.

NEXT STEPS - UP-FRONT EMISSIONS:

Builders/designers — Specify and install carbon-storing materials whenever possible. Seek out education about sourcing, installing and maintaining these materials. Have conversations with clients about your reasons for wanting to use carbon-storing materials.

Manufacturers — Generate EPDs for products, and include biogenic carbon quantities as an identifiable element of the total GWP. Lower the GHG emissions of existing products. Develop market awareness of low-carbon and carbon-storing options. Seek reliable and ecologically-sound sources of biogenic carbon for materials. Develop healthy products with the highest carbon storing potential.

Policy-makers — Require designers to generate a building-specific emissions profile as part of the permitting process. Create a staged series of emission caps for buildings. Offer incentives to builders for making significant reductions in GHG emissions.

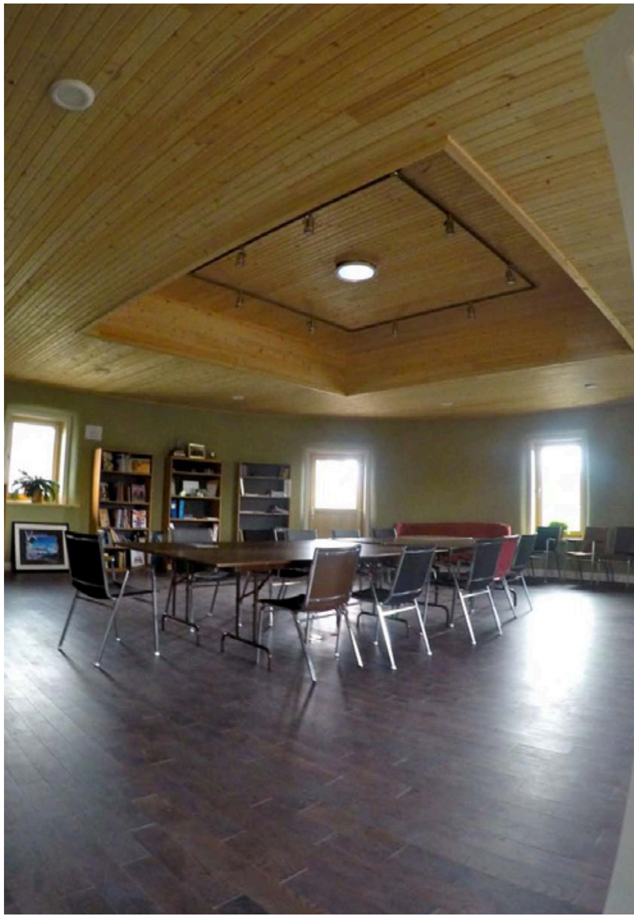
NEXT STEPS - CARBON USE INTENSITY:

Builders/designers —

- Stop using fossil fuels for heating buildings. Where grid electricity is carbon-intensive, purchase clean energy from third party providers.
- Set goals for improving air tightness. Train crews to achieve air tightness targets. Perform on-site testing of all buildings to confirm targets are being met.

Policy-makers —

- Move away from requirements for energy efficiency and begin requiring Carbon Use Intensity as the performance metric. Ensure that net zero energy requirements are aligned with actual reductions in emissions, rather than requiring simple mathematical achievement of net zero energy.
- Signal intent to require on-site air tightness testing of all buildings.




5-10 year goal
Carbon Storing
-20 to -250
kgCO$_2$e/m^2
3-5 year goal
Zero Carbon
50 to -20
kgCO$_2$e/m^2
2-3 year goal
Moderate Carbon
250-50
kgCO$_2$e/m^2
Stop doing this now!
High Carbon
500-250
kgCO$_2$e/m^2

Builders for Climate Action will be undertaking a number of initiatives aimed at helping the low-rise sector move to becoming a site of net carbon storage:

Distribution of this white paper

We hope the case presented in this study is compelling, and encourages people in the building industry to begin taking important steps toward carbon positivity.

Carbon calculator

We will build on the research compiled for this study and develop a simple and effective embodied carbon calculator tool that will enable building designers and material specifiers to understand the up-front emissions in their buildings and make conscious choices to meet lower thresholds with their buildings.

Specification & guidebook

We will create a guidebook that covers the most effective, affordable actions for reducing up-front emissions in buildings on a cost-per-tonne basis, and provide specifications and details for incorporating these choices in building designs.

Carbon Storing Building Challenge

We will sponsor a nationwide contest for buildings that are certifiably carbon storing.

Municipal incentive policy

We will use a cost-per-tonne calculations to help municipalities offer appropriate incentives to builders for creating fewer GHG emissions.

Low carbon curriculum

We will help develop curriculum for design and building schools to help a new generation understand how they can make choices that ensure a carbon positive balance in the building industry.

Code development

We will help to develop building codes that mandate thresholds for up-front embodied carbon emissions.

Supply chain development

We will help innovators and manufacturers create low-carbon and carbon-storing materials and to support those materials in the market.

CASE STUDIES

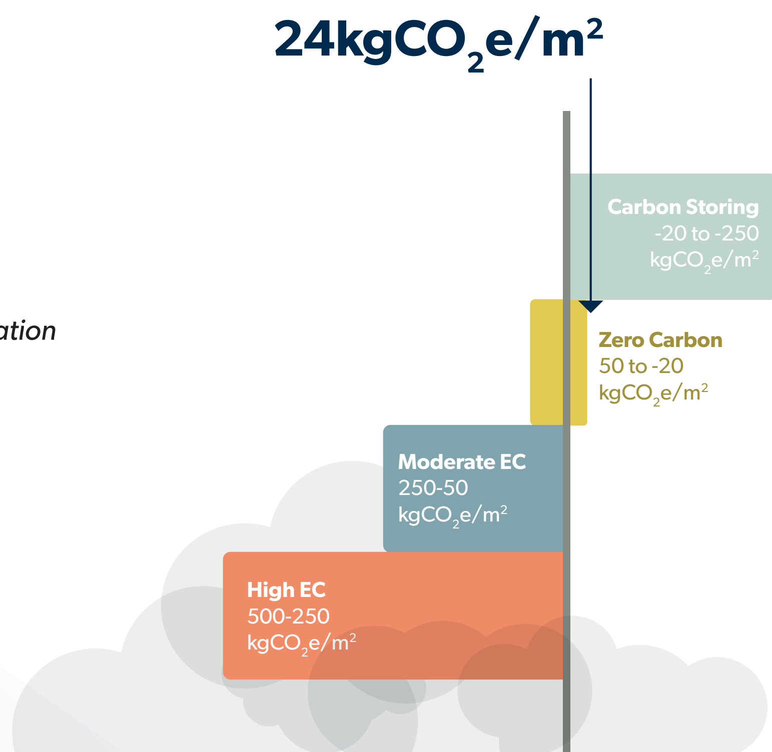
Canada’s Greenest Home - Urban infill, near net-zero design

Design: Endeavour Centre
210m² three bedroom home

5 tonnes net carbon storage

Key carbon storing materials: Prefab straw bale walls, cellulose roof insulation, Nexcem ICF foundation, FSC wood siding, subflooring and flooring, sustainably harvested cedar shingles, clay plaster.

Energy: 85% on site generation of solar electricity
0.8 ACH/50 air tightness

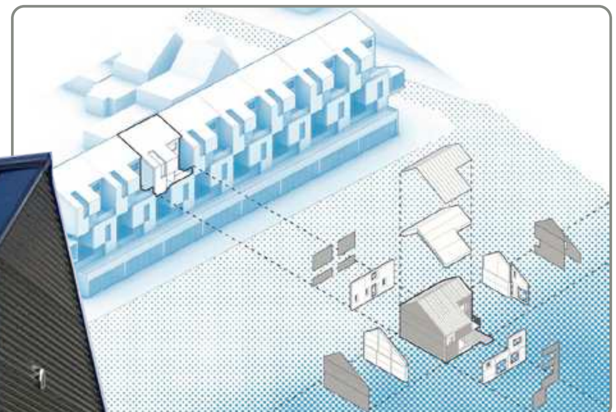


Zero House - Prefab modular home, net zero design

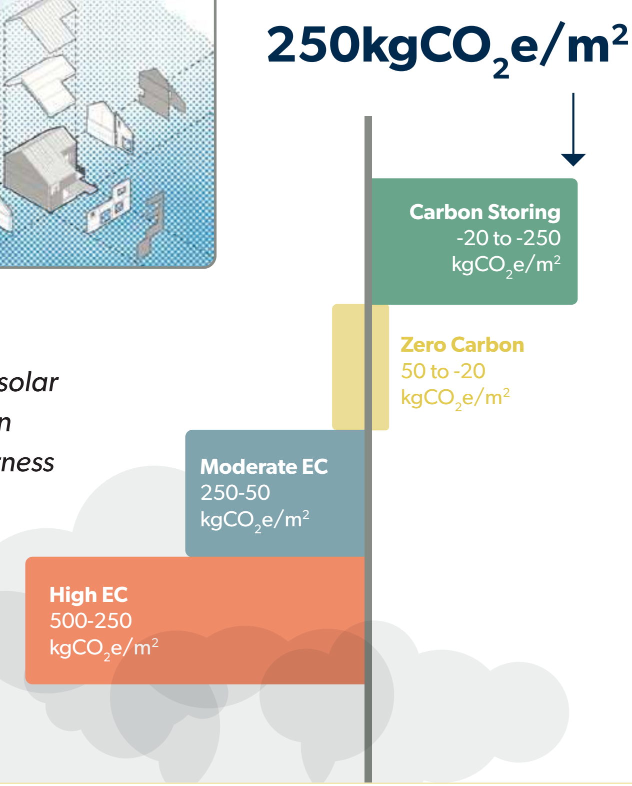
Design: Ryerson University & Endeavour Centre
100m^2 single unit two-bedroom
Designed to be one unit in a 16-unit development

25 tonnes net carbon storage in a single unit
400 tonnes storage potential in 16-unit development

Key carbon storing materials: Prefab straw bale walls, prefab cellulose wall, roof & floor panels, MSL Fibreboard exterior insulation board, ReWall interior sheathing, Mycofoam insulation, cork sheathing panels, FSC wood floor and plywood interior wall cladding.



Energy: 75% on site solar electricity generation
1.0 ACH/50 air tightness



Offices & Meeting Hall - Urban infill, net-positive design

Design: Endeavour Centre
225m² three offices, large meeting room, staff room

81 tonnes net carbon storage

Key carbon storing materials: Straw bale and cellulose wall insulation, cellulose floor and roof insulation, Nexcem ICF foundation, FSC wood siding and flooring, clay plaster, sustainably harvested timber frame.

360 $kgCO_2e/m^2$

Energy: 105% on site generation of solar electricity
0.6 ACH/50 air tightness

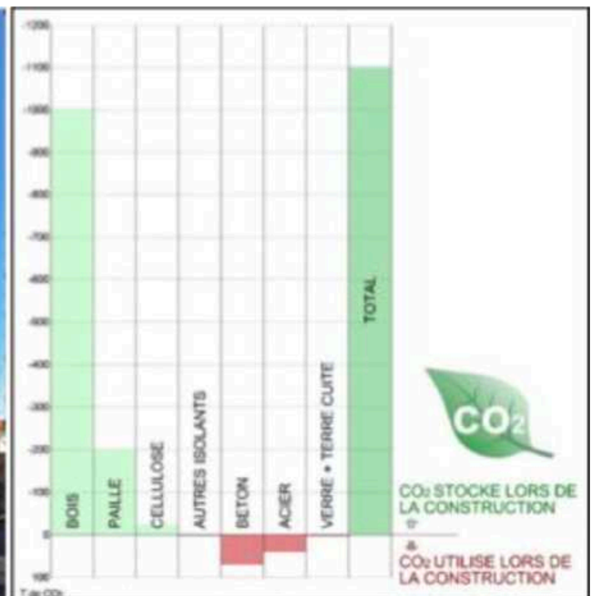
Carbon storage at larger scales

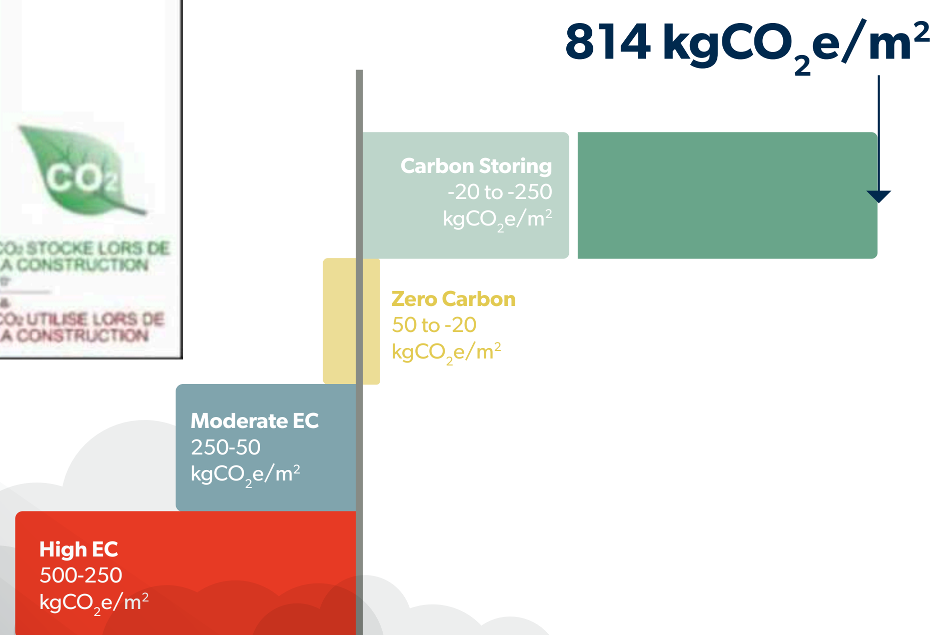
Jules Ferry Apartment Complex, Saint-Die-des-Vosges, France
Design: ASP Architecture
1350m² seven story residential building

1100 tonnes net carbon storage

(Embodied carbon accounting was not performed using the same protocol as this study)

Key carbon storing materials: Prefab straw bale wall panels, sustainably harvested timber structure.





This study outlines three important elements required to bring GHG emissions from low-rise buildings to zero, or better:

1. **Reduced up-front embodied carbon and maximized carbon storage in materials**
2. **Reduced GHG intensity of fuel sources for buildings**
3. **Energy efficiency as required to meet GHG targets**

Of these three aspects, up-front embodied carbon and GHG intensity of fuels is shown to have the largest impacts. GHG intensity of fuels is something that is most effectively tackled at the government level, while up-front embodied carbon is the aspect for which individual designers, builders and homeowners have the ability to make the most difference.

Builders for Climate Action is a project of:

ENDEAVOUR THE SUSTAINABLE BUILDING SCHOOL

GreenUP

Supporters:

City of Peterborough

Ontario Natural Building Coalition

Building Alternatives

LETT Architects

Great Northern Insulation

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Friends:

475 High Performance Building Supply

Bobby Ilg

Christopher Tworkowski, Architects

Dwellings

Stephen Hill

Tooke Tree Passive Homes

We wish to thank the following people and organizations for their direct or indirect contributions to this work:

Ace McArleton
Andy Shapiro
Architecture 2030
Arkin/Tilt Architects
Andrew Himes
Bruce King
Carbon Leadership Forum
Craig White
Ecological Building Network
Embodied Carbon Network
Emily Niehaus
Erin McDade
Fin MacDonald
Fourth Pig Worker Cooperative
Jacob Deva Racusin
Jennifer Martin
Kate Simonen
Larry Strain
Massey Burke
Melinda Zytaruk
New Frameworks Natural Design Build
Nori, The Carbon Removal Marketplace
Ryan Zizzo
Tim Krahn

To view the complete research paper Opportunities for Carbon Dioxide Removal and Storage in Building Materials, go to:
https://www.researchgate.net/publication/336171374_Opportunities_for_CO2_Capture_and_Storage_in_Building_Materials

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