

Our homes as a win-win solution: Solving for climate change & human health

*Chris Magwood,
Manager, Carbon-Free Buildings, RMI
Board member, Builders for Climate Action*

*Muskoka Summit on the Environment, 2025
Living Smarter in a Changing Climate*

What is RMI?

Think. Do. Scale.

Carbon-Free Buildings

Carbon-Free Electricity

Carbon-Free Transportation

China Program

Climate Finance

Climate-Aligned Industries

Climate Intelligence

Global South

India Program

Strategic Insights

Technology & Innovation

Urban Transformation

US Program



Jules Ferry Residence, France (2013)



Hyllie High Rise, Sweden (2025)



84 Harrington Ave, Cape Town, SA (2023)



[sapeople.com](https://www.sapeople.com)



Marks & Spencer mall, UK (2012)



DeRoomly Sports Hall, Netherlands (2019)



<https://2021.prizes.new-european-bauhaus.eu/node/269001>

Enterprise Centre, University of
Nottingham, UK (2015)



<https://www.architype.co.uk/project/the-enterprise-centre-uea/>

Louise Michel School, France (2015)



THERE ARE MANY CRITERIA TO CONSIDER



Code compliance



Maintenance & input



Material costs



Resilience



Labour costs & sources



Indoor environment quality



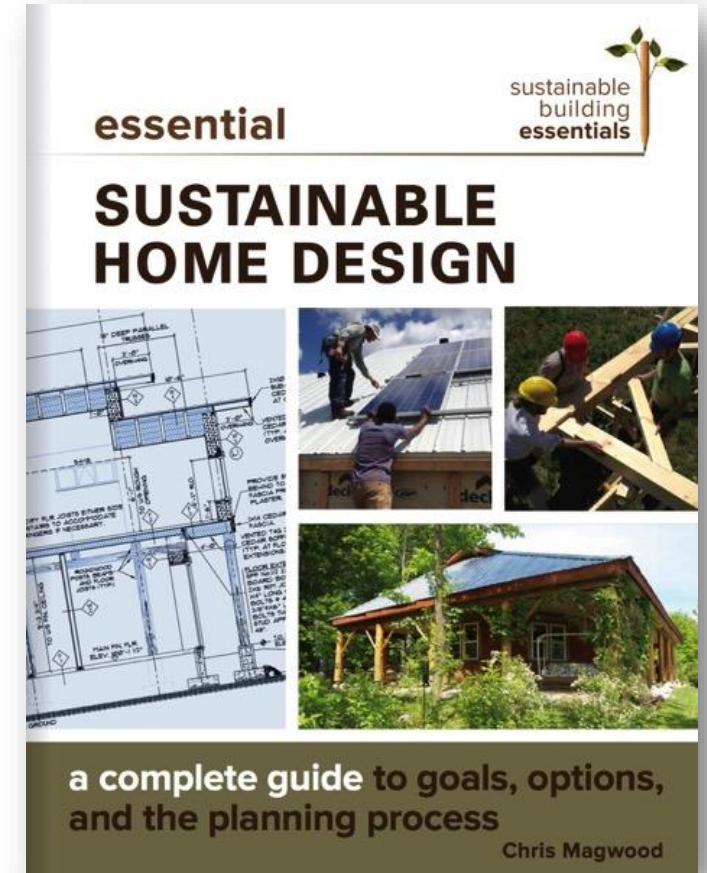
Energy efficiency



Ecosystem impacts



Waste



THERE ARE MANY CRITERIA TO CONSIDER



Embodied carbon



Indoor environment quality



Energy efficiency



Ecosystem impacts



Waste



Resilience



Maintenance & input



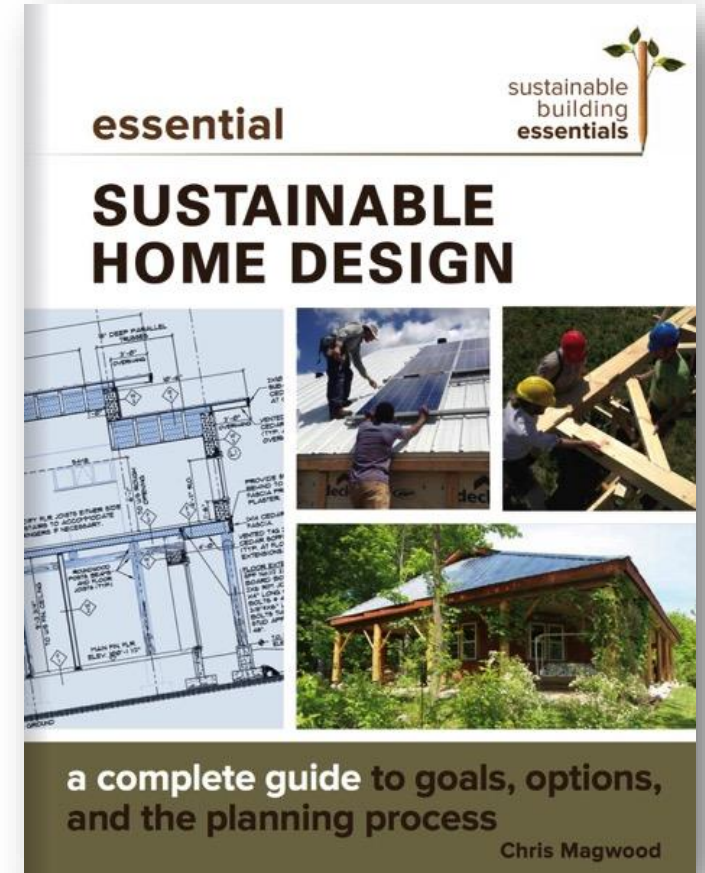
Code compliance













Material costs



Labour costs & sources



Criterion	1	2	3	4
 1. Ecosystems impacts	Code compliance: No particular requirements.	Some environmentally preferred products <i>Applicable standards:</i> LEED certified/silver, NGBA bronze/silver, R-2000, Active House minimum thresholds.	Majority environmentally preferred products <i>Applicable standards:</i> LEED gold/platinum, NGBA gold/emerald, Active House mid-range thresholds.	All environmentally preferred products <i>Applicable standards:</i> Living Building Challenge, Active House high thresholds.
 2. Embodied carbon	Code compliance: No particular requirements.	Reduced carbon: Footprint 25–50% lower than conventional standard. <i>Applicable standards:</i> Active House minimum threshold.	Low carbon: Footprint 50–90% lower than conventional standard. <i>Applicable standards:</i> Active House mid-range thresholds.	Ultra-low, net zero, or negative embodied carbon <i>Applicable standards:</i> Living Building Challenge, Active House high thresholds.
 3. Energy efficiency	Code compliance: Meets minimum local standard.	Reduced energy use: On-site energy use 25–50% less than code. May incorporate on-site renewable energy and/or renewable primary energy sources. <i>Applicable standards:</i> Energy Star, LEED certified/silver, NGBA bronze/silver, R-2000, Active House minimum thresholds.	Low energy use: On-site energy use 50–75% less than code. Likely to incorporate on-site renewable energy and/or renewable primary energy sources. <i>Applicable standards:</i> LEED gold/platinum, NGBA gold/emerald, R-2000, Active House mid-range thresholds.	Ultra-low, net zero, or net positive energy use: On-site energy use 75–100% less than code. Incorporates on-site renewable energy and/or renewable primary energy sources. <i>Applicable standards:</i> Living Building Challenge, Passive House.
 4. Indoor environment quality	Code compliance: No particular requirements.	Some low-emissions and non-toxic options <i>Applicable standards:</i> LEED certified/silver, NGBA bronze/silver, R-2000, Active House minimum thresholds.	Majority low-emissions and non-toxic options <i>Applicable standards:</i> LEED gold/platinum, NGBA gold/emerald, Active House mid-range thresholds, WELL silver/gold, IBN principles followed.	No emissions, fully non-toxic <i>Applicable standards:</i> Living Building Challenge, Active House high thresholds, WELL platinum, IBN tested.
 5. Waste	No measurement.	Basic management plan and sorting; minimal reduction targets <i>Applicable standards:</i> LEED certified/silver, NGBA bronze/silver, Active House minimum thresholds.	Comprehensive management plan; 25–50% reduction <i>Applicable standards:</i> LEED gold/platinum, NGBA gold/emerald, Active House mid-range thresholds.	Comprehensive management plan; 50–100% reduction <i>Applicable standards:</i> Living Building Challenge, Active House high thresholds.
 6. Resilience*	Code compliance: No particular requirements.	Minimal resilience targets: 3–7 days of potential self-reliance; siting accounts for major flooding/storms.	Moderate resilience targets: 7–28 days of potential self-reliance. <i>Applicable standards:</i> Resilient Design Institute principles inform some design decisions.	Complete resilience targets: Continuous potential self-reliance. <i>Applicable standards:</i> Resilient Design Institute principles and strategies fully employed.

Criterion	1	2	3	4
 7. Occupant Input and Durability*	No regular input required: Homeowner does not intend to be involved with systems or material maintenance.	Annual or bi-annual input may be required: Homeowner willing to engage in some minimal regular involvement.	Seasonal input required: Homeowner willing to engage in seasonal chores or maintenance.	Daily or weekly input required: Homeowner willing to engage in chores or maintenance as part of regular functioning of home.
*The number range for this criterion does not represent a quantitative value, only a preference for a more or less active involvement in the operations of the building. The answer range will have a major impact on mechanical systems and some material and finishes decisions. Frequency of occupancy, response times from HVAC equipment, and adaptability to changing life circumstances can all be important factors here.				
 8. Building code compliance*	Code compliance: Full use of prescriptive pathways.	Use of referenced standards: Code compliance includes some or full use of recognized standards, prescriptive pathway.	Some alternative compliance: One or more major elements of the building require an alternative compliance pathway.	Alternative compliance: A large number of building elements require an alternative compliance pathway.
*The number range for this criterion does not represent a quantitative value, only a preference for a more or less prescriptive approach to code compliance. There may be time and cost impacts for the answer range at the higher end of the spectrum.				
 9. Material costs*	Less than conventional production costs (<\$100/sq. ft.): Project likely to use site-harvested, local, and/or recycled materials. Cost will be a factor in all material decisions.	Equal to conventional production costs (\$100-150/sq. ft.): Project will use conventional materials or will balance use of lower-cost materials with higher-cost.	Equal to conventional custom costs (\$150-250/sq. ft.): Project will incorporate custom design elements and some higher cost materials.	High end or luxury costs (\$250/sq. ft. and up): Project will consider most or all other criteria before cost.
*The number range for this criterion represents a general quantitative value based on current North American market averages for construction costs (not including property costs, but including development fees, permits, and profit margins). These costs are based on conventional construction models, and they reflect common priorities (such as full basement foundations and standard kitchen cabinetry). It may be possible to employ strategies that lower costs compared to conventional figures in some areas to support higher costs in other areas. The number range should be used for evaluative purposes only, and full budget estimating must be undertaken to ensure the desired budget targets will be met.				
 10. Labor costs and sources of labor*	Entirely owner built: Project organized by owner and uses no or minimal paid labor.	Owner is general contractor; some hired labor: Project organized and built by owner; certain trade work contracted to professionals.	Owner is general contractor; most or all labor hired: Project organized by owner; professionals hired for build.	General contractor hired: Project is initiated by owner; general contractor responsible for all construction work and coordination.

Climate- and health-friendly homes should be easy because...

...Our building code already mandates these things:

HEALTH: “An objective of this code is to limit the probability that... a person in the building will be exposed to an unacceptable risk of illness due to indoor conditions.”

(OH1.1 specifies “indoor air quality”)

ENVIRONMENT: “An objective of this code is to limit the probability that... the natural environment will be exposed to an unacceptable risk of degradation.”

(OE1.1 specifies “emissions in the air”)



It's NOT easy because...

There is **not a single line of code** that directly addresses OH1 or OE objectives!

In fact, there are **absolutely no regulations** regarding the chemical content or carbon footprint of building materials.

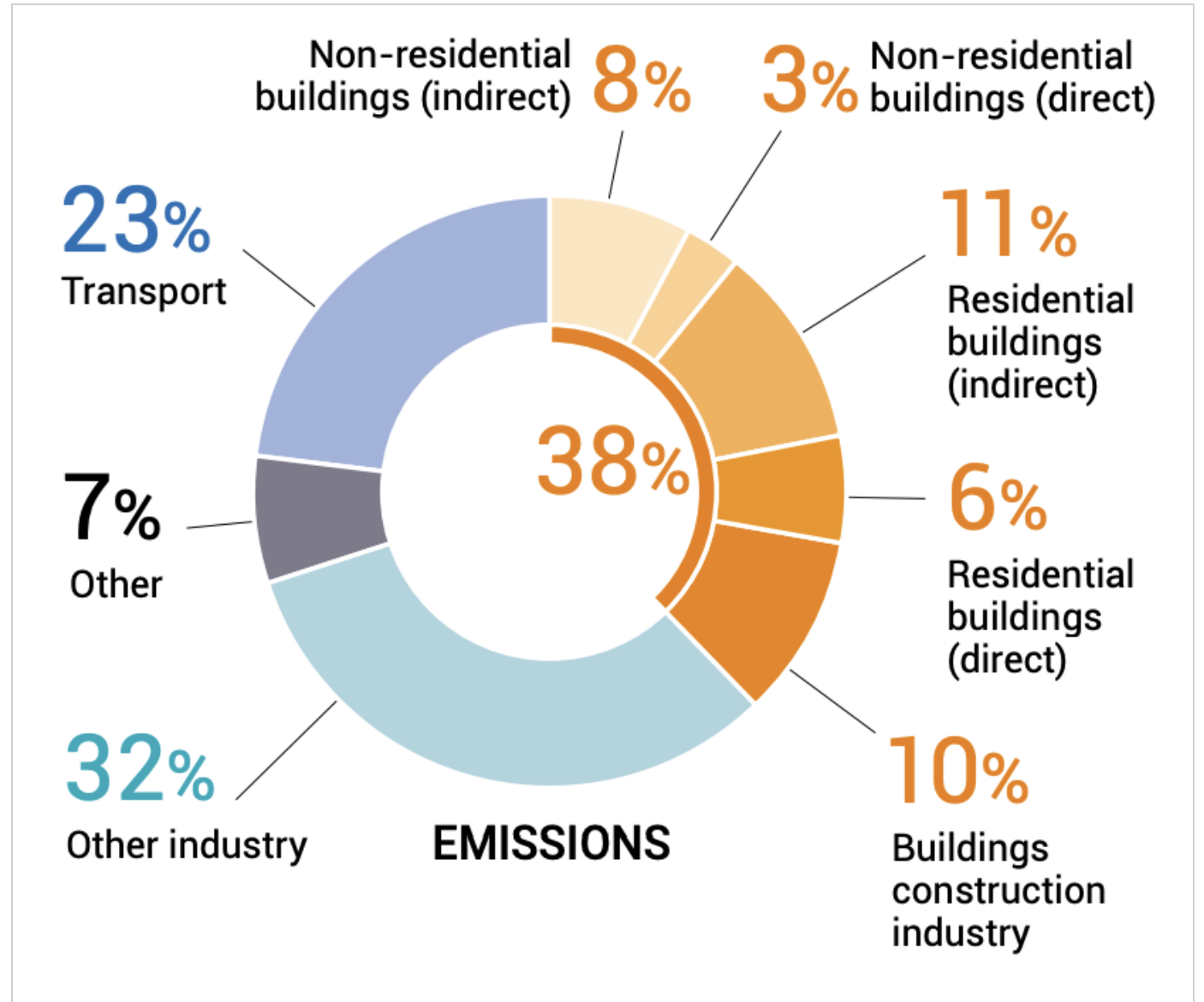


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Climate & buildings?

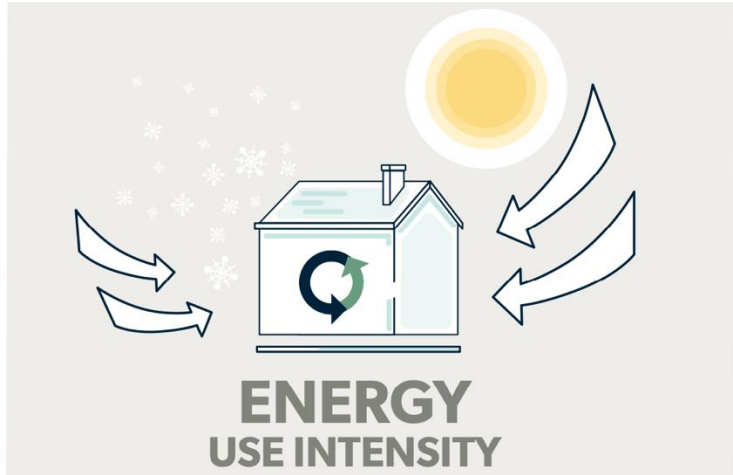
Climate change:

Buildings responsible for ~38% of all anthropogenic emissions¹



¹United Nation's Environment Programme's Sustainable Building and Climate Initiative (UNEPSBCI)

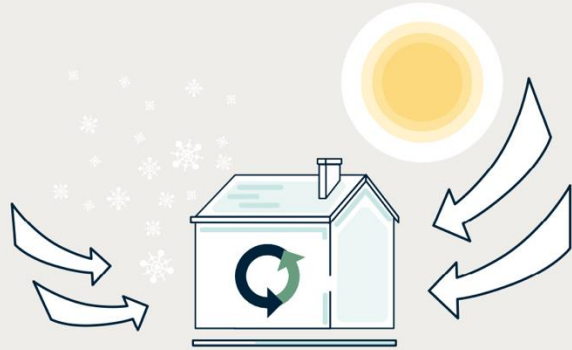
Climate & buildings



Amount of **energy** used
in a building

Climate & buildings

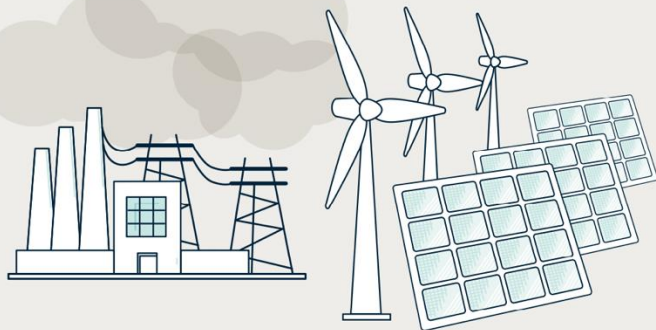
OPERATIONAL CARBON EMISSIONS



ENERGY
USE INTENSITY



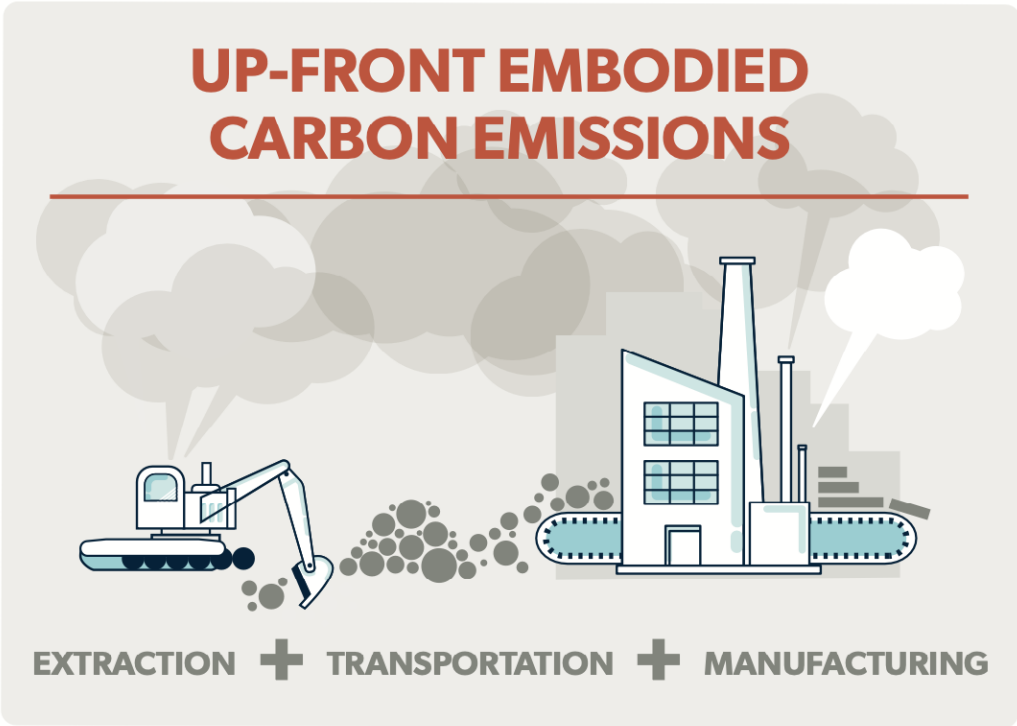
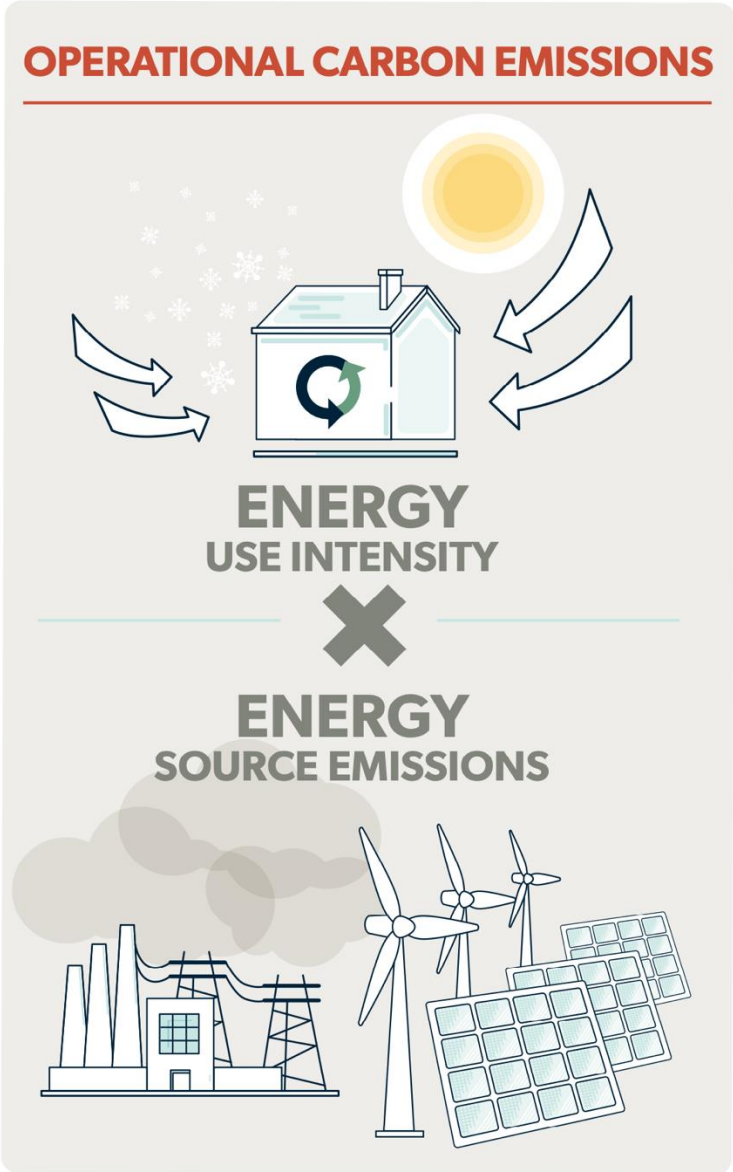
ENERGY
SOURCE EMISSIONS



Emissions intensity of energy sources varies widely

Fossil fuels have high emissions
Renewables have very low emissions

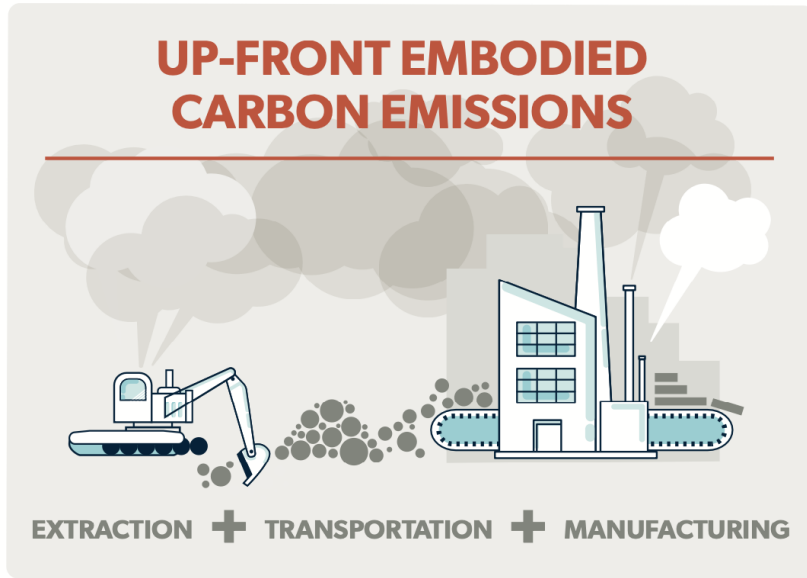
Climate & buildings



Emissions from producing materials have not typically been considered

Product-stage embodied carbon is a major issue

Low-rise residential construction:



Average per house: **40** tonnes

GTHA estimate: **840,000** tonnes/yr*

Canadian estimate: **14,000,000** tonnes/yr**

US estimate: **55,000,000** tonnes/yr***

*EMBARC report

**Achieving Real Net Zero Emission Homes

***The Hidden Climate Impact of Residential Construction

Climate change and buildings

GTHA 2-story
new home



70
tonnes
(3.5 t/yr)

Operating emissions w/gas heating
(20 years)

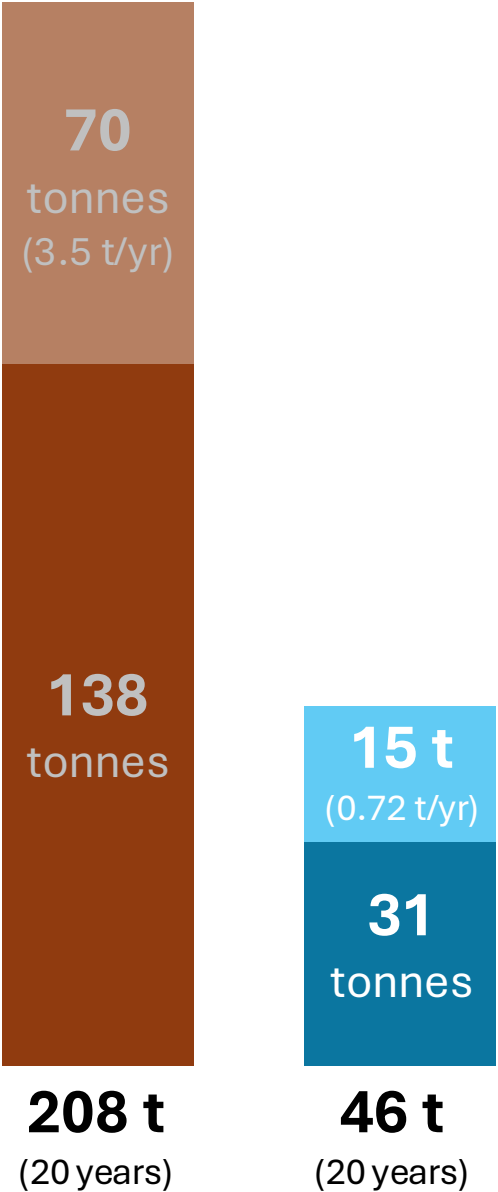
138
tonnes

Up-front emissions
(high emission materials)

**Achieving Real Net Zero Emission Homes

Climate change and buildings

GTHA 2-story
new home



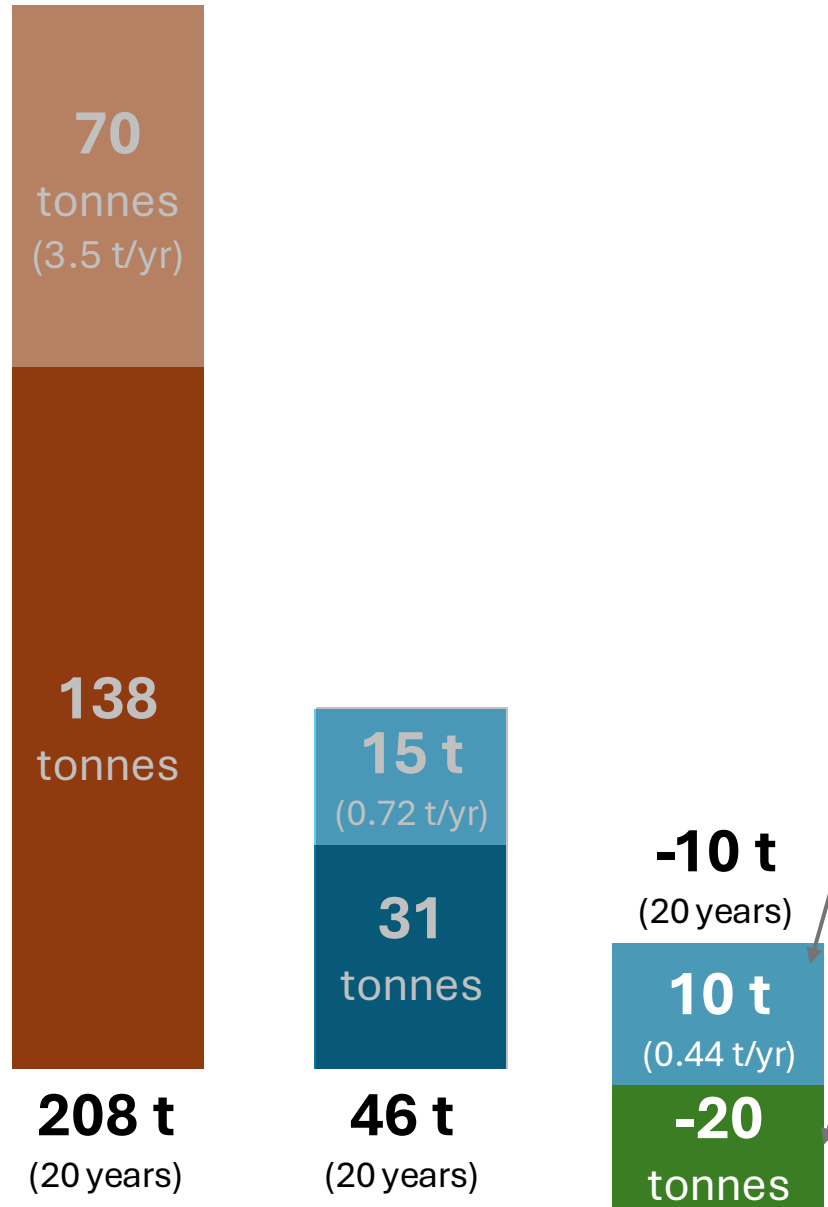
Operating emissions w/ clean-ish
electric heat
(20 years)

Up-front emissions
(low emission materials)

**Achieving Real Net Zero Emission Homes

Climate change and buildings

GTHA 2-story
new home



Operating emissions w/electric heat, high efficiency, (20 yr)

Up-front emissions
(net carbon storage materials)

**Achieving Real Net Zero Emission Homes

What are these magical, carbon-storing materials?



Timber
(sustainably harvested)



Wood fiber board



Hemp hurd & fiber



Cork



Natural insulation
(hemp, wood, wool, cellulose, grass, etc)



Cellulose (waste paper fiber)



Waste textiles

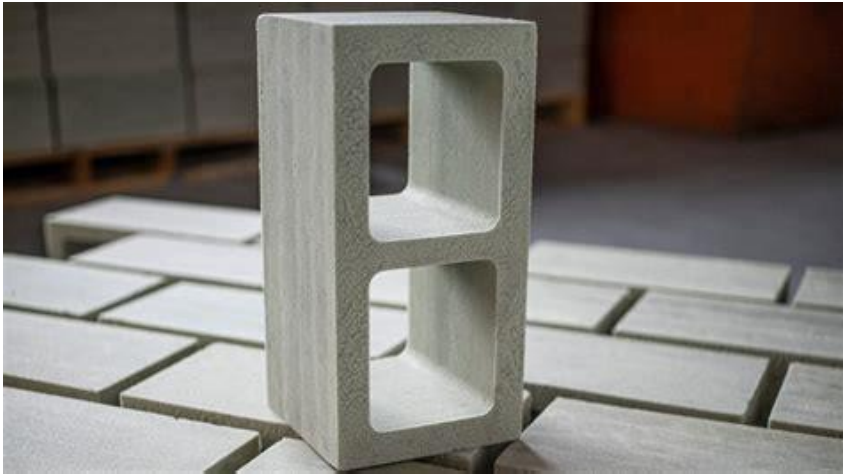


Straw (waste ag fiber)



Bamboo

More to come: Paradigm shift to purpose-grown materials

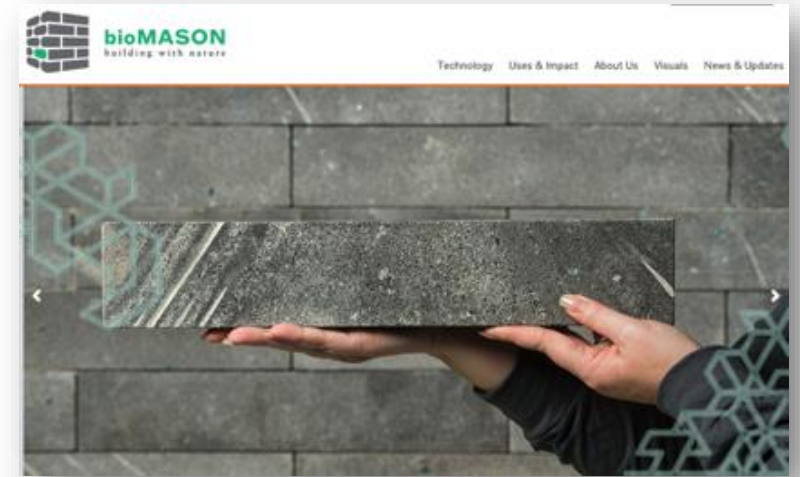


Prometheus
algae-grown
bricks & blocks

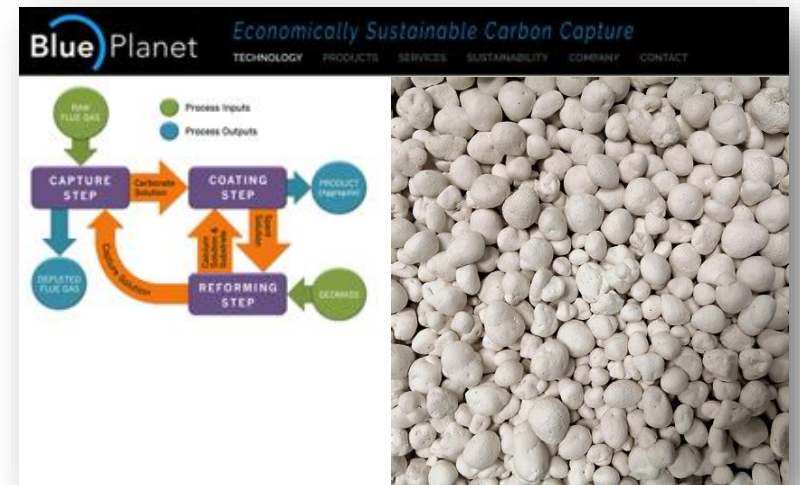


Okomwrks
structural mycelium
composites

bioMASON
microbe-
grown bricks &
blocks

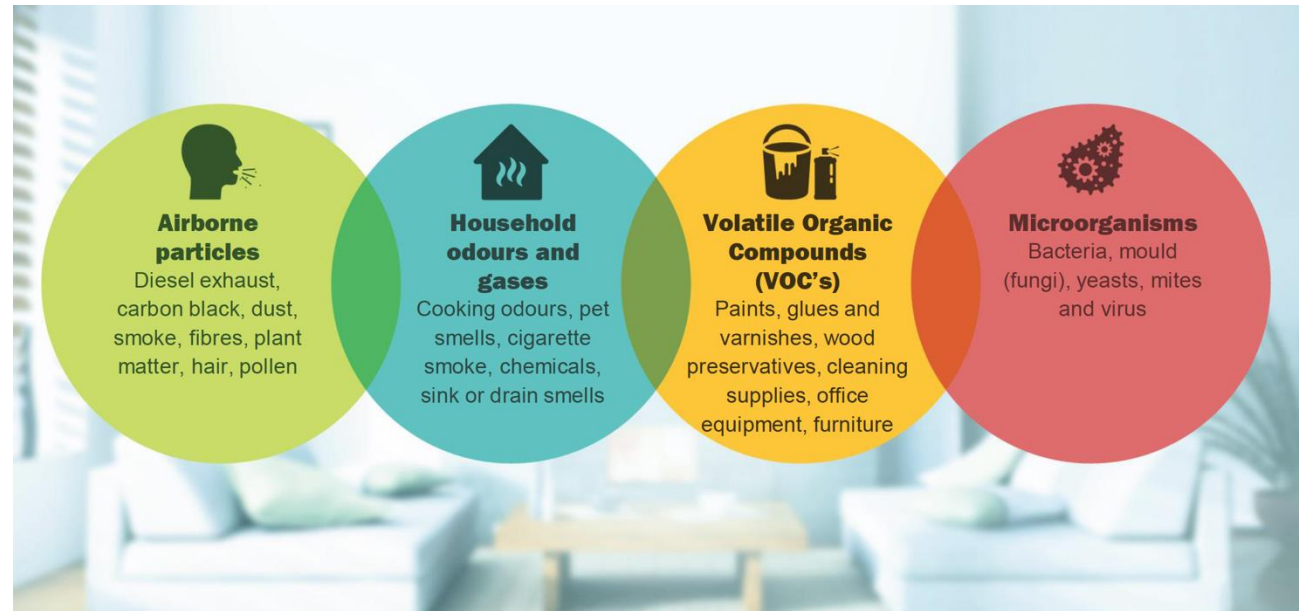


Blue Planet
aggregate
from waste
CO₂



Health & buildings

*“Comparative risk studies performed by US EPA’s Science Advisory Board consistently rank **indoor air pollution** among the **top five environmental risks to public health.**”¹*



¹<https://www.epa.gov/iaq-schools/why-indoor-air-quality-important-schools>

Health & buildings

There are **NO regulations for chemical content** in building materials in Canada. Only asbestos and lead are prohibited from being used in building materials.

*“**Indoor air pollution is often higher than outdoor air pollution.** This has been observed in indoor spaces including public buildings, schools, kindergartens and homes in developed countries.”¹*

*“The scientists found that in the green condition – where air was better ventilated and had lower carbon dioxide and VOC concentrations – **participants scored 61 percent higher in cognitive function** compared with those in conventional office building conditions.”²*

¹ European Environment Agency, Environment and Human Health, 2013 EEA Report #5/2013

² Newsweek, Your Office Air is Killing You, 6/2/16

Health & buildings

It is remarkably difficult to make a building and avoid **Red List chemicals**...

The Red List

Alkylphenols

Asbestos

Bisphenol A (BPA)

Cadmium

Chlorinated Polyethylene and Chlorosulfonated Polyethylene

Chlorobenzenes

Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs)

Chloroprene (Neoprene)

Chromium VI

Chlorinated Polyvinyl Chloride (CPVC)

Formaldehyde (added)

Halogenated Flame Retardants (HFRs)

Lead (added)

Mercury

Polychlorinated Biphenyls (PCBs) Perfluorinated Compounds (PFCs)

Phthalates

Polyvinyl Chloride (PVC)

Polyvinylidene Chloride (PVDC)

Short Chain Chlorinated Paraffin

Wood treatments containing Creosote, Arsenic or Pentachlorophenol

Volatile Organic Compounds (VOCs) in wet applied products

Health & buildings

...let alone the US
**EPA's 187 Hazardous
 Air Pollutants:**

CAS Number	Chemical Name
75070	Acetaldehyde
60355	Acetamide
75058	Acetonitrile
98862	Acetophenone
53963	2-Acetylaminofluorene
107028	Acrolein
79061	Acrylamide
79107	Acrylic acid
107131	Acrylonitrile
107051	Allyl chloride
92671	4-Aminobiphenyl
62533	Aniline
90040	o-Anisidine
1332214	Asbestos
71432	Benzene (including benzene from gasoline)
92875	Benzidine
99077	Benzotrichloride



MATERIAL SAFETY DATA SHEET BEADEX® Lite All Purpose Drywall Joint Compound

MSDS #61-360-025
 Page 2 of 9

CARCINOGENICITY CLASSIFICATION OF INGREDIENT(S) All substances listed are associated with the nature of the raw materials used in the manufacture of this product and are not independent components of the product formulation. All substances, if present, are at levels well below regulatory limits. See Section 11: Toxicology Information for detailed information.

MATERIAL	IARC	NTP	ACGIH	CAL- 65
Vinyl Acetate Monomer	2B	Not Listed	A3	Not Listed
Acetaldehyde	2B	2	A3	Listed
Formaldehyde	1	2	A2	Listed
Crystalline silica	1	1	A2	Listed

Section 3: Hazards Identification

Potential Acute Health Effects:

Very hazardous in case of skin contact (irritant), of eye contact (irritant), of inhalation (lung irritant). Hazardous in case of ingestion. Slightly hazardous in case of skin contact (permeator). Inflammation of the eye is characterized by redness, watering, and itching. Skin inflammation is characterized by itching, scaling, reddening, or, occasionally, blistering.

Potential Chronic Health Effects:

Hazardous in case of inhalation (lung irritant). CARCINOGENIC EFFECTS: Classified + (PROVEN) by OSHA. Classified A3 (Proven for animal.) by ACGIH, 2B (Possible for human.) by IARC. MUTAGENIC EFFECTS: Not available. TERATOGENIC EFFECTS: Not available. DEVELOPMENTAL TOXICITY: Not available.

Section 3: Hazards Identification

Potential Acute Health Effects:

Hazardous in case of eye contact (irritant), of ingestion, of inhalation (lung irritant). Slightly hazardous in case of skin contact (irritant, permeator).

Potential Chronic Health Effects:

Hazardous in case of skin contact (irritant). Slightly hazardous in case of skin contact (sensitizer). CARCINOGENIC EFFECTS: Classified 2B (Possible for human.) by IARC. MUTAGENIC EFFECTS: Mutagenic for mammalian somatic cells. Mutagenic for bacteria and/or yeast. TERATOGENIC EFFECTS: Classified POSSIBLE for human. DEVELOPMENTAL TOXICITY: Not available. The substance may be toxic to liver. Repeated or prolonged exposure to the substance can produce target organs damage.

Section 3: Hazards Identification

Potential Acute Health Effects:

Very hazardous in case of eye contact (irritant), of ingestion, . Hazardous in case of skin contact (irritant, sensitizer, permeator), of eye contact (corrosive). Slightly hazardous in case of skin contact (corrosive). Severe over-exposure can result in death. Inflammation of the eye is characterized by redness, watering, and itching.

Potential Chronic Health Effects:

Hazardous in case of skin contact (sensitizer). CARCINOGENIC EFFECTS: Classified A2 (Suspected for human.) by ACGIH, 2A (Probable for human.) by IARC [Formaldehyde]. MUTAGENIC EFFECTS: Mutagenic for mammalian somatic cells. [Formaldehyde]. Mutagenic for bacteria and/or yeast. [Formaldehyde]. Mutagenic for mammalian somatic cells. [Methyl alcohol]. Mutagenic for bacteria and/or yeast. [Methyl alcohol]. TERATOGENIC EFFECTS: Classified POSSIBLE for human [Methyl alcohol]. DEVELOPMENTAL TOXICITY: Not available The substance may be toxic to kidneys, liver, skin, central nervous system (CNS). Repeated or prolonged exposure to the substance can produce target organs damage. Repeated exposure to a highly toxic material may produce general deterioration of health by an accumulation in one or many human organs.

“That’s okay, I used no-VOC paints in my house...”

The US EPA addressed this in their publication *“Inside IAQ”*:

- ...**The results illustrate that “no-VOC” does not necessarily mean no-emissions.** The common indoor air definition of VOC only includes those organic compounds with boiling points between 50 and 260°C. A number of hazardous air pollutants (e.g., formaldehyde with a boiling point of -21°C) are not accounted for by this definition. Also, the VOC contained in the bulk paint may not be the VOC emitted since VOCs can be formed as byproducts of chemical reactions after the paint is applied. ***The results also indicate that EPA Reference Method 24 is probably not an adequate method for measuring the VOC content of low-VOC latex paints.*** ...Current bulk analysis and emission test results showed that the VOC contents of low-VOC latex paints (e.g., less than 0.1%) are well within the uncertainty range of Method 24, and the method is apparently not precise enough to accurately define the VOC content of those paints. -EPA/600/N-98/003



FEDERAL TRADE COMMISSION
PROTECTING AMERICA'S CONSUMERS

Paint Companies Settle FTC Charges That They Mised Consumers; Claimed Products Are Emission- and VOC-free and Safe for Babies and other Sensitive Populations

Orders require companies to show paint emits no harmful chemicals at the time paint is applied when making unqualified zero-emission/zero-VOC Claims



Choosing healthier paints...



Lime Paint ▼

Mineral Silicate Paint ▼

Acrylic/Latex Paint Free of APEs and PFAS ▼

Waterborne Alkyd Paints Free of APEs and PFAS ▼

Acrylic/Latex Paint Containing APEs and/or PFAS ▼

Waterborne Alkyd Paints Containing APEs and PFAS ▼

Solventborne Alkyd Paints ▼

Typical paints are in three worst categories



Isn't foam insulation a “green” product?

5-20% of the weight of foam insulation is flame retardants, due to the high flammability of the material.

Flame retardants are highly toxic to human health and the environment. The Green Science Policy Institute has found them all to be **“persistent, bioaccumulative, and/or toxic. Additionally, some of these FRs are carcinogens, mutagens, and/or reproductive, neurological, thyroid, and/or developmental toxins.”**¹



¹ The Flame Retardant Dilemma, Green Science Policy Institute, <http://www.greensciencepolicy.org/wp-content/uploads/2013/12/Green-Building-HFR-Insulation-fact-sheet-November-2010.pdf>

Isn't foam insulation a “green” product?

The **San Antonio Statement** (2010)¹: “[They] can undergo long-range transport, are persistent and bioaccumulative (leading to food chain contamination), lack adequate toxicity information, do not have a proven overall fire safety benefit in some cases, increase fire toxicity which is a leading cause of fire deaths, and produce toxic dioxins and furans when burned.”

And yet the market is sunny for flame retardant chemicals: **“Flame retardants market size may reach over 2.9 million tons by 2023.** Construction application may account for over 25% of the overall volume by 2023.”²



¹ San Antonio Statement: <https://greensciencepolicy.org/docs/san-antonio-statement-impacts-11.pdf>

² Flame Retardant Chemicals Market Size, 2016-2023, Global Market Insights, <https://www.gminsights.com/industry-analysis/flame-retardant-chemicals-market>

Intersection of climate & health: Paint



EMBODIED
CARBON,
kg CO2e

17.2

Lime Paint



48

Mineral Silicate Paint



265

Acrylic/Latex Paint Free of APEs and PFAS



Waterborne Alkyd Paints Free of APEs and PFAS



288

Acrylic/Latex Paint Containing APEs and/or PFAS



Waterborne Alkyd Paints Containing APEs and PFAS



369

Solventborne Alkyd Paints



Intersection of climate & health: Insulation



-2,235	Expanded Cork Boards	220	Kraft-Faced Fiberglass Batts
-795	Blown-In Wood Fiber (Loose Fill and Dense Pack)	-584	Cellulose/Cotton Batts
-237	Blown and Batt Sheep's Wool	-695	Blown-In Cellulose (Dense Pack and Wet-Blown)
-178	Hemp Fiber Batts	220	PSK or FSK-Faced Fiberglass Batts
-2,706	Wood Fiber Batts and Boards	554	Standard Mineral Wool Batts and Boards
328	Blown-In Fiberglass or Mineral Wool (Loose Fill, Dense Pack, and Spray-Applied)	820	Standard Fiberglass Boards
220	Unfaced Fiberglass Batts	782	Halogen-Free Polyisocyanurate Boards
429	Formaldehyde-Free Mineral Wool Batts and Boards		ASJ- or FSK-Faced Fiberglass Boards
-348	Blown-In Cellulose (Loose Fill)	1,234	Expanded Polystyrene (EPS) Boards
308	Unfaced Formaldehyde-Free Fiberglass Boards	782	Standard Polyisocyanurate (Polyiso) Boards
		1,605	Extruded Polystyrene (XPS) Boards
		4,306	Spray Polyurethane Foam (SPF)

EMBODIED
CARBON,
kg CO2e

THERE ARE MANY CRITERIA TO CONSIDER



Ecosystem impacts



Resilience



Embodied carbon



Maintenance & input



Energy efficiency



Code compliance



Indoor environment quality



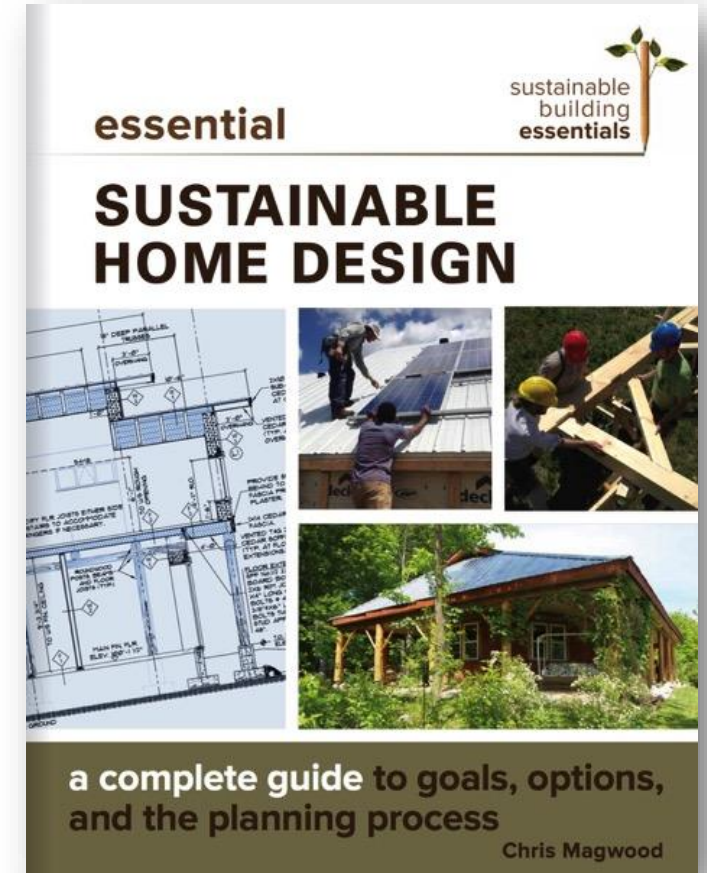
Material costs



Waste



Labour costs & sources



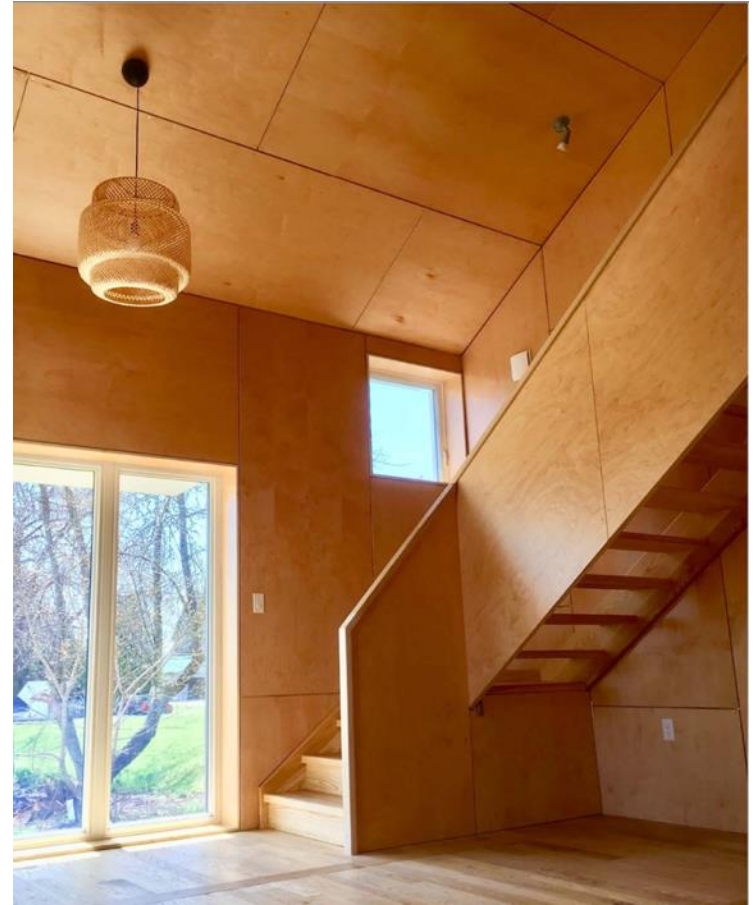
CASE STUDY

Zero House

1,100 ft²

Straw bale insulation
Cellulose insulation
Mycelium insulation
FSC wood interior

14 tons storage



CASE STUDY

Solstice Northeast

23-unit passive
house

40 kg CO₂e/m²

Cellulose insulation
Engineered wood
siding

FSC certified lumber

90 tons storage

1.7% budget increase



Photo by Footprint Development

Baseline	Solstice Northeast	Carbon Reduction
Fiberglass batt insulation	Dense pack cellulose insulation	-20.6 tCO₂e
Fiber cement siding and full-depth brick	Engineered wood siding and thin brick	-14.4 tCO₂e
Standard carpet and LVP	Interface™ carpet and LVP	-9.2 tCO₂e
Standard gypsum wall board	USG EcoSmart™ Panels	-9.1 tCO₂e

CASE STUDY

Baysville duplex

Passive house

51 kg CO₂e/m²

Prefab panels:

Cellulose insulation

Wood fiber insulation

FSC certified lumber

5 tons storage



More information:

www.rmi.org

www.buildersforclimateaction.org

