The City of Nelson's first edition of its...

MATERIAL CARBON EMISSIONS GUIDE

MARCH 2022

This guide was developed as part of the FortisBC-funded Low Carbon Homes Pilot (LCHP). This pilot aimed to promote a more holistic way of addressing building emissions by considering material carbon emissions, also referred to as embodied carbon or embodied emissions, alongside operational emissions. Material carbon emissions refer to all emissions associated with the creation of a building apart from the operating emissions (i.e., energy use).

The Low Carbon Homes Pilot analyzed 34 recently constructed Part 9 (less than 600m^2 and otherwise known as low-rise) residential homes in Nelson and Castlegar to estimate an average amount of upfront material carbon emissions and identify which materials, if targeted, could result in the biggest emission reductions. This guide aims to make this recently compiled data accessible and facilitate its use.

The guide is split into three main sections:

- The first section introduces the work and describes how to use this guide.
- The second section offers insight on how to reduce material carbon emissions associated with all eight of the material categories represented in the LCHP study. It visualizes EPD data for a variety of different products within the four most impactful material categories in the form of product rankings. The data provided in this guide is most relevant to municipalities with similar building practices but highlights numerous considerations that are universally relevant.
- The third section offers additional resources that may help folks take action. This includes some information about embodied carbon calculator tools and answers to a series of frequently asked questions.

Learn more about the findings of the LCHP by reading the benchmarking report, which is available on the City of Nelson's website.

This guide was developed by Builders for Climate Action and the City of Nelson with editing support from 3West Building Energy Consultants Inc., and financial support from FortisBC and the City of Castlegar. More specifically, it was created by Chris Magwood, Director of Builders for Climate Action, and Natalie Douglas, Embodied Carbon Pilot Coordinator at the City of Nelson, with editing help from Michele DeLuca, Energy Advisor at 3West Building Energy Consultants.

1 How to Use this Guide

This section describes the structure of this guide and how municipal staff, builders, and others may use it to help identify ways to reduce their material carbon emissions.

This guide relies on data collected from Nelson and Castlegar for the LCHP study and more general information from the back end of the soon-to-be released Materials Carbon Estimator (MCE[2]) tool (see section 3 of this guide to learn more about this tool).

It is first important to recognize that the material carbon emissions data in this guide relies on cradle-to-gate (phases A1 - A3 of a life cycle assessment) analyses of different categories of building materials. In this context, cradle refers to resource extraction and gate refers to the factory gate (i.e., before the product is transported to the consumer). In other words, this guide tells you which materials have less emission intensive raw material acquisition and manufacturing processes and therefore a smaller carbon footprint. It should be noted that although this does not account for the full life cycle emissions associated with these products, 65-75% of the overall material carbon emissions associated with building products sit within the A1-A3 phase of its life cycle. For this reason, we have focused our efforts on highlighting the materials with high A1-A3 emissions (otherwise known as upfront embodied carbon) to make a significant dent in overall material carbon emissions.

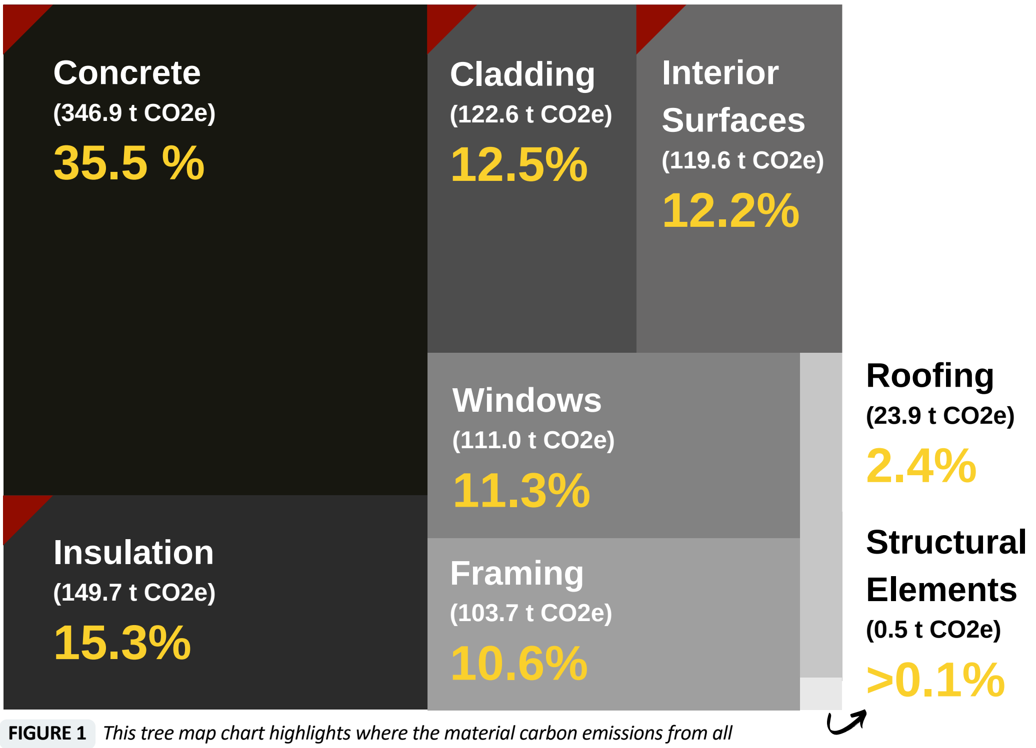
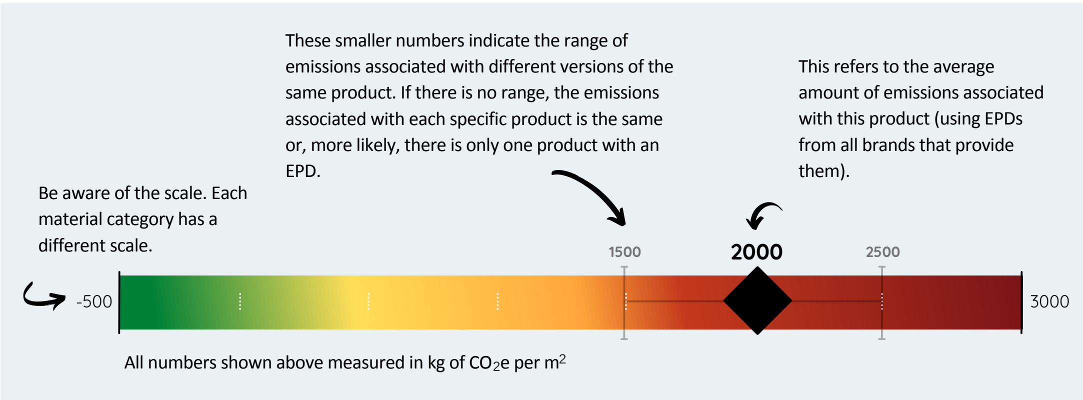


FIGURE 1 *This tree map chart highlights where the material carbon emissions from all homes in the study came from based on eight main material categories.*

Figure 1 shows the impact of each of the eight material categories in the LCHP study. Not dissimilar from findings across Canada, the majority of the material carbon emissions in Nelson and Castlegar's Part 9 building sector come from concrete, insulation, cladding, and interior surfaces.

The red triangles in the top left corner of the concrete, insulation, cladding, and interior surfaces squares, on the last page, indicate that there was enough data to offer more detailed information about these material categories. Practically this means that the information provided for these material categories will be more robust than the remaining four categories (windows, framing, roofing, and structural elements). These categories contribute less to the overall emissions profile in this study and have fewer low carbon alternatives, thus receive less attention in this guide.

The more robust analyses offer product rankings that are presented in a manner similar to the fuel efficiency ratings you find for automobiles, providing comparative figures based on standardized assumptions. Each of the material categories with these ranking will be based on a specific amount of material, noted below each section title (e.g., concrete emissions for 1 m^3at 25 mPa strength), and are based on source data obtained from Environmental Product Declarations (EPDs). EPDs are internationally recognized standardized reports on product impacts. Most green building certifications processes require Type III EPDS, which means that the EPD has been reviewed by a third party. This guide does not list all products because not all products have EPDs. That being said, most products within the same material types have similar manufacturing processes and thus, tend to rank similarly according to their material carbon emissions.



These product rankings help facilitate low-carbon decision making by giving consumers a sense of the average amount of material carbon emissions associated with different product types.

The data presented in this guide seeks to help municipal staff, builders, and other interested parties begin to compare the material carbon emissions associated with different material types. It should not be seen as something that replaces a life cycle assessment. It instead seeks to offer itself as a starting point for integrating the consideration of material carbon emissions into more decision making processes. This guide seeks to support the overall goal of improving the reliability, transparency, and ubiquity of high-quality material carbon emissions data and highlight the need for continued research on the topic.

2 Key Findings

This section contains the most important information in the guide. It describes what material categories tend to contribute the most emissions to an average Part 9 building based on the LCHP study. It also illustrates this material carbon emission data, taken from EPDs, to enable generalized comparisons between product types.

The following section summarizes key findings from the LCHP study within each of the eight material categories outlined in section 1. It seeks to offer the reader some of the most important considerations for reducing emissions associated with each material category. The most emission intensive categories (concrete, insulation, cladding, and interior surfaces) have information about what product types, within each category, contributed the most emissions in the LCHP study and product rankings that show the emission intensity of a variety of product types based on EPD data. The remaining categories (windows, framing, roofing, and structural elements) have less information provided as they tend to offer fewer opportunities to reduce emissions through material choices. The material categories are listed according to their impact in the LCHP study with concrete contributing the most and structural elements contributing the least.

The following bullet points briefly describe offerings for each of the eight material categories:

- The concrete category is the first summarized in this section as it represents the largest material contributor to overall material carbon emissions in the LCHP study. It hosts an overview of the category, some information about how often each product type was used in the LCHP study, and a generalized ranking for different concrete mixes.
- The insulation category offers an overview, LCHP specific data, and generalized product rankings.
- The cladding category offers an overview, LCHP specific data, and generalized product rankings.
- The interior surfaces category offers an overview, LCHP specific data, and a generalized product ranking for flooring only (a subcategory of interior surfaces).
- The windows category offers an overview only.
- The framing category offers an overview only.
- The roofing category offers an overview only.
- The structural elements category offers an overview only.

In the product type rankings, the product types (e.g., brick) in each major material category (e.g., cladding) are listed from highest emissions to lowest emissions. To reduce the material carbon emissions associated with a building, select products that are further down on the list of each. It is important to recognize that this guide is recommending that the material carbon emissions discussed in this guide be considered in conjunction with energy efficiency considerations and other priorities (e.g., FireSmartBC and other disaster resilience and climate adaptation strategies).

Concrete accounts for 35.5% of the total material carbon emissions from the 34 homes in the LCHP study. The large majority of the emissions associated with this category come from the concrete itself. A small, almost negligible, amount come from the rebar, wire mesh, and aggregate used in the homes. It is important to note that this product type breakdown (see Figure 2) accounts for the amount of uses rather than focusing on the emissions intensity associated with these product types. Due to its relative emissions impact, the rankings on the next page focus exclusively on concrete mixes and addresses the question of emissions intensity.

The manufacturing of portland cement (the binder portion of concrete) creates emissions in two ways: from the burning of fossil fuels to heat and chemically transform limestone and from the CO_2 that is driven out of the limestone when heated. Globally, cement is one of the leading emitters of GHGs and thus, an important component to understand when seeking to reduce emissions associated with concrete.

Reducing concrete emissions is difficult not only because of the emissions associated with cement but also because of how pervasive the use of concrete is. There is also unfortunately no easy 1:1 material substitution for concrete. The LCHP study reinforces however that there are some emission reduction opportunities. Using lower carbon concrete mixes is currently one of the quickest ways to reduce emissions associated with Part 9 buildings if concrete needs to be used. By using concrete mixes that substitute a significant portion of the cement content with Supplementary Cementitious Materials (SCMs), the GHG impacts of concrete can be reduced by 5-35% without negatively affecting the strength of the product. The product rankings on the next page demonstrate the range of material carbon emissions associated with different concrete mixes.

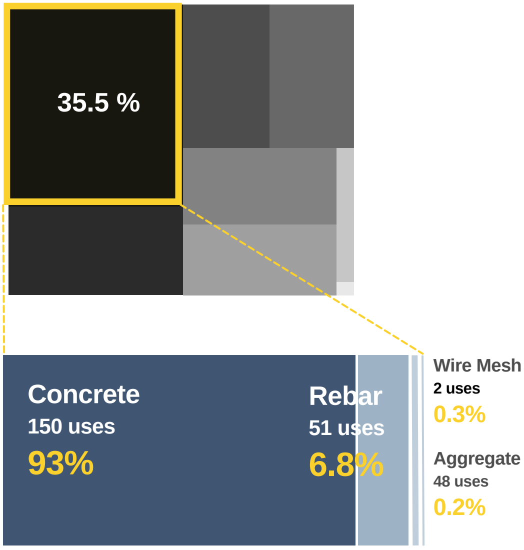


FIGURE 2

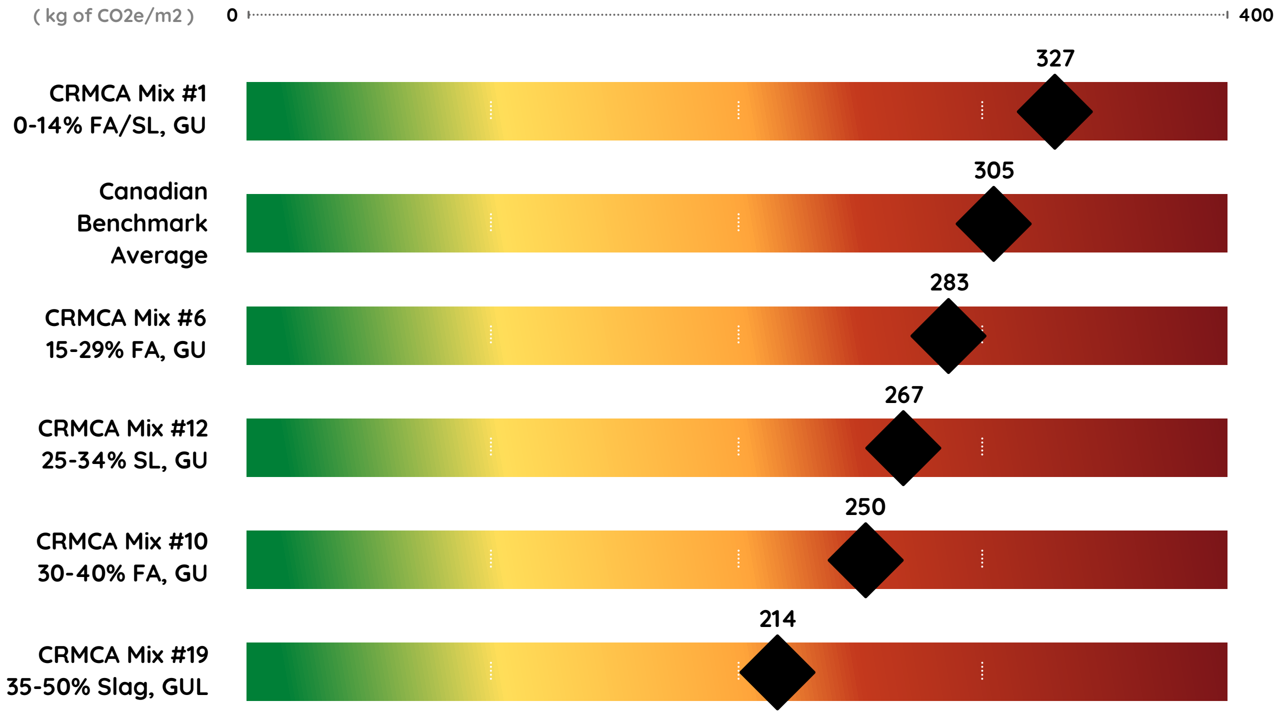
Figure 2 shows the product types that make up the material category: concrete, rebar, wire mesh, and aggregate. It illustrates how each product type contributes to the 35.5% and how often each product type is used in the LCHP study.

"Use" in this context means that the product type has been selected for a building component within a section of the project. It is a rough method of highlighting the emissions intensity of products. For example, 0.3% of emissions associated with the concrete material category come from 2 uses of wire mesh across the 34 homes whereas 0.2% of emissions come from 48 uses of aggregate, suggesting that wire mesh is likely more emissions intensive than aggregate. This measurement does not account for the exact amount of the product consumed per 'use', which is why the product rankings prove helpful as they compare uses based on a certain quantity of the material.

Figure 2 ultimately aims to draw attention to what materials are most commonly used in newly constructed homes in Nelson and Castlegar. It, in conjunction with the product rankings, seek to offer the local building community insight into what may be most strategic to focus emission reduction efforts on.

Concrete

concrete emissions for 1 m^3 at 25 mPa strength



Results from the Canadian Ready Mix Concrete Association of Canada (CRMCA) EPD of standard mixes available across the country.

FA	=	fly ash
SL	=	slag
GU	=	general use portland cement
GUL	=	portland limestone cement

Of Note: Concrete suppliers will have access to different types of cement and SCMs. In general, the higher the proportion of SCMs in a mix, the lower the carbon footprint. High SCM mixes often have higher final strength, but may take longer to develop their full strength. Typically, SCMs have a lower cost than portland cement, so reducing material carbon emissions by using higher proportions of SCMs in a mix may not raise the cost of the concrete.

Of Note: One of the most important things to remember when seeking to integrate the consideration and reduction of material carbon emissions is the role that building designers, engineers, and architects play. These professionals can design shapes, structures, and aesthetics that lead to less material carbon emissions. Homeowners can request or require these considerations. Reducing material carbon emissions means applying their consideration as early in the design phase as possible.

Insulation accounts for 15.3% of total material carbon emissions in the LCHP study. Most of the emissions within this insulation category can be attributed to EPS and XPS foam while mineral wool, fiberglass, and polyiso make up the rest.

Although XPS foam has the highest material emissions intensity (i.e., the most amount of material carbon emissions associated with each use of the product), EPS was used more often in the homes in this study and thus, represents more of the overall emissions. Similarly, despite fiberglass being used often, it represents fewer overall emissions because its material emissions intensity is relatively low. Figure 3 demonstrates the cumulative impact of each insulation product in the study whereas the product rankings on the next two pages highlight the material emissions intensity per product type.

Insulation is used in homes to prevent the loss of heat. Increasing the quantity of insulation is a key strategy for improving energy efficiency and helping reduce operational emissions. However, as the LCHP study made clear, using insulation with particularly high material emissions may eliminate all potential GHG emissions savings from reduced operational efficiency. As one of the three major contributors to material emissions, choosing lower emitting insulation materials is generally seen as an easy and cost-effective way of meaningfully reducing overall emissions. Homes use a lot of insulation and thus represent an excellent opportunity to reduce overall material emissions. Since energy efficient homes typically use more insulation, choosing an insulation that sequesters can amplify material carbon emissions reductions while still reaching high energy efficiency targets.

This guide divides insulation into two categories. Cavity insulation is typically used to insulate walls and attics. Board insulation is used as continuous insulation on walls, foundations, and some roofs. Many homes will use both types of insulation.

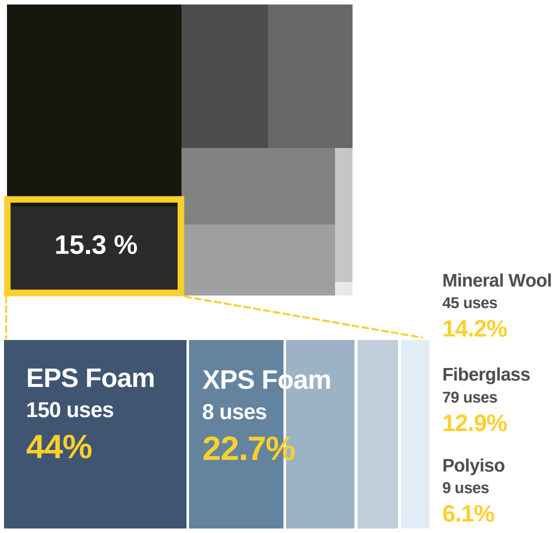


FIGURE 3

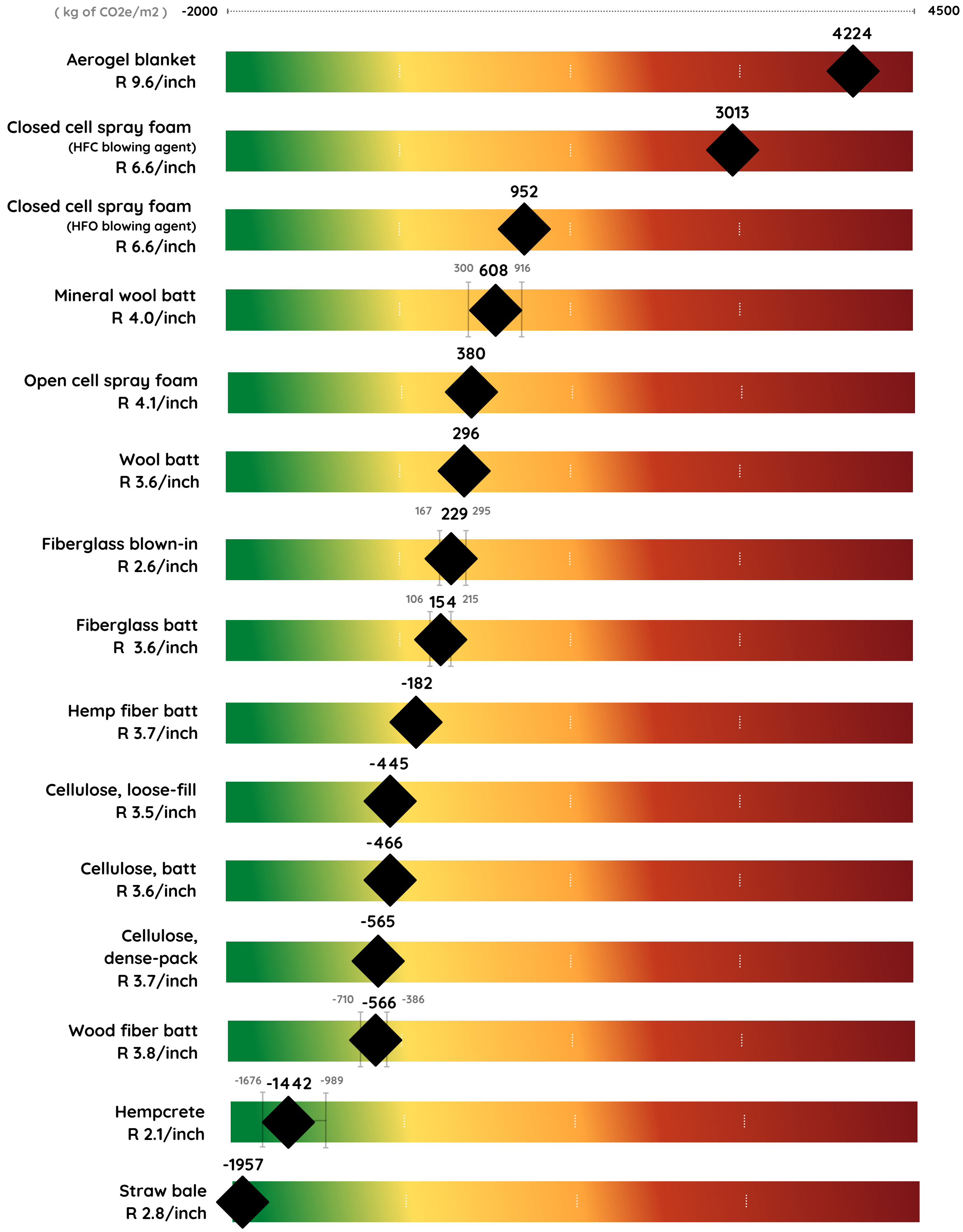
Figure 3 shows the product types that make up the insulation material category: EPS foam, XPS foam, mineral wool, fiberglass, and polyiso. It illustrates how each product type contributes to the 15.3% and how often each product type is used in the LCHP study.

For example, 14.2% of emissions associated with the insulation material category come from 45 uses of mineral wool across the 34 homes. This suggests that mineral wool is relatively common in Nelson and Castlegar and that it seems to be more emissive than fiberglass. To confirm the material emissions intensity, review the products rankings on the following two pages.

Of Note: All the XPS foam used in the homes included in the LCHP study was made from the legacy formula. As of January 2021, Canada prohibited any person to import or manufacture a plastic foam or a rigid foam product in which an hydroflurocarbon (HFC) is used as a foaming agent if the global warming potential of the foaming agent is greater than 150. This new legal requirements has led to the development of next-generation blowing agents and updated XPS formulas. These new formulas will become more widely available in 2022.

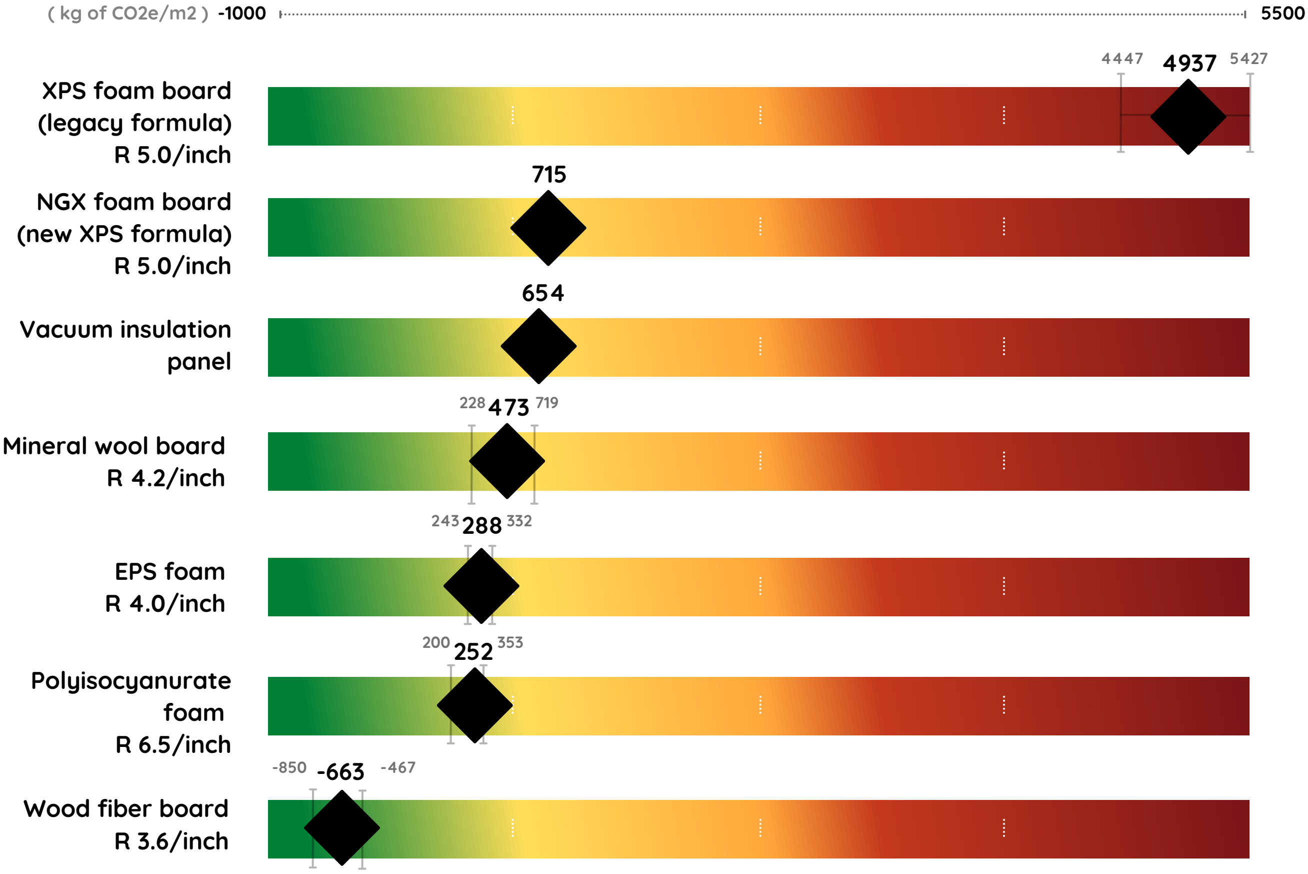
Wall Cavity & Attic Insulation

insulation emissions based on 100 m² (at R-13)



Rigid Insulation Boards

insulation emissions based on 100 m^2 (at R-5)



Of Note: Insulation materials have different R values per inch of material thickness, and this must be taken into account in home designs. They also have different performance attributes and thus, it may not be feasible to swap one material for another. It is important that impacts such as installation method, water/moisture performance, durability, and compressive strength are considered alongside material carbon emissions.

Of Note: Be aware that there may be some product types listed in this guide that your local retailers will be unfamiliar at this point. Although the large majority of them are easily available at most building supply stores, there are some that are newer and/or less commonly used.

Cladding accounts for 12.5% of total material carbon emissions in the LCHP study. Most of the emissions within the cladding category can be attributed to fiber cement siding and steel with minimal contributions from acrylic stucco, aluminum, wood, and brick.

Cladding covers the exterior of a home, and an essential role in protecting a home and defining its appearance. There is a wide range of material carbon emissions associated with different cladding options. Choices of cladding must balance GHG emissions, appearance, cost, durability, and maintenance.

Cladding has become an important component of FireSmartBC's programming. For this reason, it has been identified that future phases of the LCHP should work to emphasize the importance of aligning low emission material choices with energy efficiency priorities plus disaster and climate resilient strategies.

The yellow symbols on the next page indicate that these materials are recommended by FireSmartBC as a non-combustible or fire-resistant siding option. In FireSmartBC's homeowner manual, it also mentions that logs and heavy timbers are reasonably fire resistant while untreated wood and vinyl siding provide very little protection against fires. The slightly faded yellow symbol indicates that these materials have fire-resistant properties but are not explicitly recommended by FireSmartBC.

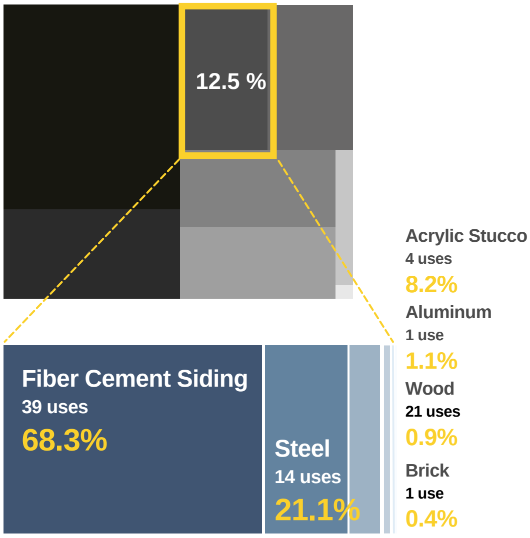


FIGURE 4

Figure 4 shows the product types that make up the cladding material category: fiber cement siding, steel, acrylic stucco, aluminum, wood, and brick. It illustrates how each product type contributes to the 12.5% and how often each product type is used in the LCHP study.

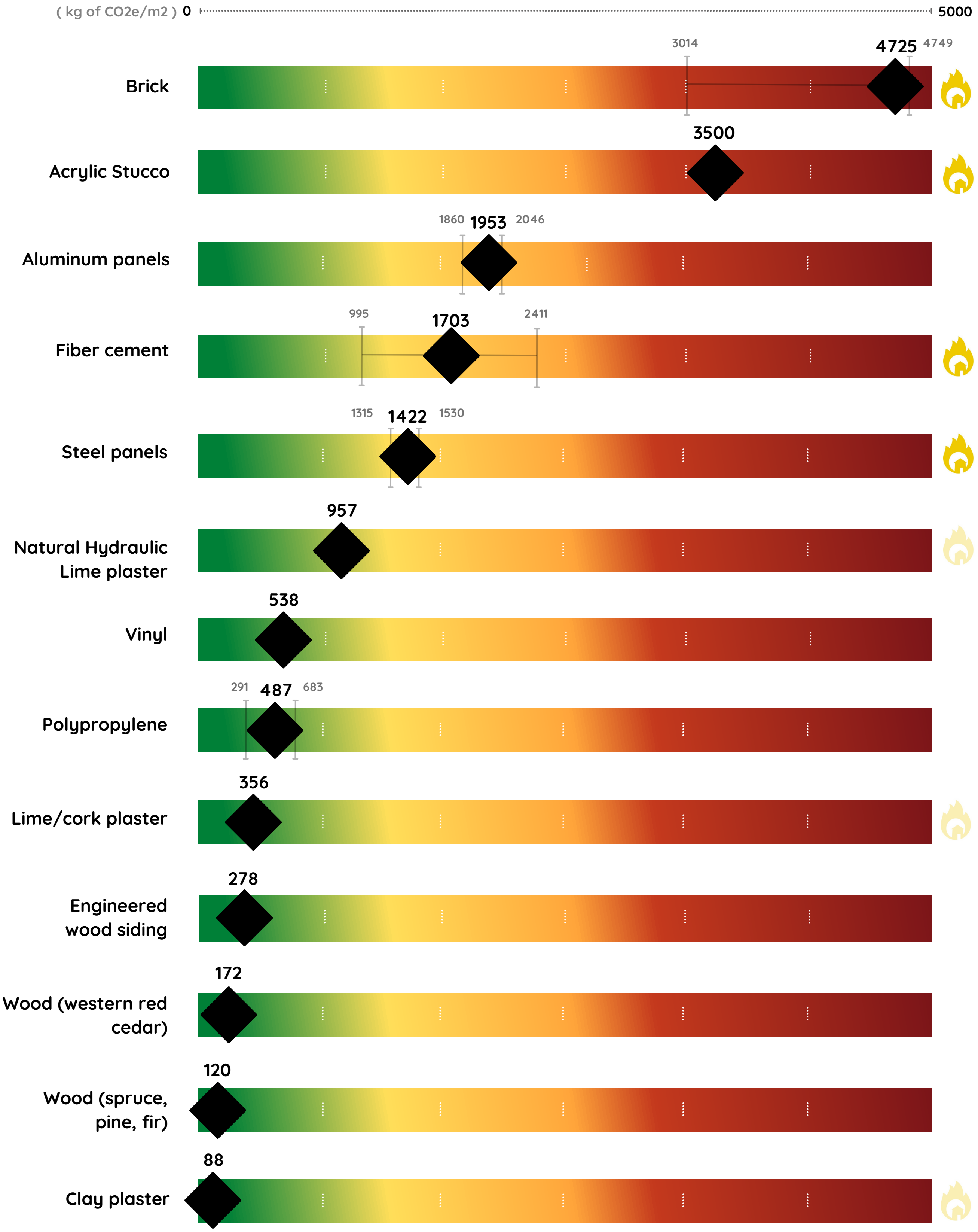
While fiber cement siding and wood appeared most often in the 34 study homes, their relative emissions impact varies greatly and suggest the need to check the product rankings / material emissions intensity. Similarly, brick made up a negligible proportion of overall emissions in the LCHP study but has an extremely high material emissions intensity. It represents a small proportion of the overall emissions purely because a tiny amount of brick was used (5% of the cladding area of one small building used brick).

As mentioned previously, this information is presented chiefly to demonstrate what materials are being used most often in recently constructed homes in Nelson and Castlegar.

Of Note: There is no one right decision when choosing low carbon and resilient building materials. Understanding the fire risk in your area is a first step. In lower risk areas, some of the less fire resistant sidings may be appropriate to use if other steps are taken to reduce fire hazard (e.g., decrease the density of nearby trees, prune lower branches, landscape yard with fire-resistant plants etc.). In high risk areas, highly fire resistant materials are often mandatory. Although many of these fire-resistant products have high material carbon emissions, in certain cases it might contribute to less overall emissions if it means that a building won't burn down and need to be replaced. All in all, further research is needed before official recommendations are made. If you want to learn more about climate resilient building, there is some innovative work being led by the Nlaka'pamux Nation (with the support of Foresight Canada) to consider embodied carbon, energy efficiency, fire resilience, and equity as the Village of Lytton and the surrounding area begin to rebuild after the devastating 2021 fire season.

Cladding

cladding emissions based on 100 m² (1,076 ft²)



Interior Surfaces

accounts for 12.2% of total material carbon emissions in the LCHP study. Most of the emissions associated with the interior surfaces material category in the LCHP study come from drywall for walls and ceilings and flooring products like vinyl and wood.

Seven different flooring types were represented in the study and thus, offered a good opportunity to demonstrate material substitution options. For this reason, the product ranking on the next page focuses exclusively on flooring options. It is worth noting however that different drywall products and brands do vary in their carbon footprint, and that selecting the lower-carbon drywall options can reduce impacts by up to 50%, as seen in the illustration below.

Of Note: To decipher what brands of drywall fall on the more emission intensive end of the spectrum, it may be necessary that you reach out to manufacturers to obtain life cycle inventory data and/or talk to a knowledgeable life cycle assessment professional who has experience assessing building materials and a good understanding of material carbon emissions.

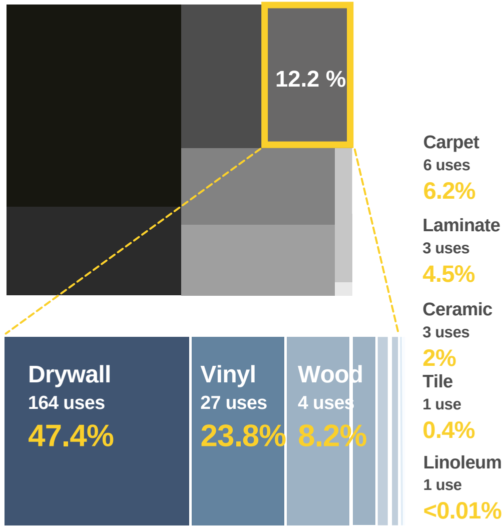
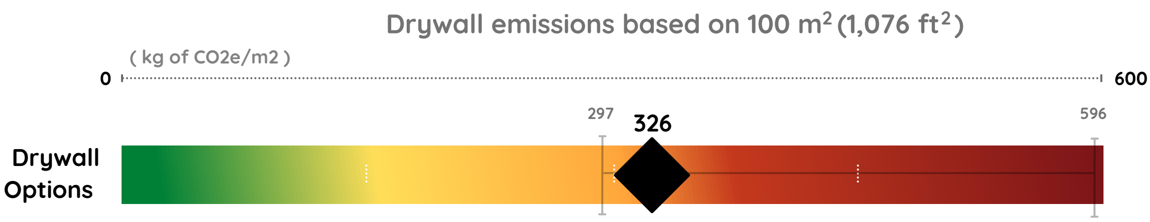


FIGURE 5

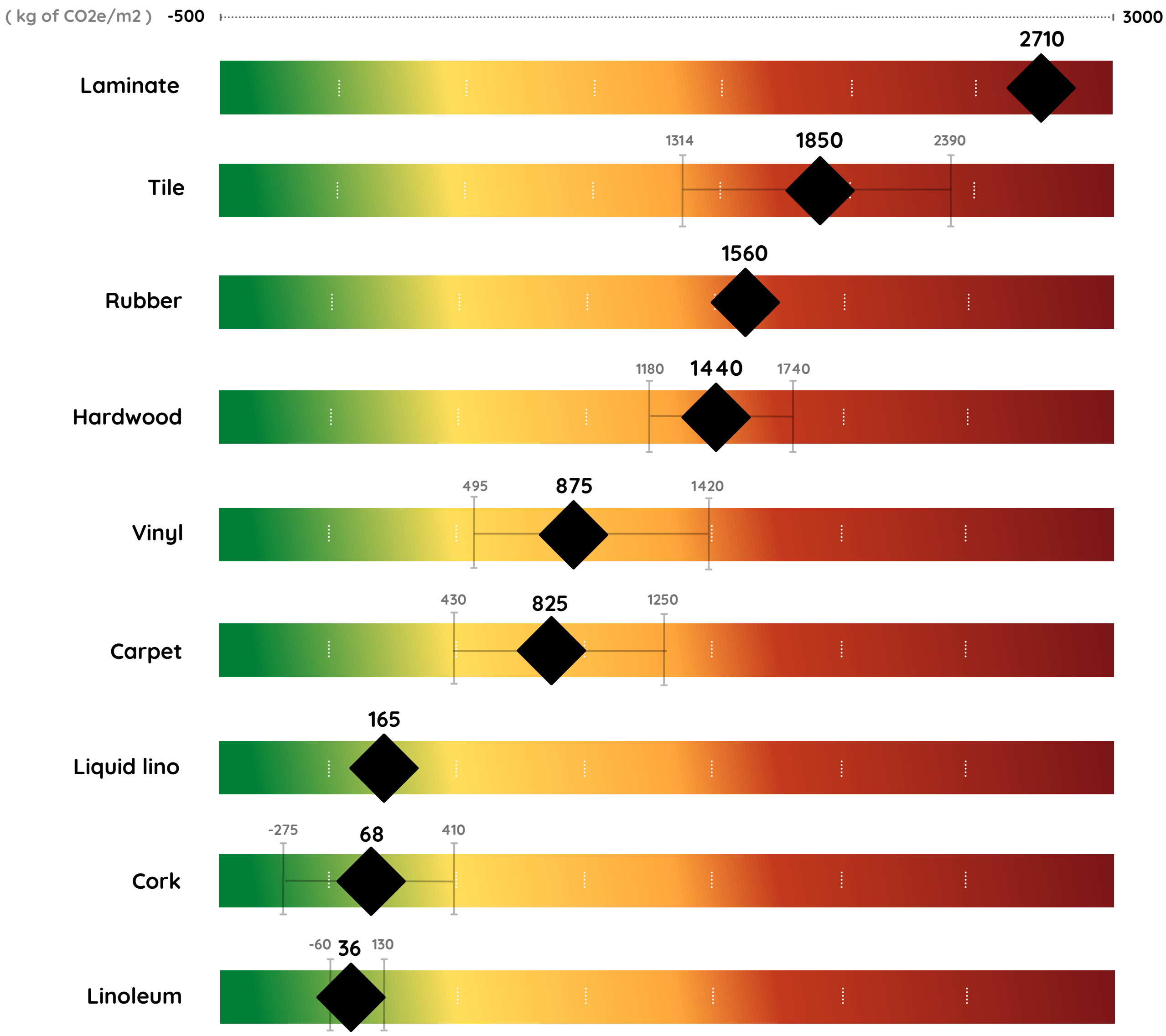
Figure 5 shows the product types that make up the interior surfaces material category: drywall, vinyl, wood, carpet, laminate, ceramic, tile, and linoleum. It illustrates how each product type contributes to the 12.2% and how often each product type is used in the LCHP study.

Similar to the concrete category, this breakdown highlights the difficulty in comparing a variety of product types with different uses (e.g., comparing drywall to flooring). It is for this reason that the product rankings on the next page focus exclusively on flooring types.



Flooring

Flooring emissions based on 100 m^2 (1,076 ft^2)



Of Note: All concrete flooring is accounted for in the concrete section. In the LCHP study, concrete flooring was modelled as the 'slab' in the foundation.

Windows

In the LCHP study, windows made up 10.9% of total material carbon emissions. Windows are commonly an important feature of reducing operational emissions (i.e., energy retrofits that improve the air tightness of the home by the use of 'better' windows). Unfortunately, windows, particularly thick ones like triple-pane windows, tend to have high material carbon associated with their manufacturing. For this reason, it is important that the material carbon emissions be considered alongside the operational emission considerations so that overall reductions in greenhouse gas emissions are assured. In an area with a high emission grid, reducing operational emissions through improved energy efficiency by replacing leaky windows might lead to significant overall emissions reductions. Whereas triple pane windows may not be worth it in a place with a low emission grid (i.e., the material carbon emissions associated with the manufacturing of the triple-pane windows may be higher than the emissions reductions from highly energy efficient triple-pane windows). This topic would also benefit from more research.

Framing

In the LCHP study, framing made up for 10.1% of total material carbon emissions. In this study, wood was the predominant material used for framing. In this case, the best action to take to reduce the emissions associated with wood framing is to source local and responsibly forested wood materials.

Roofing

In the LCHP study, roofing made up for 2.3% of total material carbon emissions. Similar to cladding, FireSmartBC material recommendations are an important consideration when deciding what materials work best for your building. If a home is being built in high risk fire area, it is often required to build with certain fire-resistant materials that have high material carbon emissions (e.g., metal, asphalt, clay, and composite rubber tiles). Many of the considerations outlined in the cladding section are relevant here as well.

Structural Elements

In the LCHP study, structural elements made up for 0.1% of total material carbon emissions. This category considers any large-dimension posts and/or beams required in the design. Although uncommon in the Kootenays, steel posts and beams are very common options for the structure in most places in Canada. Similar to framing, wood was the only product used in the structural elements category in the LCHP study and the main recommendation to reduce material carbon emissions in this case is to source locally and to make sure the wood is responsibly forested.

3 Additional Resources

This section offers insight into the calculation tool that was used in the LCHP study and a list of other tools and some answers to commonly asked questions. It seeks to further facilitate the consideration of material carbon emissions in the practice of a variety of building professionals and encourage innovation and practical problem-solving on the topic.

Calculator Tools

Want to learn more about how to calculate the material carbon emissions for your Part 9 building?

Check out the free Material Carbon Emissions Estimator Tool (MCE^2). This tool, co-developed by Builders for Climate Action and Natural Resource Canada (NRCan), allows individuals to input their Hot2000 energy modelling data and material data to get both the operational carbon emissions (i.e., emissions relating to energy use) and material carbon emissions (i.e., emissions relating to material use) for your home. This excel-based tool relies on EPD data to be able to give users the ability to look up the quantity of material carbon emissions associated with a variety of commonly used building products.

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In the LCHP study, this calculator tool was used to quantify the average amount of material carbon emissions associated with recently built Part 9 buildings in Nelson and Castlegar. It is able to do this by using EPD data and material quantities to come up with an average amount of material carbon emissions.

If you are a homeowner, builder, building specialist etc. and are interested in obtaining a more detailed and expansive material carbon analysis of a specific building, we recommend checking out the MCE^2 calculator tool. We also recommend looking out for Builders for Climate Action's BEAM calculator tool. BEAM shares its database and methodology with MCE^2, so a user will get the same result from both tools. BEAM however will be a web based application rather than a spreadsheet, enabling the data to be updated without the user needing to download new version of the tool and simplifying some of the interface elements. It will also contain a wider selection of alternative materials than the MCE^2 tool. Both of these tools are expected to be freely available by April 2022.

Of Note: There are various other embodied carbon calculator tools that are currently available. For example, the Athena Impact Estimator for Buildings (free), One-Click LCA (free version + paid version), Tally (paid), and Embodied Carbon in Construction Calculator (EC3) tool (free).

FAQs

Who can help me assess the material carbon emissions for my house or a renovation project?

An architect, engineer, home designer, energy advisor, or anyone else who is familiar with house plans and material takeoffs can use the MCE^{2}or BEAM tools, and can present you with options. It should be noted that this concept has only recently started to get integrated into education programs and thus, not all professionals are currently well versed on the topic but they are the best suited to use these tools if they're keen to learn.

How do I know which specific products within a product type to buy (e.g., which carpet should I choose)?

This guide did not seek out to offer such granular advice. It is not our intention to promote specific companies or products. If you're especially committed to getting the lowest emission product within a certain product type, we recommend that you ask the manufacturer for an EPD and seek out guidance from a embodied carbon or lifecycle specialist that will be most well suited to assess the EPD. As more manufacturers seek to reduce their emissions and create Environment Product Declarations (EPDs), the easier it will be to make low-carbon decisions.

Is there any work being done to align other considerations (e.g., fire smart, energy efficiency) with low material carbon materials?

Yes, in Phase II of the Low Carbon Homes Pilot, we'll be working to address this lack of alignment by seeking to integrate embodied carbon / low carbon material recommendations into existing ones for fire smart and energy efficient products. This was identified as a priority when engaging with stakeholders in the building community in Nelson and Castlegar in fall 2021.

Are there any rebates to do this work?

As of now, no. This will likely change within the next 2 years as governments seek to align embodied carbon considerations with energy efficiency work (e.g., BC Step Code and the Canada Greener Homes Grant) but for now, there are no rebates available. However, as part of the Low Carbon Homes Pilot, Nelson will be offering free embodied carbon analyses and technical guidance for the first 20 houses to participate in our program.

Why isn't wood included as a carbon storing material?

The carbon storing ability of wood is dependent on how it was harvested. Currently, there is not enough information about that harvesting process, thus hindering our ability to assess what types of wood might be considered carbon storing. There is a lot of interest and momentum to develop wood-based EPDs so we expect this information to be available within the next couple of years. It should also be noted that wood normally still performs well as compared to other material types even if it's not considered carbon storing.

Do the scales without a range mean that only one EPD was used to calculate the MCEs associated with a certain material?

Yes, it does. Of course, some of these materials wouldn't change much even if all manufacturers produced easily accessible EPDs as most product types don't have huge material carbon emission ranges due to the manufacturing process for each product type being quite similar. We would encourage you to request EPDs from manufacturers of all products you purchase for your home to signal to manufacturers that consumers are seeking lower-carbon products. It should also be noted that a single EPD is often actually an industry average EPD, which means that numerous manufacturers are represented within one EPD.

How long will these product rankings stay relevant?

As manufacturers create lower emission products and more EPDs get created, these rankings will need to be updated. Ideally, this type of document would be updated every 1-3 years depending on capacity.