Benchmarking Report

Establishing the Average Upfront Material Carbon Emissions in New Low-Rise Residential Home Construction in the City of Nelson & the City of Castlegar

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Table of Contents

Introduction

How did this get started?

This work began with a question of whether pursuing the highest steps of the BC Step Code could lead to a higher overall emissions profile if Material Carbon Emissions[1] (**MCEs**) are not considered in tandem with Operational Carbon Emissions[2] (**OCEs**). This came up in 2020 as Nelson's Climate Action Plan, Nelson Next, was being developed and as the senior building inspector, Sam Ellison, began to learn more about MCEs.

In late 2020, the City's development services department commissioned work to learn more about the correlation between increased energy efficiency and higher MCEs. To achieve this, 3West Building Energy Consultants (3West) was contracted out to assess the MCEs associated with 3 recently built homes in Nelson who had all achieved different BC Energy Step Code[3] levels. This preliminary investigation sought to model how substituting certain materials with accessible and affordable low-carbon alternatives might have influenced the overall MCEs associated with the building. These preliminary findings suggested that MCEs might increase as the Step Code level increases, and found that by substituting low-carbon materials available through existing retail outlets, the MCE could have been reduced by an average mean of 77%[4].

These findings were compelling enough to initiate further research, but were not intended to be conclusive. Instead, this investigation aimed to stimulate conversation about how we account for building emissions and to justify further research. Ultimately, it recommended immediate action on material use (i.e., limiting concrete use where possible; using concrete mixes with high amounts of supplementary cementitious material when concrete use is necessary; using natural building materials[5] where possible; and avoiding foam-based insulation) and the development of a larger, more detailed and representative study. This led to the creation of the Low Carbon Homes Pilot (LCHP or the "Pilot").

OF NOTE: This report only references the Material Carbon Emissions (**MCE²**) estimator tool but in the past brief published in May 2021 by the City of Nelson, the Building Emissions Accounting for Materials (**BEAM**) tool is also referenced. The MCE² tool was co-developed by Builders for Climate Action (**BFCA**) and Natural Resource Canada (**NRCan**) for the purpose of integrating material carbon emission considerations into existing operational emission programming (i.e., Hot2000 energy modelling software). The BEAM embodied carbon calculator tool was developed exclusively by Builders for Climate Action and acted as the foundation for the development of the MCE² tool. BEAM does not have a feature in which Hot2000 energy modelling data can be integrated.

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[1] Material carbon emissions are also commonly referred to as embodied carbon and embodied emissions. This report uses the term MCE because the authors of this research found that it was more intuitive than embodied carbon or embodied emissions. Material carbon emissions refers to the emissions produced through the creation of building materials, construction processes, and material disposal throughout its lifecycle. As is mentioned in the title, this study looks at the 'upfront' material carbon emissions, which means the emissions accounted for the A1-A3 lifecycle of the product (i.e., extracting and manufacturing of the material).

[2] Operational emissions which refers to the greenhouse gas emissions produced through energy use associated with building use (e.g., heating, cooling, ventilation, lighting etc.).

[3] The BC Energy Step Code refers to a regulation brought in by the provincial government to offer local governments in BC a way to incentive and eventually require energy efficient new construction. The province aims for all homes to hit Step 5 (the highest energy efficiency level) by 2032. For Part 9 buildings, Step 1 represents the base requirements according to the BC Building Code, while Step 2 is 10% more efficient, Step 3 is 20% more efficient, Step 4 is 40% more efficient, and Step 5 is Net Zero Ready.

[4] It should be noted that in this preliminary investigation, wood was counted as a carbon storing material. For this Pilot, the project team decided that wood would not be considered a carbon storing material in further study on the topic as there are not currently enough ways to assess how wood has been harvested and thus confirm its carbon storing properties (i.e., not releasing more carbon through poor forestry practices).

[5] Some examples of natural products include cellulose, wood fiber board, cork etc.

What is it?

This Pilot intended to delve deeper into the potential correlation between higher Step Code homes and higher MCEs and to establish an average amount of MCEs for homes being built in Nelson and Castlegar. It is rooted in a desire to better understand and quantify both OCEs and MCEs to more effectively lower the overall GHG footprint of the built environment and meet ambitious climate action goals. This project consisted of three phases: data collection, analysis and engagement, and guide development. This benchmarking report seeks mainly to summarize the findings of the data collection and analysis phases of work. The Material Carbon Emissions Guide is complementary to this report. It seeks to visualize some key findings from the benchmarking study in a manner that enables people to choose lower carbon materials. The guide can be accessed on the City of Nelson's website.

Who's involved?

The Pilot was initiated and managed by the City of Nelson with support from material carbon emission experts from BFCA and a specialized energy advisor from 3West. The technical components of this benchmarking study relied heavily on the expertise of these two contractors. BFCA is part of the not-for-profit Endeavour Centre, based in Peterborough, Ontario, and is focused on developing tools and research that help builders lead the way to a decarbonized and carbon-storing building sector. BFCA co-developed the MCE² estimator tool that is used in this study to determine the average amount of MCEs associated with newly built Part 9[6] residential buildings in Nelson and Castlegar. 3West is a BC Interior and Kootenay based consultancy offering energy use quantification, planning, and site support to advance provincial energy efficiency targets.

In this benchmarking study, 3West calculated dimensions from building plans, inputted these values into the MCE² tool, and provided the data to BFCA. This data was then verified, formatted, processed, and analyzed by the BFCA team who led the process of synthesizing the major findings of the research. Together, the contractors calculated the average amount of material carbon emissions associated with all new builds. The development of this report was led by the project coordinator at the City of Nelson with significant contributions from 3West and BFCA.

The City of Nelson initiated the process by conducting the preliminary investigation using City funds but required funding from FortisBC to conduct the benchmarking study. The Pilot was born as part of the broader FortisBC Built Better grant, which also gave the City funding to cover the cost of a number of blower-door tests in the City. The City of Castlegar was unable to use similar grant funds they had received from FortisBC due to the pandemic and thus, decided to redirect the remainder of their funds to expand the scope of this pilot project (i.e., bring on Builders for Climate Action for extra guidance and analyze homes from Castlegar as well). The contracts were finalized and research began in June 2021.

[6] Part 9 buildings are defined in the BC Building Code as buildings that are 3 storeys or less and have a building area less than 600m^2. They are also often referred to as low-rise residential buildings.

Benchmarking Study

Methodology

This study aimed to establish a benchmark[7] for MCEs associated with new Part 9 residential buildings in the City of Nelson and City of Castlegar and establish any direct correlations between high MCEs and the upper tiers of the BC Energy Step Code. The work intended to help identify homes with MCEs that are much higher or lower than the average and attempt to correlate factors such as home size and typology with MCE. The study results were used to identify specific material and design choices that result in the highest and lowest levels of emissions and make suggestions for ways to achieve overall emission reductions in local homes.

The study considers the MCEs and OCEs of 34 homes built in 2020 in the cities of Nelson (24 homes) and Castlegar (10 homes). A total of 72 homes were built in Nelson and Castlegar in the year, meaning that this study relies on a sample size of 47% of all homes constructed. The study contained homes of all low-rise residential typologies: 18 single detached homes, 5 single detached homes with a secondary suite, 5 laneway homes, 5 duplexes, and 1 row houses.

The homes were selected from a pool of homes that had received energy modelling services from 3West, using the HOT2000 energy modelling program from Natural Resources Canada (NRCan). The energy use and associated GHG emissions from these HOT2000 models were used in the study to establish OCE results. The study included houses from all five of the Energy Step Code levels: 3 at Step 1, 3 at Step 2, 11 at Step 3, 15 at Step 4, and 2 at Step 5.

The MCE for each home was established using a beta version (V4.1) of the **MCE²** tool, co-developed by BFCA and NRCan. This uses data from Environmental Product Declarations (EPDs) to provide material emission figures for the “cradle-to-gate” emissions (the product stages, A1-A3, of a Life Cycle Assessment) for the materials specified in the building plans for each home based on quantity takeoff calculations[8] provided in the MCE² tool. Michele Deluca from 3West built each of the MCE² models for the study. The team at Builders for Climate Action then provided a detailed review of the models and customized entries for materials and assemblies that were not included in the beta tool.

The results of the MCE study were noted in two forms: gross MCE (reported in tonnes of CO_2e) and **Material Carbon Intensity (MCI)**. MCI is calculated by dividing gross MCE by the heated floor area[9] of each home (reported as kilograms of CO_2e per square meter or kg CO_2e/m^2). MCI provides a means of comparing material emissions from buildings of different sizes by presenting a metric that compensates for the fact that larger homes use more materials and will likely have a higher gross MCE even if they use materials with lower emissions. Gross MCE is a metric useful to municipalities to gain a better understanding of the total emissions associated with their jurisdiction, compare gross MCE emissions to gross OCE emissions, and compare overall emissions contributions of one city versus another. This metric is something that a municipality could use in an emissions inventory[10]

[7] In this context, establishing a benchmark is desirable for future policy work on the topic as it offers a point of reference against which future projects can be compared (e.g., incentive programs that reward achieving a certain target amount of MCEs, requiring that new builds hit a certain % reduction off the average, etc.)

[8] Quantity takeoffs is the process of estimating material amounts based on building plans and construction assembly details. The MCE² tool offers a quicker means of calculating emissions associated with certain quantities of materials.

[9] Heated floor area is the gross floor area for all spaces within a building that are heated by mechanical means. It does not include garages, unheated basements, attic storage areas, or partially enclosed decks or patios. The MCE² tool uses the heated floor area metric as it most closely aligns with the energy simulation data that Hot2000 provides.

[10] It should be noted that consumption-based emissions inventories are best suited to host material carbon emissions metrics as they account for emissions released outside the territory. Typically, cities rely on territorial-based emissions inventories but are increasingly becoming aware of the need to consider the life cycle impacts of product consumption behaviours.

and could help identify what an appropriate benchmark is to reach GHG emission reduction targets and measure progress. Additional metrics generated in this study are discussed in the *insights for municipal staff and regulators* section.

In addition to tabulating gross MCE and OCE emissions for each home, additional information about each home was collected:

- Total floor area and heated floor area in m^2
- Annual operational emissions estimate from HOT2000
- Fuel source for space heating and domestic hot water
- Number of bedrooms
- Number of stories
- Total interior volume in m^3
- Window to wall ratio
- Garage size and materials

These factors were used to examine potential correlations with MCE, with the aim of providing insight into factors that may influence MCE and municipal actions to motivate emission reductions.

The results from each sample home were used to provide data on the relative impact of different broad categories of materials and the breakdown of specific material types within each category. This data was compiled to better understand the relative impacts of each category and present insight on which categories and/or materials may be most important to address. The material categories considered include: concrete, insulation, cladding, windows, interior surfaces (flooring, ceiling and wall board), framing, roofing, and structural elements.

Limitations

Like all research, it is important to identify and recognize its limitations. Here is a summary of some of the key limitations of this benchmarking study:

- **Tool:** MCE² is an estimator tool and does not purport to present precise MCE results. The limitations of the tool are fully described in Appendix I. The tool is similar in its application to energy modelling software, which can predict relative impacts of changes to a building using a standardized set of assumptions but does not necessarily predict the exact energy usage of a building. MCE² is the only tool that uses a consistent data set of EPDs and material take-off formulas created specifically for Canadian low-rise residential construction, and as such provides important comparative information.
- **Human Error:** The majority of a building's dimensions in MCE² are exported from HOT2000, and while every effort was made to ensure that the dimensions were an accurate reflection of the actual building plans, it is possible that some errors or omissions were missed in the original entry. BFCA did not review these dimensions for accuracy.
- **Scope:** This study initially included an examination of energy efficiency retrofits as part of its scope, but due to a lack of data, budget and time constraints this was not completed. It is the hope of the project team that this will be able to be integrated into future work on the subject.
- **Scope:** This study only accounted for the emissions associated with the product stages (A1-A3) and thus, does not account for emissions associated with construction, installation, maintenance, deconstruction/demolition and disposal. Although the majority of material carbon emissions have been found to come from the A1-A3 product stages, more data on the other product stages could offer complementary recommendations that could help contribute to overall emissions reductions.

- **Scope:** Affordability will be an important consideration for regulators to consider in any new programs to address MCE. The cost implications of making material choices to reduce MCE/MCI were not directly considered in this study. However, a recent study for Natural Resources Canada concluded that "the result shows no direct correlation between the cost and MCE of materials."[11] In the study, it was found that the material option with the lowest MCE could have the lowest, highest or average cost, depending on the material and category, so that "builders would be able to make material choices that would balance cost concerns and favourable MCE results."

Overarching Findings

This research found that the homes assessed in Nelson and Castlegar had an average MCE of 28.8 t CO_2e and average MCI of 149.6 kg CO_2e/m^2. This research asserts the importance of using metrics that align with other City and/or program priorities. For example, one that includes the consideration of both OCEs and MCEs (i.e., carbon use intensity) and another that includes the consideration of interior volume and bed count to help the prioritization of densification (i.e., material carbon intensity by density function). Importantly, this research found that it is absolutely possible to build homes that have both low operational and material carbon emissions. An important first step to achieving this is to choose building materials that encourage and/or don't hinder highly energy efficient homes and have low material carbon emissions.

The key findings from this study are split into the following sections: metrics, Step Code, and material selection. The metrics section will outline the quantitative findings of this research, the Step Code section will briefly articulate the lack of evidence that there is any between high step code homes and high material carbon emissions, and the material selection section will reassert the positive impact and emission reduction potential that low carbon material substitutions can have.

Metrics

Material Carbon Emissions (MCE): Gross MCE exhibited a wide range, from a high of 63.6 to a low of 5.9 tonnes of carbon dioxide equivalent (t CO_2e), with a mean of 28.8 t CO_2e. The distribution of the samples was quite even, with the median falling in the middle of the sample range, suggesting that no outliers had an undue impact on the results. The total MCE from all 34 homes is 978 t CO_2e. Applying the average of these 34 homes to all 72 homes built in the study area, this would indicate that emissions from materials in new home construction in 2020 in Nelson and Castlegar would amount to approximately 2,070 t CO_2e. This would be the equivalent of the annual emissions of just over 500 cars.

[11] Magwood, C., et al., 2021, "Achieving Real Net Zero Emission Homes: Embodied carbon scenario analysis of the upper tiers of performance in the 2020 Canadian National Building Code."

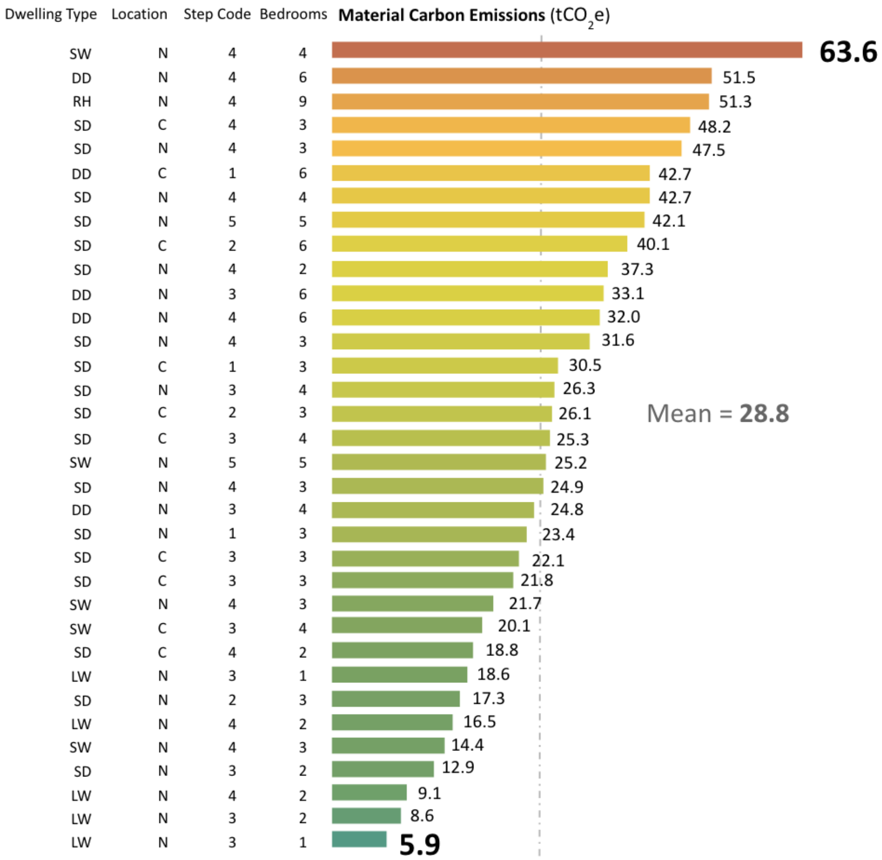

Figure 1. *This bar chart shows the MCE of the 34 homes in the study from worst to best alongside the number of beds, step code level, location/city, and dwelling type (SW meaning single detached house with a secondary suite, DD meaning duplex, RH meaning row house, SD meaning single detached, LW meaning laneway house).*

Material Carbon Intensity (MCI): MCI is the gross MCE divided by the heated floor area of each home. MCI results are shown in Figure 2, and ranged from a high of 309.1 to a low of 71.6 kg CO_2e/m^2, with a mean of 149.6 kg CO_2e/m^2. As with MCE, the distribution of MCI results is quite evenly spread, with no outliers impacting the results. The median is near the halfway point of the distribution range.

The results in Figure 2 show no appreciable difference in MCI between homes built in Nelson or Castlegar, nor between housing typologies, or number of bedrooms. As with Step Code levels, the results seem to indicate that material selection and quantity is the leading factor in driving MCI higher or lower and that any type of home with any number of bedrooms in either municipality is capable of achieving low MCI with the proper attention paid to material selection.

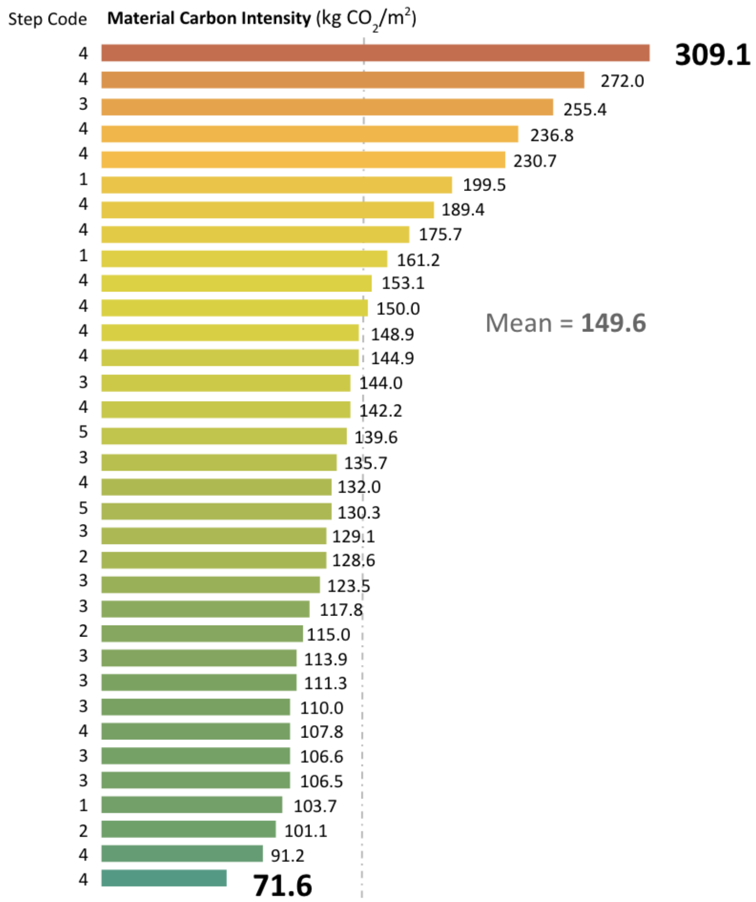

Figure 2. *This bar chart shows the MCI of the 34 homes in the study from worst to best alongside the Step Code that they achieved.*

Carbon Use Intensity (CUI): This study included results for both material carbon emissions (MCE) and operational carbon emissions (OCE). By combining MCE and OCE it is possible to understand the overall CUI of each home and examine it over any period of time. For example, a CUI_{30} (indicating a time horizon of 30 years) for Nelson and Castlegar would mean adding 28.8 t CO_2e to OCE at 1.26 t CO_2e/year, getting a total CUI of 66.6 t CO_2e over its 30-year lifespan.

Perhaps most importantly, examining CUIs can enable regulators to understand the relative impacts of MCE and OCE and to gear any regulatory efforts to align with broader climate goals. For example, an examination of CUI in this data set shows that MCE will be the leading source of emissions from new homes in the region over the next two decades. Using the average results in Nelson and Castlegar of MCE at 28.8 t CO_2e and OCE at 1.26 t CO_2e/year, it will be at least 23 years before OCE approaches the total value of MCE.

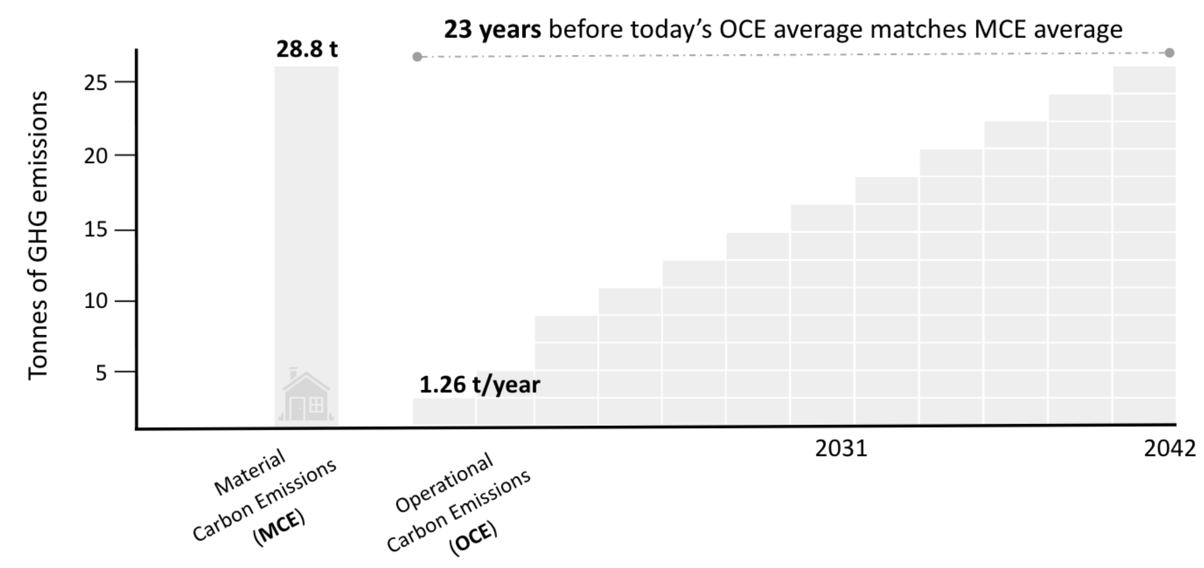

Figure 3. *This graph illustrates the importance of addressing material carbon emissions, showing that it will take 23 years before the cumulative operational carbon emissions equal the amount of material carbon emissions associated with the house by the time it is first built.*

For the 11 most emissive intensive homes in the study, it will take between 90-100 years for OCE to equal MCE. As the BC Step Code is already addressing operational emissions in line with climate targets, this study shows that these efforts must be combined with actions aimed at reducing MCE in order to address the full emissions spectrum from the home building sector. In a region with a relatively low carbon grid, reductions in MCE could be much more significant than those achieved from OCE, although the most successful strategies combine both metrics. Without addressing MCE, all the work done to reduce OCE may be entirely negated by the overall results of an efficient home made with products with high MCEs.

Material Carbon Intensity by *Density* Function (MCI_{F1})[12]: While the researchers employed MCI as a simple metric to account for size differences between homes, there was a concern that such a simple metric may not reflect the complex issues faced by municipal staff (e.g., planners) when attempting to regulate material carbon emissions. As regulators in British Columbia are learning that Step Code levels are not necessarily reflective of GHG emissions from homes, the research team was concerned that the MCI metric may potentially penalize smaller homes with higher occupant density and reward larger homes with lower occupant density. This is because smaller homes tend to have a lower surface area to floor area ratio, meaning that they require more materials per square foot of living space but still have a much lower overall MCE. A metric was created that would fairly balance MCE with building size and number of bedrooms, using the formula: (# bedrooms/house volume in m^3) * (1000/MCE). This metric would enable planners to incentivize homes with low MCE while factoring both building size and the number of occupants served by the carbon footprint of the building thus, encouraging density (I.e., another low carbon tactic aimed at addressing the largest emission contributor in most Canadian municipalities). The results generated using this metric are shown in Figure 4. These bar charts show that the Material Carbon Intensity by Function metric generally gives higher (better) scores to smaller homes with low cumulative material carbon emissions and that some homes with higher bed counts were still able to score decently well. Overall, it shows that this metric generally supports the overall use of less materials and higher density housing.

[12] We use F1 to indicate the specific inputs (i.e., bedroom count, interior volume etc.) that were selected to capture density. If further research wanted to use different inputs, F2 etc. could be used.

Figure 4. *These bar charts demonstrate the homes in the study ranked by the Material Carbon Intensity by Function metric alongside the inputs for this new metric.*

Step Code

This research was in large part undertaken to examine the potential influence of higher energy Step Code levels on MCI ahead of pursuing higher Step Code minimums in the City of Nelson. The results of this study do not indicate any direct correlation between higher Step Code achievement and higher MCI. This lack of correlation is made clear in Figure 2, where different Step Codes are associated with various MCIs. The two highest and two lowest MCI results are for homes at Step 4, and examples from all steps appear distributed relatively evenly across the data set. These results would suggest that material selection and quantity is the leading factor in driving MCI higher or lower, and that it is possible to achieve both high levels of energy efficiency and low MCI.

Material Selection

Material selection was the most important factor in pushing both MCE and MCI higher or lower in this study. The average impact of all material categories for the homes is shown in Figure 5. The Material Carbon Emissions Guide (available at www.nelson.ca/programs) contains graphs that further break down the materials used in each category and their relative impacts.

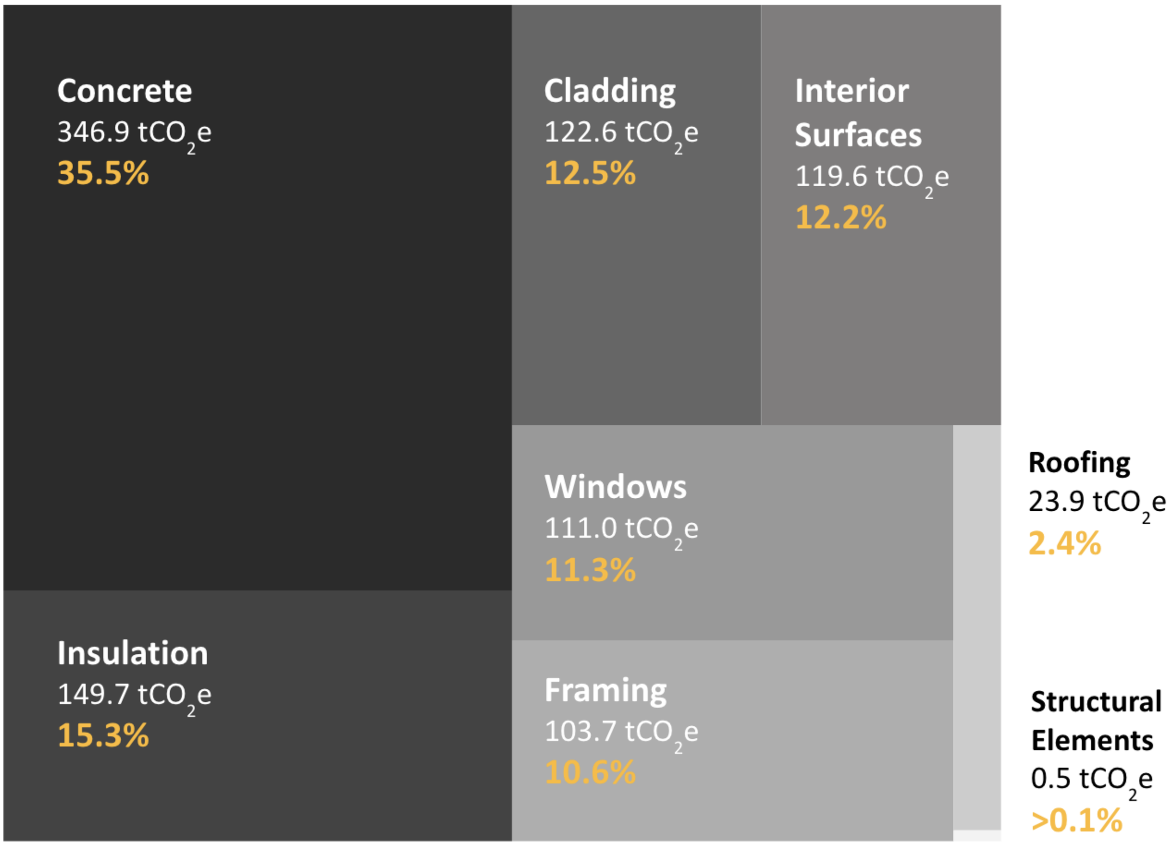

Figure 5. *This tree chart illustrates which materials contributed the most amount of overall emissions across all 34 case study homes.*

Concrete (35.5%), insulation (15.3%), cladding (12.5%) and interior surfaces (including flooring, wall and ceiling materials) at 12.2% were the highest impact material categories when averaged across the study. These are also the areas in which material selection can have the greatest impact due to the number of options available to home builders. This project will deliver a "materials guide" focusing on these material categories that will help designers and builders in the region to understand the relative impacts of material choices in these categories. Windows (11.3%) and framing (10.6%) are also major contributors, but there are less opportunities for material substitution in these categories.

The insulation category included one material -- cellulose insulation – that is carbon storing. Carbon storing materials contain more atmospheric carbon in the physical material than was emitted in producing the material, resulting in a "negative" number in the overall carbon accounting for the study. Cellulose insulation, used in 17 of the homes in the study, subtracted 41 t CO_2e from the overall impact of insulation. In total, all the cellulose insulation used in the study offset close to 5 percent of the total MCE from all of the buildings. While cellulose insulation was the only carbon storing material that appeared in this study, there are more carbon-storing options available to home builders, and wider adoption of carbon storing materials could considerably mitigate the overall MCE of homes. The MCE Material Guide shows, in greater detail, the comparative impact of this carbon-storing material.

The results from the home with the highest MCI in the study was examined in the MCE² tool to determine the impact of applying different materials to six high-impact material categories within the same home design in order to determine the extent of emission reductions possible through straightforward material substitutions.

Table 1 lists the specific material substitutions that can lead to a 69% reduction in emissions (best conventional materials) and a 140% reduction in emissions (best possible materials).

As-Built Materials	Best Conventional Material Substitution	Best Possible Material Substitution
Average concrete	High SCM concrete	High SCM concrete
EPS sub slab insulation	-	Foam glass gravel
EPS ICF	Wood chip ICF	Treated wood foundation
Mineral wool cavity insulation	Cellulose	Straw bale
Continuous insulation	Wood fiberboard	-
Hardwood floors	½ linoleum flooring	Linoleum & cork flooring
Mineral wool roof insulation	Cellulose	Cellulose
309.1 kg CO2e/m2	**151.3** kg CO2e/m2	**55 kg** CO2e/m2

Table 1. *This table demonstrates the impact that material selection can have on overall material carbon emissions.*

Targeted Insights

MCEs are a relatively new consideration for the building sector. This study represents the first time that a group of as-built new homes has been examined for MCE using a consistent methodology and the results draw attention to a wide range of opportunities to act. The building sector is complex, with many stakeholders having influence over the design and construction of new homes. We have attempted to direct insights arising from this study to particular stakeholder groups to promote the practicality of this report. It should be noted that in many cases the insights are overlapping.

Insights for Building Designers

Building designers can play a crucial role in reducing MCE and achieving lower CUI from new homes in several ways, from early schematic design to product specification. Designers can inform their clients on the climate impacts of their decisions, help guide them towards decisions that lead to better outcomes for the environment and climate, and quantify the results of these decisions. More specifically they can:

- Employ tools such as MCE[2] or BEAM to inform schematic design and use the tools to refine design and material choices throughout the design process
- Design homes to minimize the use of concrete and by specifying concrete with the lowest possible MCE
- Minimize the amount of uninhabited floor area by eliminating or reducing the size of garages, and unfinished basements
- Specifying materials that have the lowest possible MCE or, where possible, carbon-storing materials (see Material Guide)

- Contacting material manufacturers to encourage them to produce Environmental Product Declarations to add to the existing data set
- Maximize building efficiency through improved passive design features and air tightness and design mechanical systems that use renewable energy rather than fossil fuels
- Engage in collaborative design process with energy advisors, contractors and regulators
- Offer feedback on the practicality of resources provided by the City (e.g., material guide) and support the evolution and betterment of these resources

Insights for Energy Advisors

Energy advisors play an increasingly important role in home building; particularly in BC where they are crucial in ensuring that designs meet Step Code requirements. An energy advisor understands the role of efficiency and fuel choices in the overall operational carbon emissions of a home, and understands the pathways to low OCE. Combining this understanding with material carbon emissions, we believe that energy advisors can play a larger role as "carbon advisors" and help to refine designs to reduce overall CUI. More specifically they can:

- Employ tools such as MCE[2] or BEAM to refine design and material choices
- Ensure that strategies to improve operational efficiency are achieved without unduly raising MCE, aiming for the lowest achievable CUI
- Inform clients of low-carbon material options and, where possible, carbon-storing options
- Contacting material manufacturers to encourage them to produce Environmental Product Declarations to add to the existing data set
- Maximize building efficiency through improved passive design features and air tightness and design mechanical systems that use renewable energy rather than fossil fuels
- Engage in collaborative design process with designers, contractors and regulators
- Offer feedback on the practicality of resources provided by the City (e.g., material guide) and support the evolution and betterment of these resources

Insights for Builders/Contractors

Builders often make final material procurement decisions and since choices that favour low-carbon and carbon-storing options can have a dramatic impact on MCE, they play an integral role in reducing MCEs. Builders are also often an important point of contact with clients and can help to introduce or reinforce the importance of climate-friendly decisions. More specifically they can:

- Employ tools such as the Material Guide to inform procurement decisions
- Inform clients of low-carbon material options and, where possible, carbon-storing options
- Contacting material manufacturers to encourage them to produce Environmental Product Declarations to add to the existing data set
- Contacting retailers to encourage stocking of low-carbon and carbon-storing products
- Engage in collaborative design process with designers, energy advisors and regulators
- Submit case studies of successful use of low carbon materials to the City to help raise awareness and build capacity
- Offer feedback on the practicality of resources provided by the City (e.g., material guide) and support the evolution and betterment of these resources

Insights for Municipal Staff and Regulators

As the significance of MCEs becomes more apparent, governments at all levels will need to provide clear information to stakeholders and ensure that any incentive programs or regulations are effective, practical and well-understood. A number of approaches were discussed with municipal staff during the stakeholder engagement portion of the benchmarking study and are summarised below.

- **<u>MCI thresholds</u>:** The data from this study is the first-time that real-world homes have been assessed for MCEs and can provide a basis for shaping targets. The average MCI in this study is 150 kg CO_2e/m^2 and 70% of the homes in the study have MCI lower than this average, indicating that this may be a reasonable threshold for an initial MCI limit. Improvements can be measured against this average and can be staged to match wider climate targets. A 40% reduction in MCI would be 90 kg CO_2e/m^2. Two homes in this study already meet this requirement, and another 10 homes are within 20 kg CO_2e/m^2 of achieving this result, indicating that such a threshold is achievable. The lowest MCI in this study is close to achieving a 60% reduction from the average.

  The "Laneway Case Study", included in Appendix III of this report, achieves an MCI of just 2 kg CO_2e/m^2, indicating that it may be possible to set an ambitious target of 80% reduction from today's average and having leading builders be able to meet or surpass this goal.

  Should municipal staff decide to implement voluntary MCI reductions, the researchers would recommend using a stepped approach modelled on the energy code, providing achievable targets along with more ambitious targets that could begin being met today.

- **<u>Alignment of priorities</u>:** During the stakeholder engagement process, a number of participants stressed the importance of ensuring that any municipal incentive programs or regulation of material carbon emissions must be accompanied by alignment with other municipal programs and regulations (e.g., energy efficient, fire smart etc.). Overlapping considerations such as height and density requirements must be examined in light of the desire for MCE reductions. Review of building plans and enforcement of building inspections must be done to ensure that MCE reductions are achievable without compromising building code requirements. A review of relevant existing policies and programs should be an important feature in any new MCE program.
- **<u>Metrics</u>:** As is described in the findings section, the use of certain metrics (e.g., MCI) may unintentionally encourage larger homes and fail to capture the nuanced and complex issues face by city staff. It is recommended that municipal staff and regulators investigate whether the Material Carbon Intensity by *Density* Function metric might better align with other low-carbon priorities (e.g., higher density housing that enable lower carbon transportation options).
- **<u>Reporting, awards and recognition</u>:** Requiring all residential building permit applications to include a material carbon emissions report would enable municipal staff to continue to add to the data generated from this study and to begin to "socialize" the notion of carbon footprint calculations among home builders. The MCE^2 and BEAM tools will become freely available sometime in 2022 and will enable home builders to easily perform calculations that could accompany permit submissions.

  Using the pool of MCE reports, municipal staff would be able to assess the homes with the lowest carbon footprint (by any of the proposed metrics) and be able to publicly award the best examples in the municipality. This would be a low-cost, low-commitment way to incentivize leaders in the sector to strive to achieve the best results. Promotion and celebration of these leaders will reward them for their efforts and increase public awareness of low-carbon construction. The municipalities can benefit from being seen as leaders for promoting and celebrating their own local leaders.

Conclusion

This is the first study assessing the MCEs of as-built new homes using a consistent methodology, and the results generated are wide-ranging and significant. They show that MCE is critical to consider if all levels of government are going to meet climate targets, as each new home is responsible for an average of 28.8 tonnes of emissions from the manufacturing of its materials, and the 34 homes in this study represent 979 tonnes of total MCEs. Since this study was one of the first of its kind there is a limited pool of existing data to compare against, but based on preliminary data coming out of a similar study in the Toronto region, these numbers seem relatively consistent with other low-rise buildings apart from some differences due to climate and local supply chains. With over 200,000 new buildings being built across the country per year, MCE can be seen as a significant source of emissions.

The range of results suggests that people could unknowingly build a home with MCEs higher than the average without proper education and/or regulation and that it is absolutely possible today to build homes with relatively low MCE and high OCE. A proper understanding of the issue and well considered regulations could transform MCE from a leading source of emissions to a leading source of reductions, with an end goal of zero emissions being entirely possible.

What's next?

As a result of the Low Carbon Homes Pilot, the City of Nelson has gained the attention of municipalities across the country. Building on its reputation of being a forward-thinking community, this benchmarking study has spurred more interest in integrating MCE considerations into energy retrofit programming, development and design practices, and procurement policies. In December 2021, FortisBC renewed its funding for the Pilot.

The Pilot will now seek to test out the findings from this benchmarking study. While the benchmarking study intended to compile locally relevant data and educate key stakeholders on preliminary findings, the next phase of the Pilot will consist of more work to engage directly with homeowners and builders on how best to support them reduce emissions and liaise with staff to update policies and/or create clear programs that enhance its service offerings. This project will continue to work to advance the City and region's climate action goals.

This work will fall into the following three categories:

- *Consumer Support*: Through the expansion of the Regional Energy Efficiency Program, MCE considerations will aim to be integrated into the existing energy retrofits concierge service and a soon-to-be-developed new build concierge service. This will aim to offer support to homeowners and builders and act as an opportunity to gather feedback that will in turn support the development of programs and policy.
- *Programmatic Support:* Through collaboration with the City of Nelson's Development Services Department, the Climate & Energy team will support the development of some of the policies and/or programs discussed in the engagement phase of the Low Carbon Homes Pilot. For example, this may include a tiered MCE program, low carbon building award, concrete procurement policy, and more education materials. Any efforts will aim to formalize the work started in the Pilot and begin to test out what actions can result in the most meaningful reductions in overall GHG emissions.
- *Peripheral Support:* Through advocacy work with the Province, Region, and relevant City departments, actions will be taken to more effectively align climate resilient work. This will aim to align strategies such as FireSmartBC with energy efficiency work and low carbon material recommendations. It is the hope of the project team that the results of this report may help prompt the provincial government to further consider how OCEs and MCEs (via the carbon use intensity metric) be considered alongside other climate change related strategies to ensure that our policies are encouraging overall emission reductions and climate resilience.

Appendix

I. Limitations of the MCE² tool

It is important to note that this calculator has a number of limitations of which you should be aware. Please read this section carefully so that you are fully informed.

Here are several factors to keep in mind regarding this calculators' accuracy:

1. **All the data is based on publicly available Environmental Product Declarations (EPDs).**
   The calculations used to create an EPD can be compared to calculating the fuel mileage for a car or truck. A series of assumptions and generic data are used to predict the carbon footprint of a material. The rules for making EPDs ensure that these assumptions are similar for all products in a particular category, but this does not necessarily guarantee that the actual figure is a perfect representation of the actual emissions from manufacturing the material. *A range of uncertainty from 5-25% is typical in EPDs.*

2. **Calculations may not reflect your practices.**
   In order to make the calculator simple to use and to minimize the number of inputs, numerous assumptions have been made in the calculations for material quantities. To the best of our ability we have chosen factors that are well-established industry norms, but these norms may not reflect the actual design or execution of your building.
   While the quantities of materials we estimate in the calculator are unlikely to be a perfect match to your actual material use, the quantities are consistent between all the options we present. This means that the comparison of emissions between materials is accurate. For example, you may use more or less framing material than we have estimated for your project but the relative difference between the framing options as depicted by the calculator will be accurate.

3. **No waste factor for materials is included.**
   Every construction project generates offcuts and waste. None of our calculations assume any waste factors due to the wide variation in on-site practices.
   If you would like your total emissions to reflect waste factors, you can add an appropriate percentage to each material category using the percentage function in Column F.

4. **We have not included data for all of the components in a building.**
   There are many materials that will go into your building that are not included here:
   - Mechanical, electrical and plumbing (MEP) systems and components
   - Damp-proofing, air/vapour barriers and membranes
   - Flashing, sealants, adhesives
   - Fasteners
   - Appliances and fixtures
   - Millwork, cabinetry and stairs
   - Paints, stains and surface finishes

   There is currently limited data available in some of these categories and/or the quantities of materials and emissions would be quite similar (e.g. toilets and washing machines don't have much variation in emissions for comparison according to the available data).
   The total of all these missing elements could be quite sizable, so it shouldn't be assumed that the results from this calculator accurately reflect the entire carbon footprint of the building. Even a carbon-banking

result may actually be a net emitter if all of these materials were included in the total.
NRCan will consider updating the calculator with EPDs in these categories as they become available.

5. **We have only included data for "cradle-to-gate" (A1-A3) emissions, not transportation to site, product use emissions/off-gassing or job site emissions.**
   Getting building materials from the factory to the job site can add a significant quantity of emissions to the overall project. Typically, transportation to the construction site adds 5-10% to the total material emissions.
   We encourage you to understand your supply chains and to attempt to do your own transportation emission calculations. The emissions from a construction site are likewise difficult to estimate, but average between 5-10% of the total materials emissions, and will depend on emissions factors associated with the energy source on the job site (electricity grid versus diesel generator).
   It should be noted that some job site emissions (A5) and/or product use emissions (B1) have been included in MCE calculations for those materials that have a necessary, sizable and very predictable volume of emissions in those life cycle phases. Examples include emissions from site-mixed foam insulation and GHG off-gassing from some rigid insulations. These types of emissions are included in A5 or B1 in many EPDs but are more related to the static emission profile of the product than to construction site or product use specific activity.

6. **No end of life emissions calculated**
   There are emission impacts at the end of life for a building component or a whole building. We have excluded end of life estimates for a few reasons:
   We have based our calculations on a time window of 30 years. While we acknowledge that there will be emissions released when these materials reach the end of their service life, we are focusing on immediate emissions.
   All the materials included in this calculator have a lifespan of at least 30 years (with the exception of asphalt shingle roofing, for which we doubled the emissions figure to cover replacement). End of life scenarios for buildings and materials are difficult, if not impossible, to predict. Thus, focusing on the reasonably measurable and predictable cradle-to-gate phases greatly reduces uncertainty and speculation by excluding later life cycle phases.
   The actual service life of a material or whole building is rarely the cause for replacement or demolition; instead factors like property value, aesthetics and planning issues tend to bring about the demise of materials and buildings, not the expected service life.

7. **No costing information.**
   No attempt has been made to include material costs in this calculator. Builders should use external costing information to understand the impact of alternative materials in their own projects.

II. Engagement Structure & Findings

The engagement process was an important piece of the Low Carbon Homes Pilot and influential in shaping the development of the materials guide. The engagement process occurred over a 3-month period from September to November 2021, after the quantitative research was collected and analyzed. It consisted of two free online webinars that introduced the topic and six workshops that aimed to educate and engage a series of stakeholders within the local building communities of Nelson and Castlegar.

Offerings

- The *webinars* presented preliminary findings of the research process. The intention of offering these webinars was primarily to introduce the building community and key stakeholders to the research.
    - This presentation had initially been planned to be hosted in-person but adapted based on public health measures. One was offered in the evening and the other in the morning to encourage attendance.
    - These webinars saw a total of 64 attendees. Contractor/builders, architects, and planners made up 67% of all attendees. **100%** of the 26 survey respondents found the presentation helpful. **Over 50%** of survey respondents felt that the presentation improved their understanding of the state of building emissions in Nelson and Castlegar (81%), improved their understanding of what actions they could take to meaningfully reduce emissions (81%), improved their understanding of the concept of embodied carbon and the terminology associated (77%), made them interested in learning more about embodied carbon (77%), and made them feel inspired to act (58%). **62%** of survey respondents also indicated that they wanted to actively participate in a workshop advance development of a program addressing embodied carbon in the region while **35%** indicated that they were interested in remaining passively connected to the work through updates from their local building department.
- The *workshops* gave the project team an opportunity to obtain feedback from the building community to help shape the development of the materials guide and guide continued policy and program development.
    - It was decided that the workshop groups would be split into: a builders etc. group (including architects, energy advisors, engineers etc.) in Nelson and another in Castlegar, a staff workshop in Nelson and another in Castlegar, a suppliers and retailers one, and one for energy retrofits staff.
    - These workshops saw 27 participants with 48% of all the participants attending the Nelson builders etc. workshop. A survey was sent to all 15 of the non-staff workshop participants and received a response rate of ~30%. **100%** of these survey respondents found the workshop helpful, **100%** indicated they would attend another workshop and/or presentation on the topic of reducing building emissions in the region, and **75%** wanted to actively participate in the development of embodied carbon programming and/or policy development in the region.

Key Findings

The key findings of the engagement process are drawn exclusively from the workshops. These findings can be grouped into five main topic areas: education, collaboration, policy development, incentives/costs, and project scope. Overall, this engagement process found that there is a clear interest in seeing this work continue and moving beyond the research phase, that more education on the topic is needed, that more work to align policy is needed, that an approach to policy and restrictions that integrates into existing programs and mimics the Step Code's gradual progression is preferred, that more advocacy needs to be done to address the lack of financial incentives for reducing material carbon emissions while energy efficiency incentives run abound, and the desire and interest from countless folks in the building community about the need to address the material carbon emissions associated with retrofits. The following bullet points describe the barriers and opportunities that surfaced during the workshops. The coloured boxes below indicate whether an opinion was discussed in talks with a certain stakeholder group (**yellow** = builders etc. Nelson, **red** = builders etc. Castlegar, **blue** = supplier/retailers, **purple** = Nelson staff, **green** = Castlegar staff, and **orange** = energy retrofits staff).

EDUCATION

- Prioritizing piloting and testing are well-suited to be applied to a project focused on integrating consideration of the MCEs of retrofits into existing embodied carbon work. If one has to be selected, education should be the priority over further research.
- Data collection should be integrated into the education and engagement to come. This data will be helpful as we develop policy and/or further programming.
- There needs to be more broad exposure to the topic. More folks in the public need to understand the importance of MCEs.
- Not enough people in the building community know what MCEs are and why they are important to address. The development of more education is absolutely crucial to the success of this project. We need to find ways to build MCE knowledge in building oriented professionals (esp. with architects and energy advisor who are already relied upon heavily by homeowners/clients) and offer them ways to integrate MCE considerations into their existing calculation tools (e.g., the MCE^2 calculator tool syncing with Hot2000 data)
- More effort needs to be paid to keeping building officials updated on newer materials. It could be helpful to compile code-compliant low-carbon material combinations that building officials have already been briefed on (/approve of) so builders can avoid unnecessary and costly involvement from engineers and architects. A prescriptive, illustrated, material assembly package could be an incredibly helpful addition to the materials guide and to the project as a whole.
- We need to integrate MCE considerations into existing OCE programming to build off of existing infrastructure and speed up the time to integrate.
- The MCE resources (e.g., materials guide) seems quite relevant to retrofits as well. Effort should be made to mention the relevance of these educational tools to retrofits wherever possible (especially ahead of any formal MCE research on retrofits).

COLLABORATION

- There needs to be more work done to align policies (e.g., fire smart, low carbon, energy efficiency, etc.)
- Collectively working towards the same goal will make a difference (e.g., lots of folks putting pressure on manufacturers to develop EPDs and/or create lower MCE products, various professionals informing clients/homeowners, and liaising with suppliers about carrying low-carbon materials)
- Working with suppliers to increase awareness and offer more resources seems like a practical and reasonable way to begin addressing material carbon emissions. However, more support may be needed to develop the content that retailers should be sharing.
- Suppliers can help the city by using the data that the City will provide on the MCE of particular materials and graphically show this in your store, supporting your staff to learn more about MCEs, advocating to manufacturers to create Environmental Product Declarations (EPD) and perhaps also to the government to help reduce the cost of creating EPDs, and continuing to stay connected with City work being done on the topic.

POLICY AND/OR PROGRAM DEVELOPMENT

- Action on MCE needs to be taken immediately but requirements and policies are likely best suited to be integrated slowly.
- Capitalize on strategic planning timelines (e.g., Official Community Plan updating process) to integrate MCE considerations into formal policy.
- Any future program must include work to assess how data can and should be managed at the City, the feasibility of asking building professionals to conduct MCE analyses, and ways to best access MCE data.

INCENTIVES

More work needs to be done to prepare for money-related questions that will inevitably come out of a council discussion (e.g., establishing where the money would come from for incentives and what the cost implications are for transitioning to lower MCE building materials).

Any future incentives must be easy to access and support efforts to streamline existing incentive schemes.

PROJECT SCOPE

More attention needs to be paid to how to address MCEs in existing homes (i.e., retrofits). This is particularly important in communities where most of the development that occurs is in the form of retrofits.

Sample Engagement Questions

- For retailers and suppliers
  - How often do you find that builders/homeowners ask about the sustainability of certain products?
  - Do you have a way of defining 'green' materials?
  - What barriers exist that hinder suppliers acting on this topic? And what worries you, if anything, about this conversation and/or topic?
  - What worries you most about a potential program? Which of them excites you most?
  - What support do you need to act on reducing material carbon emissions?
  - Moving forward, how do you practically see yourself acting to reduce building emissions?
- For builder/contractors, architects, energy advisors, etc.,
  - What barriers do you see holding yourself and your profession back from reducing material carbon emissions?
  - What are you currently doing to reduce operational and material carbon emissions in the building sector?
  - How often do your clients ask about low-carbon materials? How about high-efficiency materials?
    - How often do you discuss low carbon building strategies with your colleagues?
  - If an material carbon emissions reduction target was established, what would allow you to get there?
  - Moving forward, how do you see yourself acting to reduce building emissions?
  - What support does the City (or some other level of govt) need to offer?
- For municipal staff (e.g., planners, energy retrofits staff etc.)
  - How does this material carbon emissions work relate to and align with your current sustainability and emission reduction work?
  - What capacity does your team have to do work on this topic?
  - How do you feel about the list of barriers and opportunities highlighted by the building community? Which potential programs and/or policies do you like best? In your opinion, which seems most implementable?

III. Laneway House Case Study

While the benchmarking study was being conducted, one of the project team members helped a local builder select low carbon and energy efficient materials for his laneway house. Mike Coen, a project manager at Pacific West Builders, worked with energy advisor Michele DeLuca to find ways - mainly through material selection - to bring down both the operational and embodied emissions associated with this house. With access to the MCE[2] calculator tool, Michele was able to offer specific suggestions that successfully brought the project's MCEs to 2.1 kg CO_2e/m^2. By 2050, based on our current projections, this project is expected to have contributed a total of only 4.4 tonnes of total operational and upfront material carbon emissions. This project was not included in the study, but makes it clear that near-zero MCE homes can be built today.

The strategies used to achieve this included reducing concrete use, using cellulose insulation, and using wood finishes. The decision to use a pier foundation over a basement or slab-on-grade significantly reduced the amount of concrete required for the project, which is a major local contributor to MCEs. By using cellulose insulation in the walls, the floor and roof structure was able to store 3.3 tonnes of CO_2e.



These material and structural choices added a small cost to the project. This was predominantly a result of the time and cost to get a lower carbon 30% fly ash mix from the local concrete manufacturer. The manufacturer was relatively receptive and charged an extra \$20 per m^3, which did not hinder the project in any meaningful way. This primarily anecdotal evidence supports assertions from other research done by the Builders for Climate Action team on the cost implications of making low carbon building material choices[13]. That being said, further localized building cost considerations amidst global supply chains issues will likely be an important piece of bringing all folks in the building community along this journey of reducing material and operational emissions.

It is important to note that the home not only sought to host low embodied emissions but also operational emissions. Currently, it is on track to reach Step 4 of the BC Step Code and thus, points the way to home building strategies that come close to having no net impact on the climate. This case study is important because it provides a real, local example of how low MCE can be attained in conjunction with achieving high energy efficiency goals. Additionally, this case study demonstrates that actions can be taken with locally available materials at little to no extra cost. This laneway house is an example of how achievable and affordable achieving near-zero material carbon emissions can be.

[13] Magwood, C., et al., 2021, "Achieving Real Net Zero Emission Homes: Embodied carbon scenario analysis of the upper tiers of performance in the 2020 Canadian National Building Code."