carbon wise

# Making the case for Embodied Carbon in renovations

Whole-building Life Cycle Assessment

February 2023

# Contents

# Project Overview

We've created this case study to investigate the life cycle benefits of deconstructing an existing structure and then undergoing a deep retrofit, as compared to building a new structure.

The building is a one-story detached home of 2,960 $ft^2$ with a basement originally built in 1958 in North Vancouver, BC.

The home was originally built using 2X4 wood frame construction, with an attic truss roof, on an unfinished concrete basement. The new home design included upgrades to a 2x6 exterior wall and a new roof design incorporating scissor truss construction and a section of flat roof. Additional floor space was added to the above-grade floor as an exposed floor area. Basement geometry was unaltered with some minimal additional material added to suit the new layout above and changes in rough openings. New framing and insulation were added to the blow-grade structure.

The intention behind the renovation was to improve the energy efficiency of the home to meet the CHBA net-zero standard (CHBA NZ or NZ).

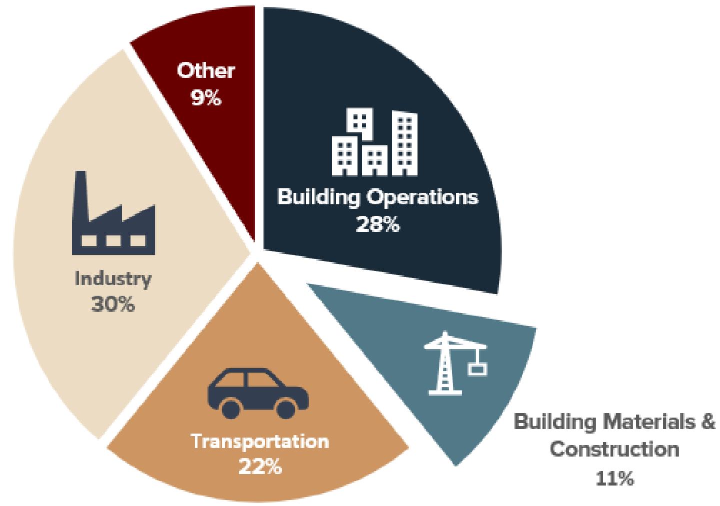
The homeowners were not only sensitive to the operational emissions of their home, but also the embodied emissions from the materials that would be used to accomplish the net-zero renovation.

Carbon Wise was brought on as a consultant to conduct a Life Cycle Assessment (LCA) of the home that included the deconstruction (C1) of the original building, and which connected that deconstruction process to the production and construction (A1 to A5) of the retrofitted home, including photovoltaic (PV) systems necessary for net-zero operation. Carbon Wise compared those results with a Life Cycle Assessment of a business-as-usual scenario in which the original home would have been demolished and the new home built from entirely new materials.

# Context

Together, buildings operation and construction are responsible for 39% of all energy-related carbon emissions in the world, with operational emissions (from energy used to heat, cool and light buildings) accounting for 28%.
The remaining 11% comes from embodied emissions, associated with materials and construction processes throughout the whole-building lifecycle[1].

Global $CO_2$ Emissions by Sector

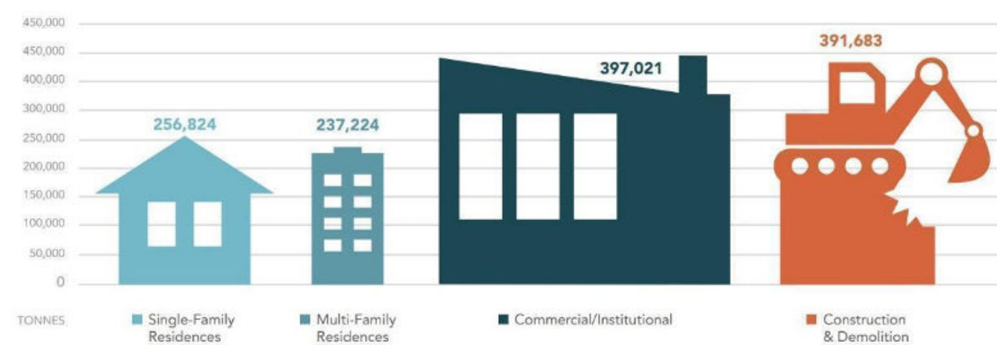



Source: Adapted from the World Green Building Council, Global Status Report, 2019

Embodied Emissions (also called Embodied Carbon) are the emissions released from the extraction, manufacturing, transportation, installation, and decommissioning of building materials.

Under the current linear model, materials from building construction, demolition, and renovation go directly to landfills, emitting emissions when decomposing. In Metro Vancouver, those materials account for one-third of our region's waste[2].

WASTE DISPOSED IN METRO VANCOUVER BY SECTOR - 2018




[1] World Green Building Council, Status Report, 2017
[2] Metro Vancouver, Construction & Demolition waste

# Context

Several municipalities such as Vancouver, New Westminster, the City of North Vancouver, and the City of Portland, OR. are implementing deconstruction and waste diversion bylaws aimed at reducing the increasing pressure on landfills to manage these waste streams. These policies are relatively recent and not universally adopted, possibly due to a lack of substantive research supporting informed awareness of both the scope of these impacts.

As a result, many homes (often far from the end of their operational lifespans) are demolished each year to make space for new construction projects, and all the environmental impacts that accompany them. The embodied emissions from the materials used to build those homes are significant but rarely accounted for when considering the operational emissions savings. If the end result of those projects is a building that meets the needs of the same number of individuals, offering only improvements in comfort or operational energy efficiency, then it is worth exploring the question of whether those same goals could have been achieved by renovating the existing building, at a significant savings of embodied emissions.

## Linking energy efficiency and embodied emissions

If you get the same home in the end, does it matter if it is new or renovated?

In the past, operational emissions have always been the focus of green building policies. However, there is an urgent need to address embodied emissions, particularly as new or renovated high-performance homes result in reduced operational emissions. Over time and as we add more materials (i.e., more insulation, triple-glazed windows, etc.) to reach energy efficiency targets, embodied emissions will account for an increasing portion of the total emissions and provide a valuable opportunity to further decrease overall emissions from the building sector.

### Using LCA to explore this question

The relationship between embodied and operational emissions is complex and must be calculated over time. As the total sample of buildings contributing emissions evolves to operate more efficiently, the relative significance of embodied emissions becomes of greater importance. However, where operational emissions savings are realized in small amounts over the whole life span of a building, the vast majority (between 70-90%) of embodied emissions occur in the relatively short timeframe between material production and when the homeowners move in.

Although a building's embodied emissions may make up a lower overall percentage (although increasing as operating emissions are reduced) of the building's lifetime emissions, those emissions will have already had their impact on the atmosphere by the time the building is constructed, where the operational emissions of the building will only be experienced by the atmosphere slowly, over many decades.

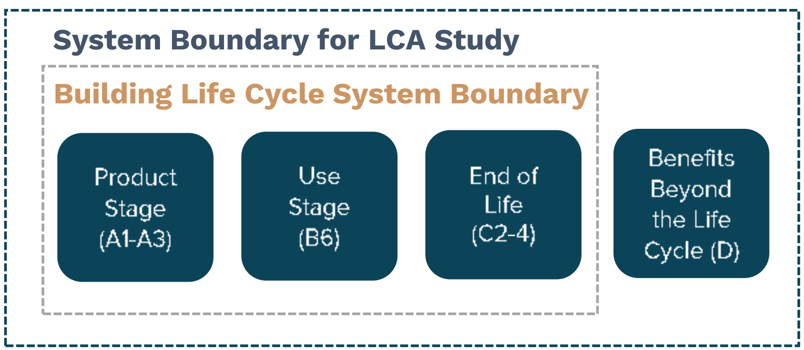
A Life Cycle Assessment (LCA) is a systematic methodology for assessing the energy use and environmental impacts of a building throughout its entire life cycle.

# Methodology

## Software used

Revue Bluebeam – Building plan assessment and Geometry Liftoffs / Markups
Hot2000 V11.11 – Operational energy modeling
BEAM / MCE2- Embodied emissions calculation

## Lifecycle stages addressed




**Modules A1-A3** were modeled using BEAM / MCE2
**Modules A4-B5** are out of the scope of this project
**Modules B6** using energy reports Hot2000 V11.11
**Module B7** is out of the scope of this project
**Modules C2-4** are based on the data from Unbuilders

### Module D

is comprised of two sets of data. One is a calculation of the materials reused in the renovated home, that would have otherwise been constructed of similar new materials. The second is estimated based on the most recent data from RMI, CLF estimating the reuptake of recycled materials salvaged from the original home.
The scope of the LCA includes all of the major structural, enclosure, and partition materials (foundations, walls, floors, roofs, windows, and cladding materials) and photovoltaic systems. This represents the majority of the mass of materials in a building project.
To account for the savings associated with reuse and retrofit, the environmental impacts of the retained materials are excluded from Module A in the retrofit LCA, but included in Module D.

### Exclusions

Not included are mechanical, plumbing, and electrical materials; paints and surface finishes; stairs, cabinetry/millwork and decks and/or exterior yard work.
The use stage (Module B1-B5) is excluded as the results would be similar for both scenarios. The focus of this case study was to show the benefits of deconstruction and deep retrofit, which primarily affect Modules A,C, and D.

# Baseline and Scenarios

**Baseline**

The existing home was evaluated and energy modeled according to EnerGuide procedures and this model was used to establish a pre-renovation baseline for operational energy use.

**Scenario 1**

**New build:** A new home is built using conventional practices with the intent to reach CHBA net-zero or net zero ready standards. Embodied and operational modeling reflects a situation where the original home has been fully demolished; assuming all demolition waste is sent to the landfill[3] and all construction utilized new materials.

- Scenario 1a, explores the home **without the installation of PV systems** (net-zero ready).
- Scenario 1b, explores the home built **with PV system to reach CHBA NZ.**

**Scenario 2**

**Deep Energy Retrofit:** The home is selectively deconstructed by Unbuilders; Some of the materials are recovered and repurposed. The home undergoes a deep retrofit with the intent to reach the CHBA NZ standard, with an emphasis on retaining as much of the existing material and structure of the building as possible[4] . Embodied and operational modeling reflect this situation. Any material that could reasonably be reused in place was calculated separately and considered as stored energy. The remaining material volumes were considered new material and calculated accordingly using the best available impact data. Operational energy modeling reflected the home constructed under these conditions.

- Scenario 2a explores the base house **without the installation of a PV system** (net-zero ready).
- 2b includes the addition of a **PV system to reach CHBA NZ.**

More details about the procedures followed can be found in **Annex 1**.

[3] At the time of this report/when the renovation started, there was no demolition waste bylaw in the District of North Vancouver.

[4] The resulting building is almost identical to the newly constructed scenario. The only exception is the slab remains uninsulated and has .5 ft lower ceiling height due to the implied limitations of not lifting the home and replacing the concrete.

# Results

## Summary of specifications and results

| Elements considered | New Build (1a & 1b) | | Deep Energy Retrofit (2a & 2b) | | Details |
|---|---|---|---|---|---|
| Heated Floor Area | 2,963 (1774 Above Grade / 1189 Below Grade) | | | | |
| Volume ($Ft^3$) | 25,954 | | 25,359 | | Renovated basement height is .5 ft lower to reflect the reality that a reno would not entail lifting the existing home. |
| ACH50 | 1.5 ACH | | | | Air Changes per hour @50Pa |
| Mechanical | Heating: Centrally ducted ASHP with HSPF 10<br>Hot Water: 50Gal Integrated air source heat pump DHW<br>Ventilation: Independently ducted HRV with 65% SRE @ 0deg C | | | | All Electric<br>Consistent across scenarios |
| Assemblies overview | Consistent across scenarios (see building construction table) | | | | |
| Operational Energy Use (kWh/year) | 1a<br>11,491 | 1b<br>0 | 2a<br>11,590 | 2b<br>0 | Renovated scenario has slightly less volume and wall area due to basement height, but because the slab has not been replaced it is not insulated below, thus increasing the heating load slightly. |
| On-site Generation needed for NZ (kW) | 12kW | | | | Despite the small difference in operational energy demand a 12Kw PV system is adequate in both scenarios |
| ERS Reference House (GJ/year) | 84.52 | | | | The same home as if built to minimum BCBC |
| On-site Greenhouse Gas emissions | 0 | | 0 | | All scenarios are fully electric with the exception of a solid wood fireplace which is considered cosmetic and omitted here. |
| Material Carbon Emissions (tonnes $CO_2$e) | 1a<br>36.2 | 1b<br>40.9 | 2a<br>28.3 | 2b<br>33 | Total Embodied Emissions |
| **Material Emissions Intensity (Kg $CO_2$e /$m^2$)** | **1a<br>132 kg** | **1b<br>149 kg** | **2a<br>103 kg** | **2b<br>120 kg** | **Total Embodied Emissions /m2** |



Source: H2k / MCE2 software outputs

# Results

## Breakdown of embodied emissions by building element

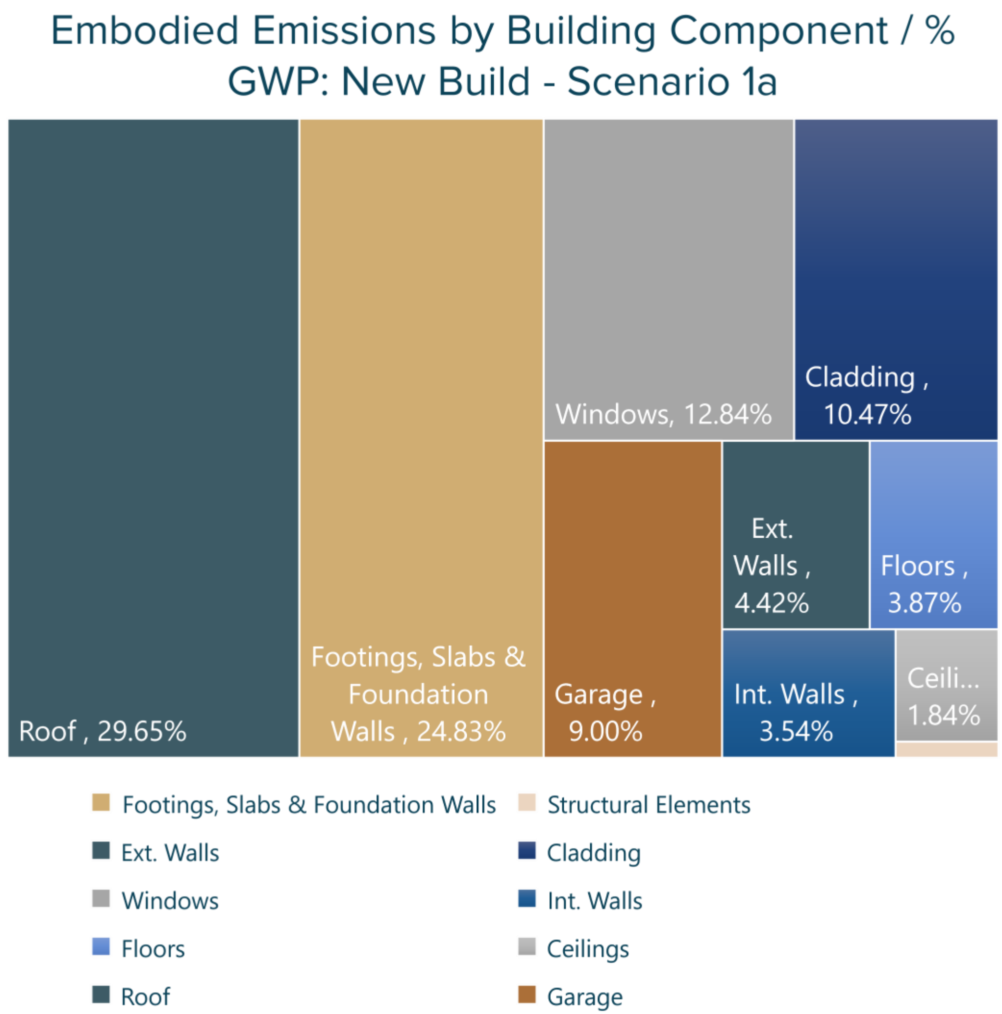
| | New Build 1a | New Build 1b | Deep Energy Retrofit 2a | Deep Energy Retrofit 2b |
|---|---|---|---|---|
| **Total Material Carbon Emissions (tonnes $CO_2e$)** | **36.2** | **40.9** | **28.3** | **33.0** |
| **Material Emissions Intensity (Kg $CO_2e$ /$m^2$)** | **132** | **149** | **103** | **120** |
| **Footings & Slabs (kg $CO_2e$)** | 5,585 | 5,585 | 0 | 0 |
| **Foundation Walls (kg $CO_2e$)** | 3,465 | 3,465 | 698 | 698 |
| **Structural Elements (kg $CO_2e$)** | 96 | 96 | 96 | 96 |
| **Ext. Walls (kg CO2e)** | 1,610 | 1,233 | 1,401 | 1,401 |
| **Cladding (kg $CO_2e$)** | 3,816 | 3,816 | 2,913 | 2,913 |
| **Windows (kg $CO_2e$)** | 4,679 | 4,679 | 4,679 | 4,679 |
| **Int. Walls (kg $CO_2e$)** | 1,289 | 1,289 | 1,167 | 1,167 |
| **Floors (kg $CO_2e$)** | 1,409 | 1,409 | 1,409 | 1,409 |
| **Ceilings (kg $CO_2e$)** | 670 | 670 | 670 | 670 |
| **Roof (kg $CO_2e$)** | 10,808 | 10,808 | 10,808 | 10,808 |
| **Garage (kg $CO_2e$)** | 3,281 | 3,281 | 3,281 | 3,281 |
| **PV systems (kg $CO_2e$)** | 0 | 4,680 | 0 | 4,680 |
| **Reused material (kg $CO_2e$)** | **-258** | **-258** | **-8,950** | **-8,950** |

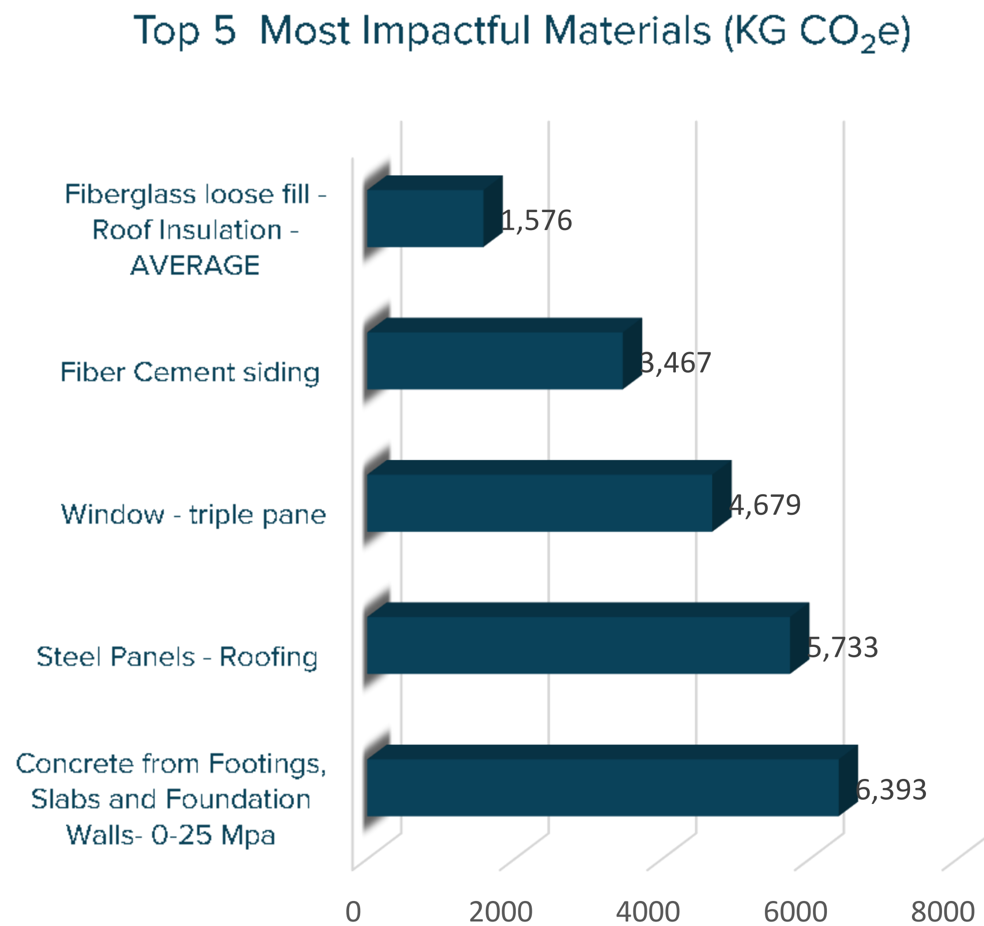


Source: H2k / MCE2 software outputs

# Scenario Results

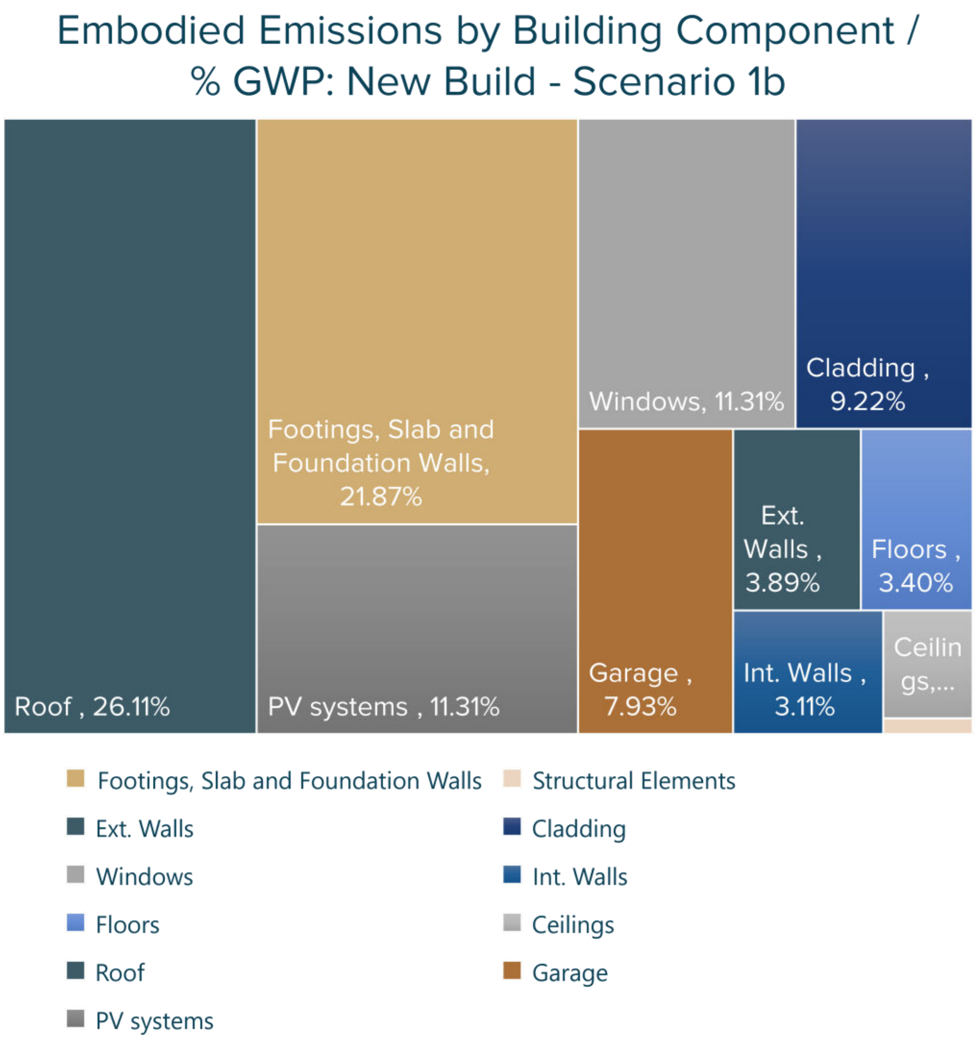
## Breakdown by element of scenario 1a – New Build (No PV)

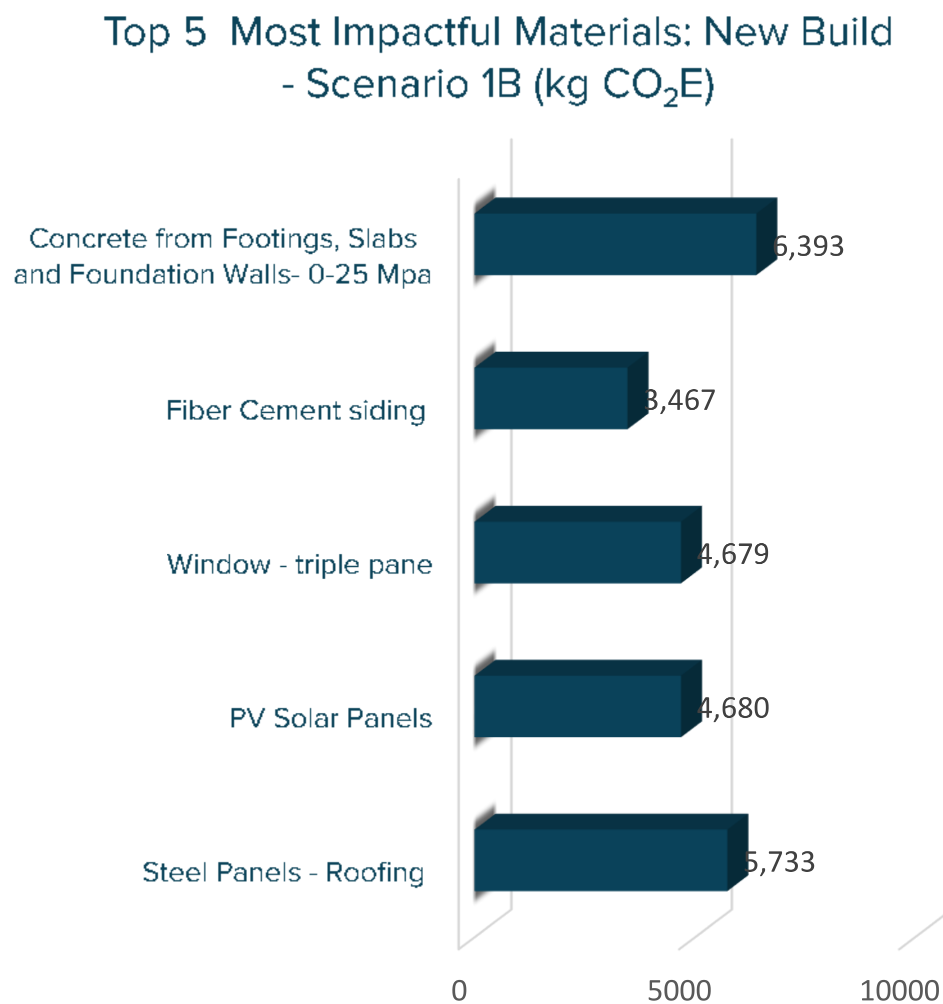


# Scenario Results

## Breakdown by element of scenario 1b – New Build (With PV)

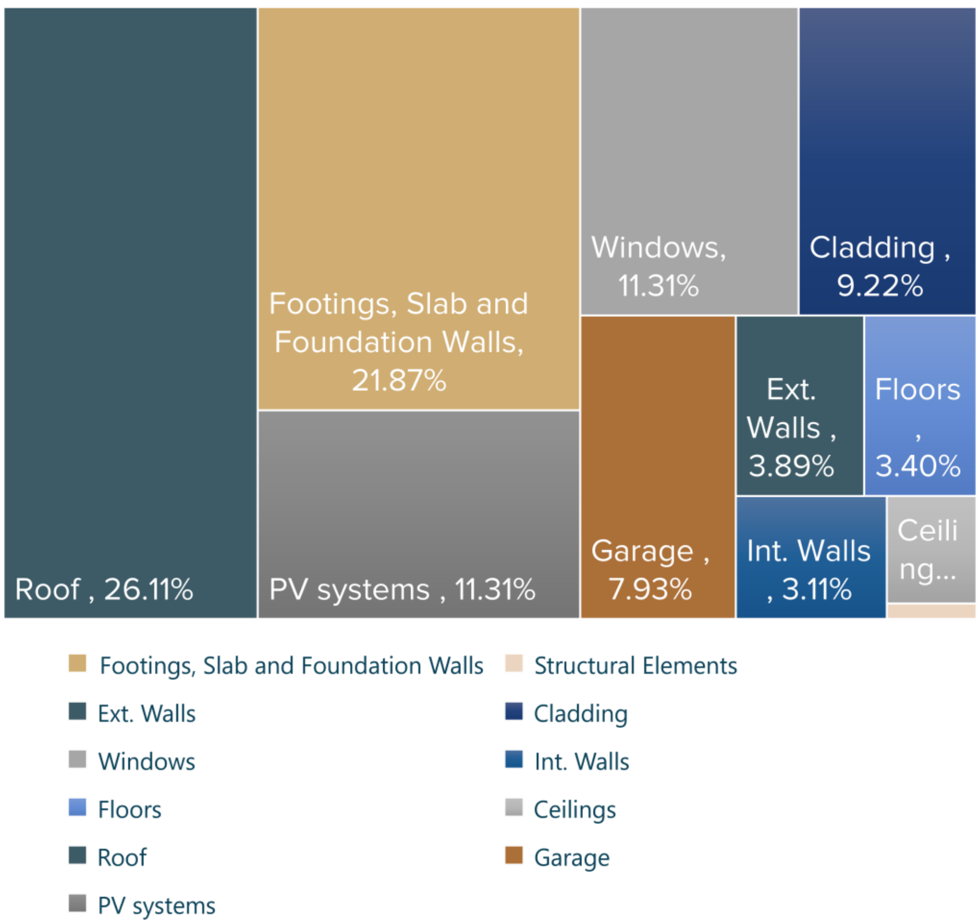


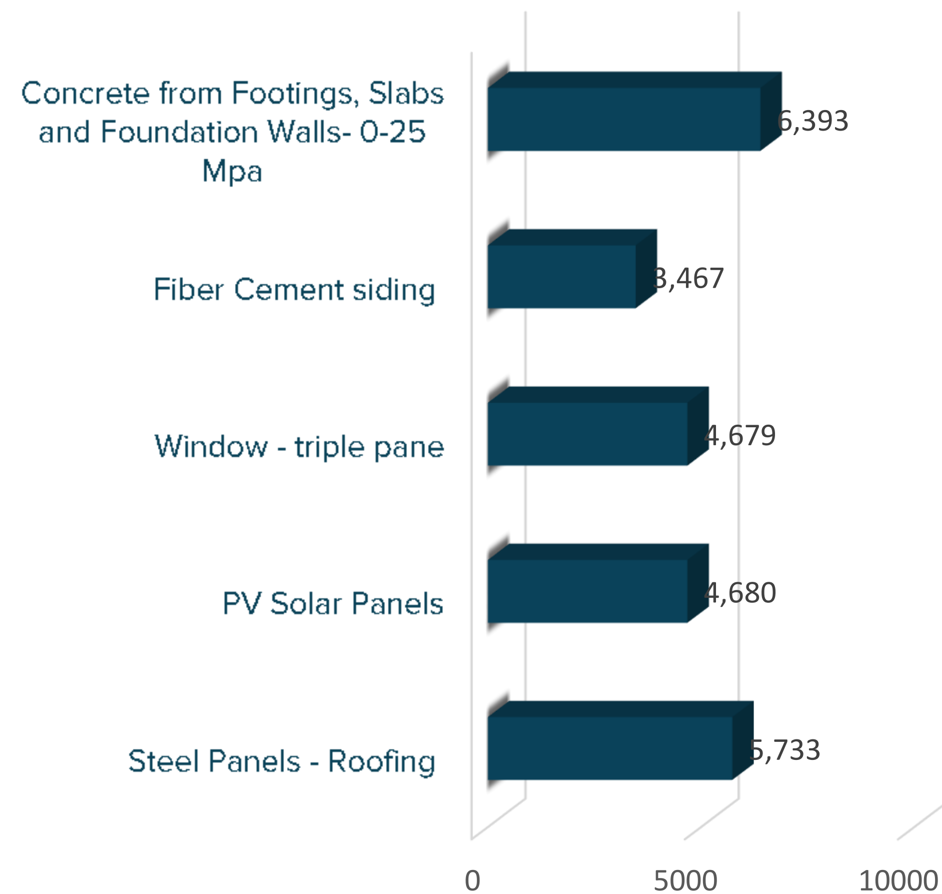
# Scenario Results

## Breakdown by element of scenario 1b – New Build (With PV)

Embodied Emissions by Building Component / % GWP: New Build - Scenario 1b



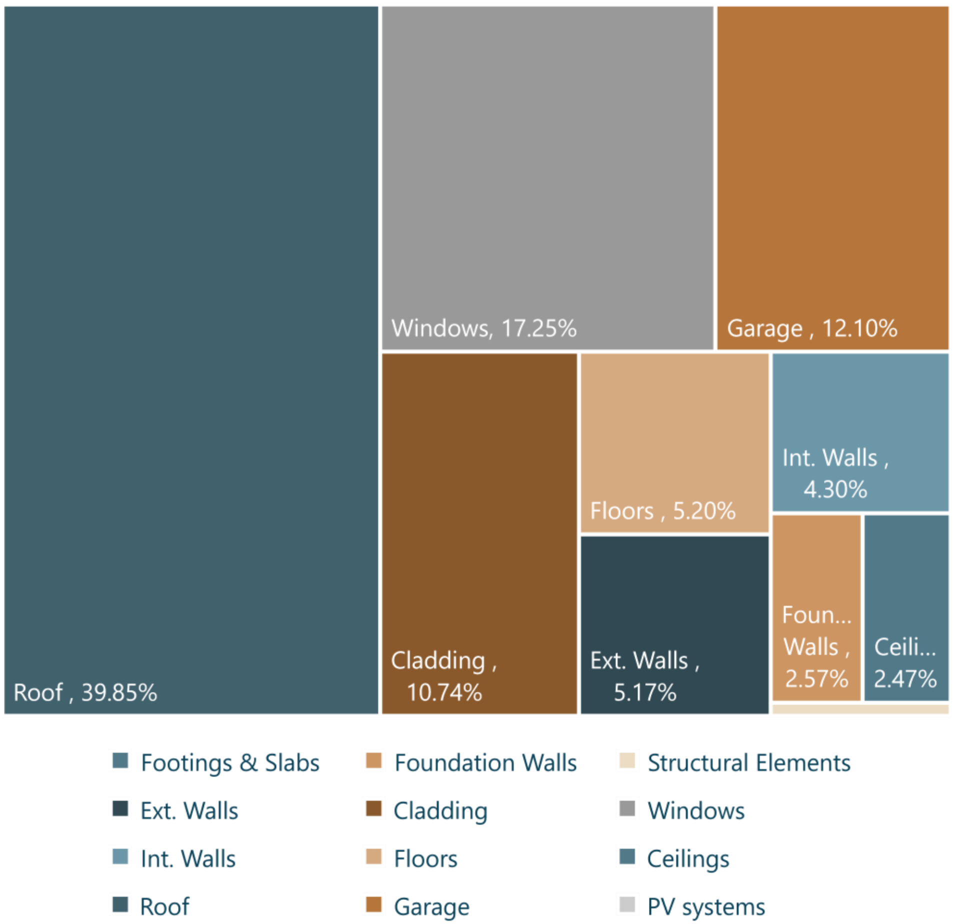

Top 5 Most Impactful Materials: New Build - Scenario 1B (kg $CO_2E$)



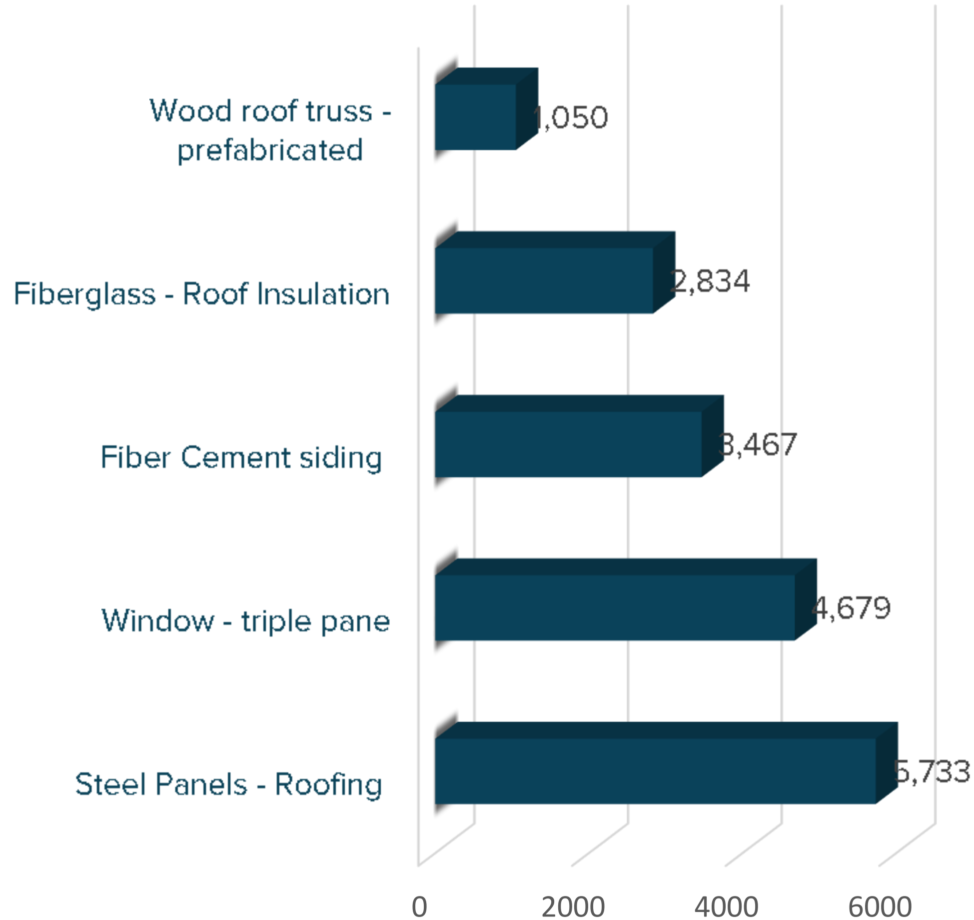
# Scenario Results

## Breakdown by element of scenario 2a – Deep Energy Retrofit (No PV)

Embodied Emissions by Building Component / % GWP: Deep Energy Retrofit Scenario 2a

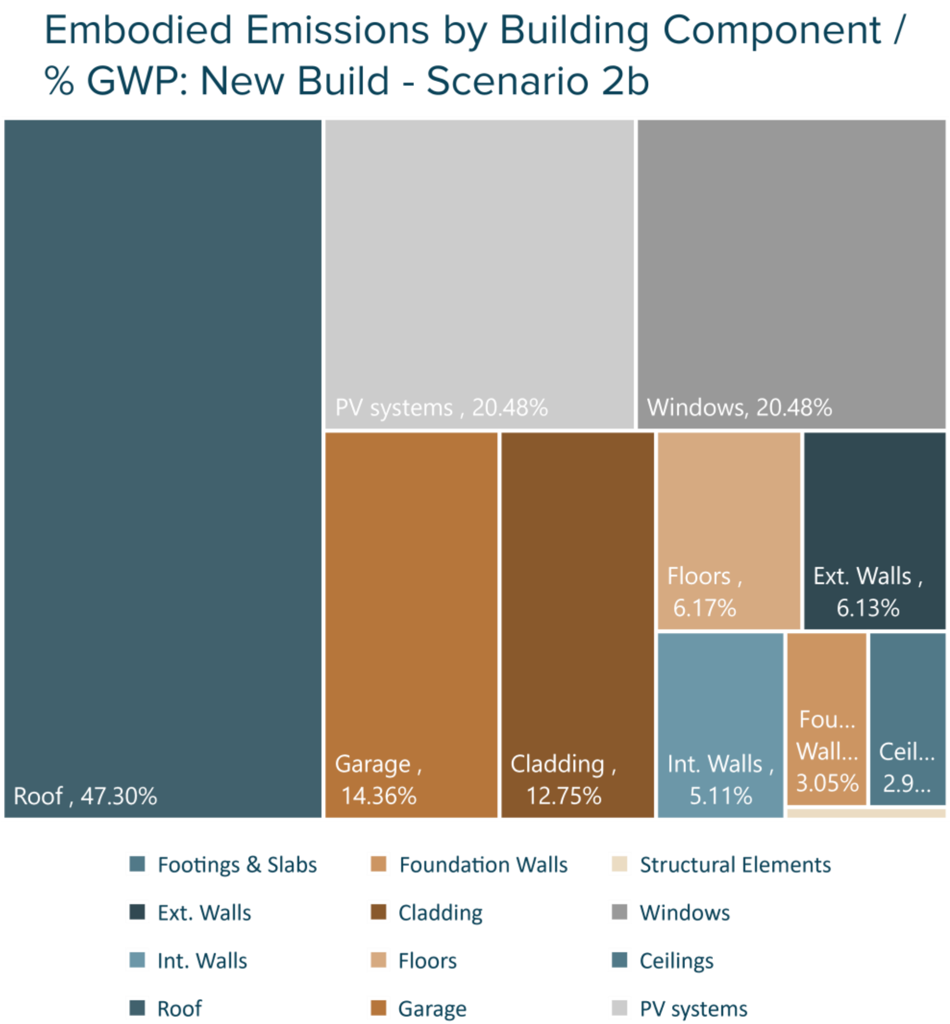


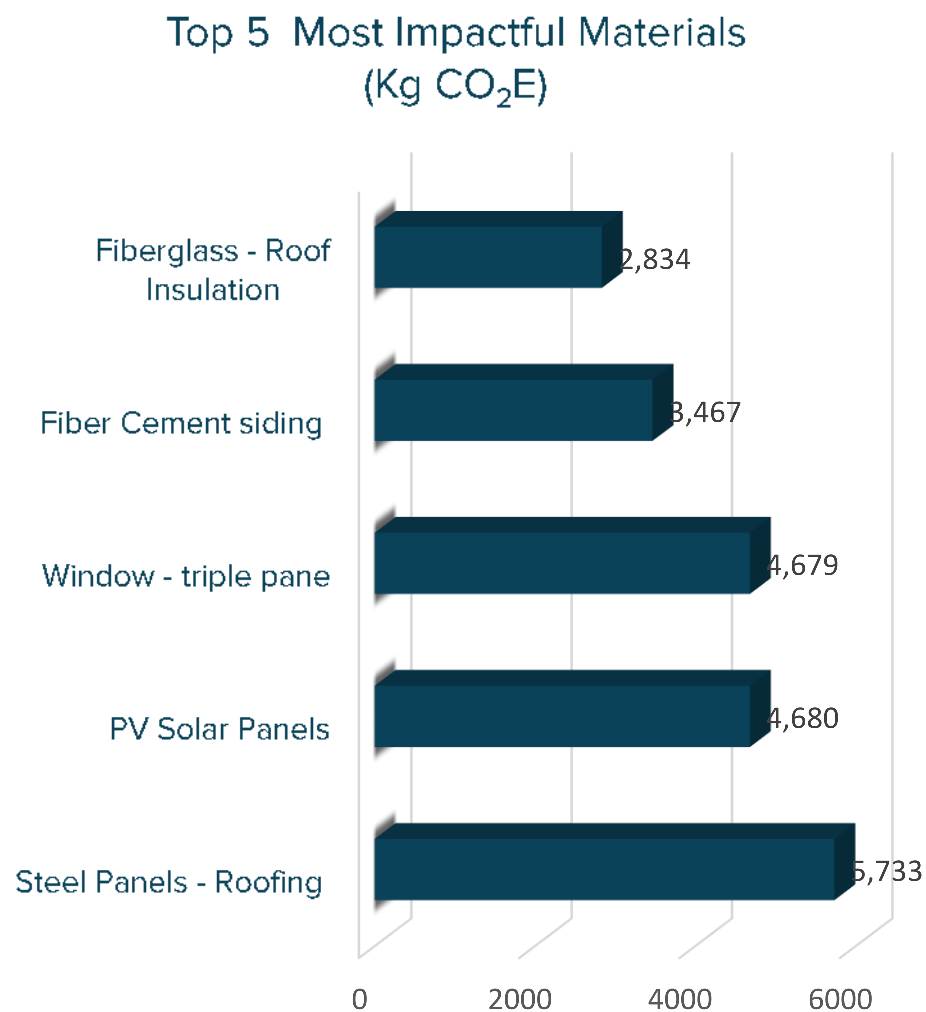

Top 5 Most Impactful Materials (kg $CO_2$e)



# Scenario Results

## Breakdown by element of scenario 2b – Deep Energy Retrofit (With PV)



The building component most impacting embodied emissions in all scenarios is the steel roof. This was a design element specified on plans, but is likely to be changed as a result of costs and the significant impacts identified. The impact of the roof was followed by the concrete found in the slab, footings, and basement walls in the new construction scenario.

The PV system included in the net-zero ready scenario variations then accounts for the largest impact followed by windows. This speaks of the significant impacts of glass as windows and PV panels each represent embodied emissions roughly equivalent to the slab and footings (excluding foundation walls) of the new build scenarios. Acknowledging this is partially due to the smaller below-grade floor area (relative to the overall heated floor area) reducing the impact of the poured concrete, and partially because all windows are triple-glazed increasing their relative impact compared to double-glazed units.

In the renovation scenarios the slab and foundation walls were not considered but are top impacting elements. The absence of concrete elements from the renovation scenarios accounts for the largest savings shown in the embodied emissions calculations. In the renovation scenarios where those impacts are eliminated the fiber cement siding and roof insulation emerge as high impacting materials.

# Reuse and Storage (Module D)

Reuse of materials and carbon storage are aspects of LCA which are not as fully defined in terms of what data is to be included and how it is to be treated. This has become an ongoing conversation among professionals working in whole-building impact assessment and cannot be fully addressed here, but relevant to the case study at hand is the question of the reuse of materials on and off-site.

Salvaging materials for potential later use rather than sending them to landfill represents a savings of energy and therefore carbon, and is a practice that should be lauded and practiced as widely as possible. However, the calculation of the energy and carbon savings is difficult. Do the savings of those impacts apply to the building they were removed from, the one they are reinstalled in, or both?

On the other hand, materials that are left in place and integrated into the structure of a new building on the same site avoid many of these uncertainties, and lend themselves to being calculated in terms of their direct equivalencies to the new materials that do not need to be produced from virgin sources. For this reason, it was determined that materials falling into these two categories would be treated separately.

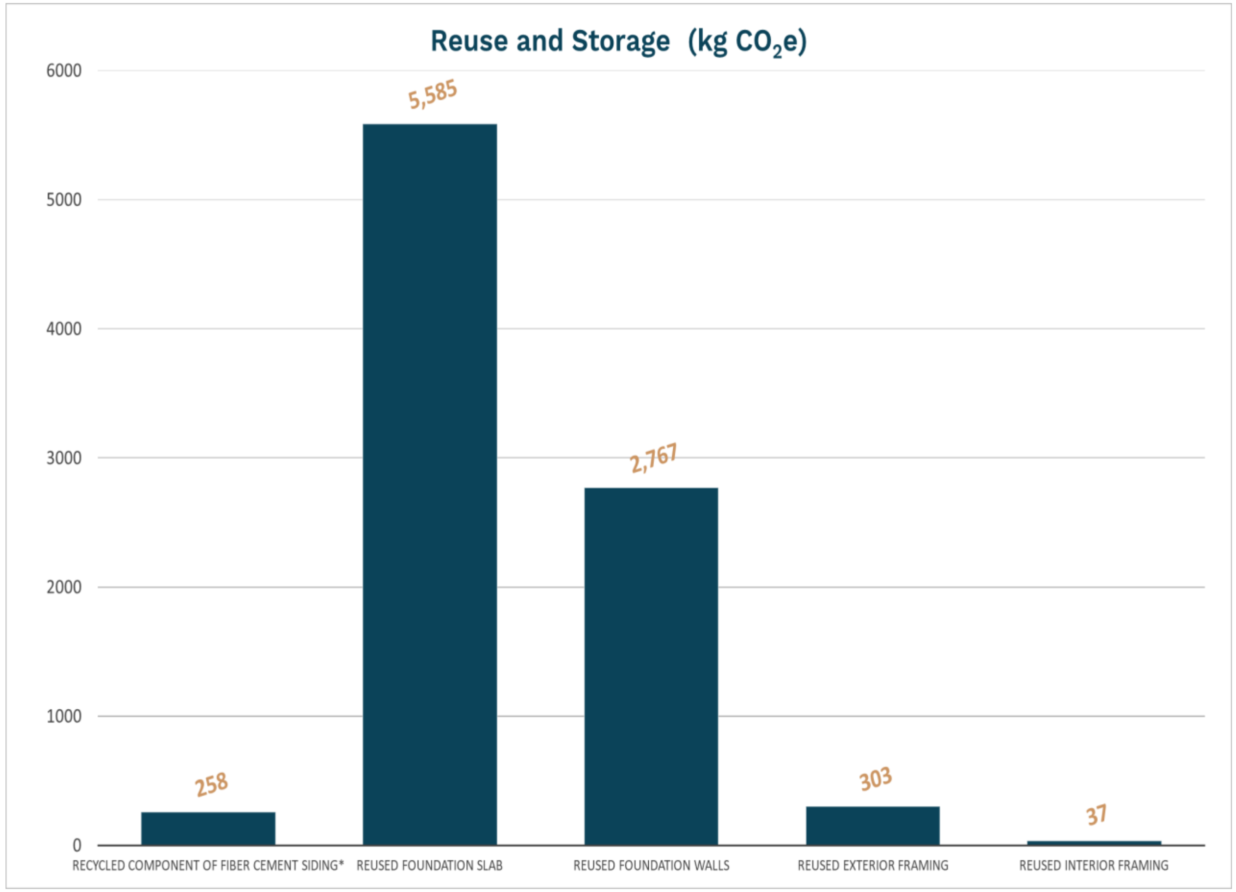
# Design Integration and Material reuse on-site

Key to being able to reuse materials on-site is the ability of designers and other consulting professionals to determine what options are possible in terms of the reuse of materials and to design structures that make the best use of these possibilities. In this case study, the analysis of the new build scenario has shown that the roof and foundation are the most impactful elements of the home. Because the home's existing roof was near the end of life and any new design would require a majority reconstruction of the roof, this impact can be seen to be best mitigated through new material selection.

Of more relevance to reuse, is the slab and foundation walls. Because of their sizeable impacts, the reuse of these elements represents the largest and most easily realized carbon savings in this project, as shown in the table below.

By designing the new residence around the existing footprint of the home in such a way that new concrete was minimized, significant savings of embodied emissions were achieved. This did not limit the overall increase in the size of the residence as new floor space was added over exposed floors, and a new roof design allowed for the redistribution of walls and living space in the interior.

Some notable, but much smaller savings were realized in the reuse of exterior walls, but this was minimized by the fact that walls needed to increase in thickness to accommodate new assembly dimensions, and so some new material was needed. Interior wall reuse was minimal due to the changes in interior layout and so does not represent large savings in this case, but could in other design scenarios.




**of the above components, the fiber cement siding is the only element consistent across all scenarios, and results form the portion of that product which come from recycled materials when it was manufactured but did not originate on site. All other components were reused parts of the original structure.*

# Deconstruction and Material reuse off-site

Some materials salvaged during deconstruction are not directly re-used on the same property. These still provide the potential for future embodied emissions savings. These are in effect, benefits paid forward for use on future construction projects. It is inconsistent with national guidelines on whole-building lifecycle assessment to include any benefits or impacts of this nature in the calculation of the impacts of the project described, as they lie outside the system boundaries[5]. For that reason, they are not considered direct benefits to the scenarios considered in this case study.

There is some guidance on how these benefits can and should be calculated offered through the national guidelines on whole-building Lifecycle assent, which references EN 15978 in regards to structuring attributional analysis and defining system boundaries, and ISO 21930 regarding calculating benefits and loads which occur outside this boundary. This is often referred to as module D and contains 4 distinct flows. D1 recognizes recycling benefits, D2 looks at reuse, D3 explores energy recovery and D4 addresses situations where energy is exported from a building[6].

The intended purpose of module D is not fully defined, and because it lies outside the boundaries of a whole-building LCA, functions more as meta-information used in project planning rather than a specific calculation of impacts.

Regulatory bodies and professionals engaged in whole-building life cycle assessments have yet to reach a consensus on how to gather and apply data related to impacts occurring outside or between the system boundaries.

There is no constant methodology or standard for measuring or tracking the amount of material removed through deconstruction. Materials diverted to municipally managed waste facilities may be sorted and handled in varied and potentially inconsistent ways. Some materials may be recycled or reused in a form similar to their original use, whereas others may be reprocessed and become input materials for other products. Techniques and related energy inputs associated with new products inevitably vary depending on the type and ratio of salvaged materials used and what additional processing was required. These challenges suggest there is more work that can be done in this area to quantify the benefits associated with these practices.

The following data was provided by Unbuilders and represents the very best efforts at tracking and quantifying material volumes salvaged during deconstruction. Materials were recycled or salvaged wherever possible with minimum use of landfill. For the reasons discussed above, a comprehensive analysis of the impacts of these materials is not possible.

The table below outlines what material volumes were recorded in the deconstruction of the home. These are connected with the best available information regarding end-of-life scenarios for those material categories, and some brief discussion of beneficial impacts that can be linked to those materials where possible.

[5] National Guidelines for whole-building life cycle assessment, 2022
[6] National Guidelines for whole-building life cycle assessment, 2022

| Materials | Weight (tonnes) | Weight (% of total) | Assumed end-of-life scenario | Impacts or benefits |
|---|---|---|---|---|
| **Asphalt** | 3.09 | 8.23% | Municipal Recycling Program – presumably used in the production of new asphalt materials with lower embodied emissions. | Asphalt recycling practices vary greatly depending on the process used and % of post-consumer material. Potential reductions: between 45%-79% of $CO_2e$ associated with the manufacture of new asphalt, if that asphalt uses between 60%-95% recycled material. (Potential Carbon Footprint Reduction for Reclaimed Asphalt, 2021) |
| **Concrete, plaster** | 12.32 | 32.83% | Transported to Municipal Recycling Program facility | Concrete absorbs carbon from the atmosphere in a process called carbonation. This process is greatly facilitated by crushing the material to increase its surface area and exposure to atmospheric carbon. Calculations of carbon uptake through carbonation require more data regarding the age, cement content, depth of carbonation, and exposed surface area of the material. It is also dependent on the timeline for which the impact/benefit is calculated because the process occurs progressively over time. |
| **Garbage** | 7.5 | 19.99% | Transported to Municipal Landfill facility | No evaluation is possible. If assumed to be wholly inorganic then transportation impacts can be considered. If organic material is present then $CO_2$ and NH4 emissions must also be considered. |

| Materials | Weight (tonnes) | Weight (% of total) | Assumed end-of-life scenario | Impacts or benefits |
|---|---|---|---|---|
| **Metal** | 0.98 | 2.61% | Transported to Municipal Recycling Program facility | The National Guidelines for whole-building lifecycle assessments guide calculations that compare the impacts of recycled vs new steel. These estimates are consistent with the assumptions: new steel has an impact of 2.01 kg $CO_2$e/kg, recycled steel 1.45 kg $CO_2$e/kg when composed of 50% post-consumer material (values are averages taken from the EC3 database). In this context, the .98 tons of recycled steel can be seen as having a benefit of **548.80 kg$CO_2$e** if used in place of new material. |
| **Recycled wood** | 6.90 | 18.40% | Generic wood products can be reused as the same or similar products. Usually redistributed through Habitat for Humanity or similar organization. | Wood products that are repurposed for use in a similar application can be viewed as having a potential reuse benefit equivalent to any new material they take the place of, less the impacts associated with transportation. In this case, if all material transports are assumed to be local and negligible then the pure material impacts of an equivalent industry-standard volume of new dimensional lumber would be **493 kg$CO_2$e.** *(calculated in MCE2 using US&Can industry average)* |
| **Salvage wood** | 6.73 | 17.93% | Less generic wood products that can be cleaned, restored, or re-processed/re-manufactured as necessary to provide usable building materials or contribute recycled material to new components. | Wood products that undergo further reprocessing can and should be calculated in the context of the products containing post-consumer material that they are used for. Insufficient data was available at the time of writing to explore the specific reprocessing of materials removed from this project. Calculations would necessarily include additional transportation, processing, and material inputs. |

Questions persist as to whether reused material should be considered products whose impacts have been amortized, and which can now enter a new building's system boundary with a value of zero. Or, should recycled materials be attributed a negative impact value equivalent to the impact that would have occurred should a new material be used instead? The first option seems to suggest the most equitable approach to ensuring that material values are not double counted or misrepresented when passing from one building or system to another. The second, however, could suggest a method of evaluating the impacts of reused and recycled materials in a way that emphasizes the positive environmental impacts that are known to accompany practices that take materials from cradle to cradle.

# Discussion

## Comparing Scenarios

The figure below compares the operational emissions over time of the baseline home compared to the four scenarios. The home pre-renovation operational emissions of 8.2 tonnes of $CO_2E$ per year, were available from a pre-retrofit EnerGuide Evaluation. Since the building was originally constructed in 1958, for this comparison the embodied emissions were taken to be zero at this point in time. We can see the time required to achieve a net savings of $CO_2e$ as a result of undertaking a new or a reconstruction project. This is the time at which **the cumulative emissions savings of the renovation or the reconstruction of the home would equal the upfront investment of emissions associated with construction.**

The results are illustrated in Figure 2 below.

In the case of a new build, the timeline for this was almost exactly 4.4 years, or 4.9 years when embodied emissions from solar panels were included in the net-zero scenario. In either renovation scenario, the payback time was shorter still, equaling 3.5 years or 4 years in the net zero variation.

This demonstrates the value of **addressing operational energy efficiency in older homes.**

A house that has high annual energy consumption very quickly emits enough operational $CO_2e$ to

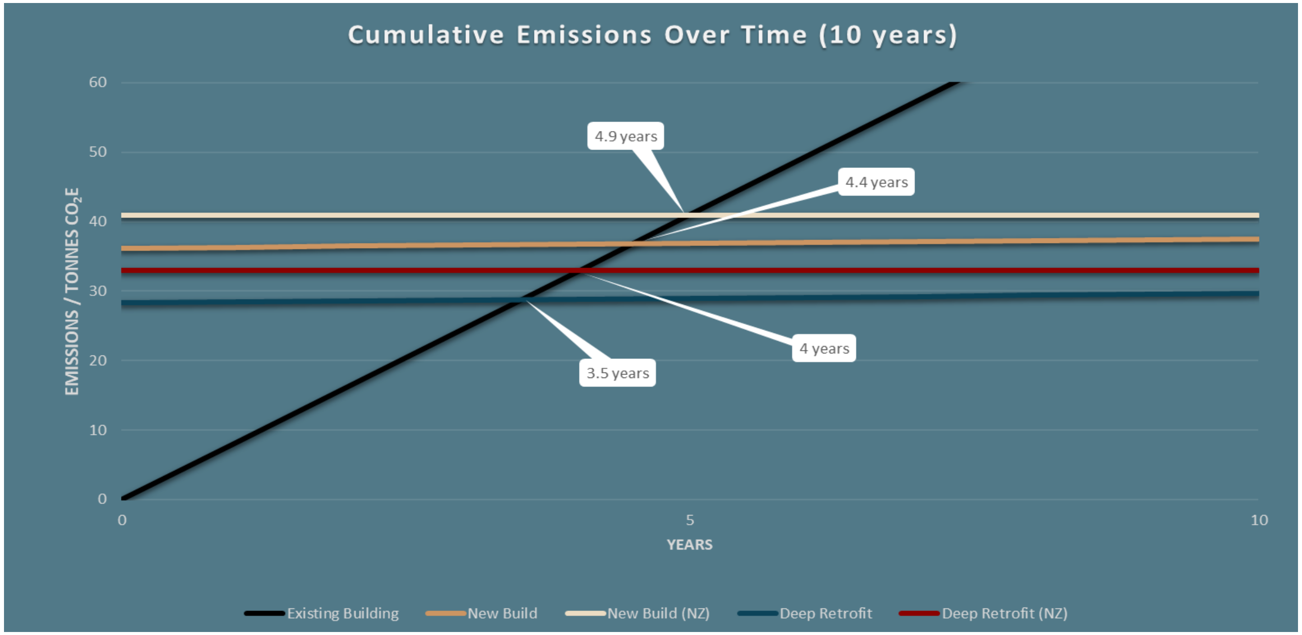



*Figure 2: Graph displaying the total cumulative emissions over time for each renovation scenario.*

equal the embodied $CO_2e$ of either renovating the building to a much higher level of energy efficiency or replacing it altogether with a new build.

However, that does not necessarily mean that both renovation and reconstruction options are equal.

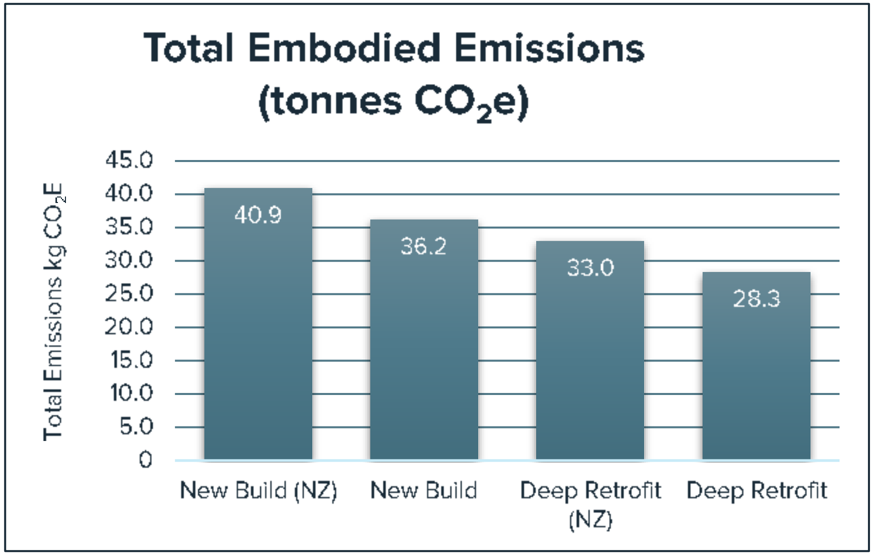
When the total emissions equivalent options are compared across these scenarios, the **embodied emissions were 7.9 tonnes $CO_2e$ lower when the home was partially deconstructed and renovated,** as compared to demolishing and building new, due to the reused components (figures are shown in the table below, left). That is equivalent to the emissions associated with the annual emissions of 2.2 passenger vehicles or 3,067 L of Gasoline[7]. This amounts to a total embodied emissions reduction of 19.3% when compared to the same home with all new materials and 21.8% if a PV system is added to the design.

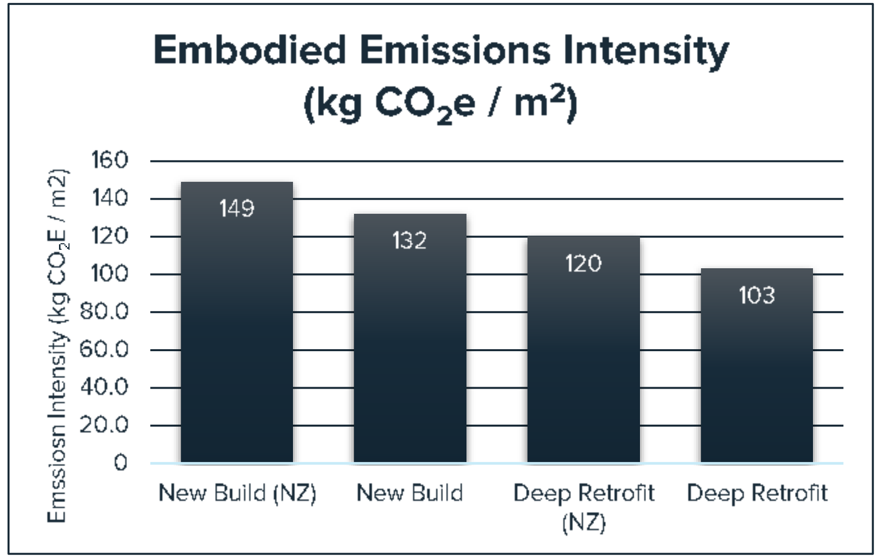
> The embodied emissions invested in upgrading the home through a deep energy retrofit or a full reconstruction can be paid back in **5 years or less** by the energy savings of a new high-efficiency home.

[7] National Resources Canada, Greenhouse Gas Equivalencies Calculator, 2023

# Discussion

## Comparing Scenarios




In both the new construction and renovation scenarios, it can be seen that the inclusion of PV systems resulted in increased embodied carbon equivalent to 4.7 tonnes of $CO_2E$ and a related increase in material emissions intensity (or the embodied emissions divided by the square footage of the home) increasing by 17kg $CO_2E$ /m2 or 11.4% and 14.1% respectively (Carbon intensity shown in the table above, right). This implies that, although contributing to the home's operational energy performance, these components also have a non-negligible effect on a building's embodied emissions impacts.

These figures begin to demonstrate some of the relationships between embodied and operational emissions.

The initial comparison of the baseline building, which was inefficient, to the range of new efficient homes, indicated an easy choice in terms of environmental impacts. The old home used enough energy and produced enough emissions to justify its total replacement with a more efficient alternative in less than 5 years.

When the scenarios are considered together there is a clear savings of embodied emissions associated with the renovation over the new construction. This holds true when any limitations or effects a renovation might have on the resulting building are factored into operational energy usage, such as the limited ability to reinsulate under the slab.

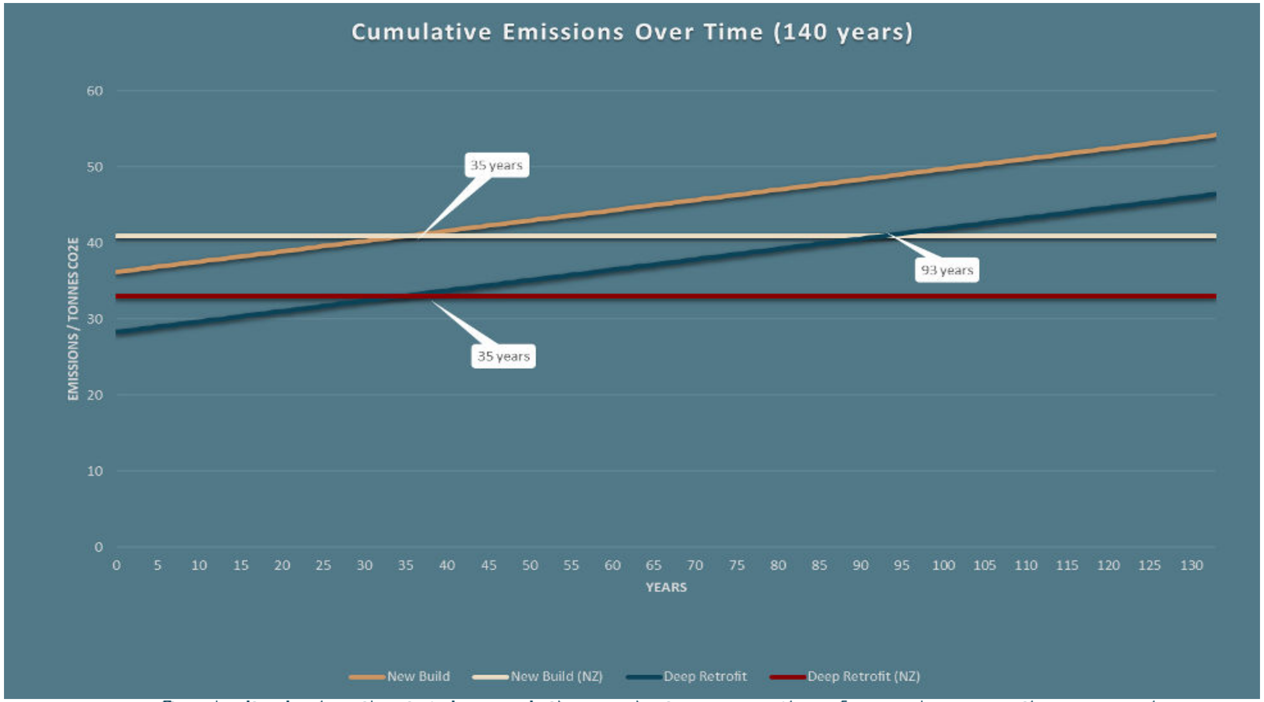
Because in both scenarios the operational emissions required to maintain comfortable temperatures in this home are quite low, adding solar panels to reach net-zero represents an additional upfront investment of embodied emissions, in this case, equivalent to 10-14% of the home's total embodied emissions.

# Discussion

## Over a longer time frame

If the scenarios are extended along an even longer timeline, it becomes possible to consider the impact of the PV panels more completely. When both scenarios are compared to their equivalent Net Zero construction, it emerges that the 4.7 tonnes of $CO_2e$ associated with the PV solar installed will take approximately 35 years to be matched by the operational energy savings those panels will allow the home to realize. This is because the new home has such a high operating efficiency that it uses less energy as well as the reality that the energy it does use is electric and comes from British Columbia's clean power grid which has few emissions associated with electricity production.

An even more striking comparison can be made when looking at scenario 1b (New Build with PV to NZ) and scenario 2a (Deep Energy Retrofit with no PV). The table below shows that this timeline is very long, with approximately 93 years of operation required for the renovated home to generate operational emissions equivalent to the 12.6 tonnes of $CO_2e$ that it would take to build the new home including PV system and operating at net-zero emissions.




*Graph displaying the total cumulative emissions over time for each renovation scenario. Emissions factors for electrical grid: 11.5 tCO2e/GWh* [8]

Put another way, the newly built home with a PV system will produce 12.6 tonnes of $CO_2e$ more than renovating the existing home to the same design, without the PV system. The renovated home operating efficiently, with ongoing operational emissions will take approximately 93 years to accumulate the same 12.6 tonnes of emissions.

Under the new build with a PV scenario those emissions would be experienced by the atmosphere immediately during construction, whereas under the renovation with no PV situation, those same emissions would be spread out across a 93-year timeline.

This demonstrates **the importance of considering both operational and embodied emissions when making energy upgrades, especially when a home is heated by the electricity from a clean grid.**

[8] Electricity emission intensity factors for grid-connected entities (Government of British Columbia, 2022)

# Discussion

## PV Systems and Embodied Emissions

The above indicates a 35-year timeline for the operational energy savings realized by adding a PV system to return the investment of embodied emissions represented by the panels in the fully electric new build scenarios. A timeline that, in reality, may exceed the operational lifespan of the panels themselves.

While this might appear to suggest that PV systems are not a wise emissions choice for all-electric homes, it simply highlights the complex relationship between embodied and operational emissions and uncovers the need for greater discussion on the topic as well as the need to investigate longer timeframes. Some of these points are briefly considered in the following discussion.

Calculating the embodied emissions of PV solar panels is complex and has only been partially explored in research. There are a limited number of EPDs available which makes industry averages difficult to determine. Best efforts were made based on currently available data (see Annex 1 for details).

Emerging research trends suggest that the embodied emissions emitted to produce PV systems are decreasing steadily as the technology becomes more widely developed[9]. This fall appears to be driven mainly by improvements in the manufacturing process and the ongoing global decarbonization of electricity and is relevant to consider when evaluating the efficacy of solar power generation[10].

British Columbia's electricity grid is largely clean. 98% of our electricity is supplied by hydroelectric power with a low emissions factor. Because of this, even before the installation of solar panels, the operational emissions of an all-electric home are minimal. By installing solar panels, we are switching from one renewable energy source to another, replacing the low operational emissions of hydroelectric power with the low operational emissions of PV generation, at the additional cost of the embodied emissions of the panels themselves. In regions where the electricity grid is largely supplied by fossil sources with high emissions factors, the immediate benefits of installing solar panels will be far greater with a much shorter payback time.

Irrespective of the point above, installing solar panels in BC still offers many benefits which are not demonstrated in the data. These include energy bill savings for the homeowner and freeing up renewable power to be exported or put to use elsewhere which, in the drive to electrify the province will only become increasingly valuable. There are also additional arguments in favor of grid diversification and decentralization which are worthy of consideration but beyond the scope of this study.

## Material Substitutions

One of the things that become possible when any form of whole-building life cycle analysis is conducted, particularly during the design phase of a project, is the possibility of making material selections and substitutions early, and with as much information as possible on what materials are related to the largest impacts. In this example, three materials are constant top impactors across all scenarios. The metal roofing, the triple-glazed windows, and the fiberglass insulation in the attic all appear within the top 6 impacting materials across all scenarios. If these materials were to be substituted for similarly performing alternatives with lower impacts, it becomes apparent how **some simple decisions made early on in the design process can reduce the embodied carbon associated with the building.**

The table below describes the relative impacts of the three top-impacting materials.

[9] Nature Energy, Understanding future emissions from low-carbon power systems, 2017
[10] Warboys, Retrieved from The rapid fall of solar's embodied carbon, 2021

# Discussion

## Material substitutions

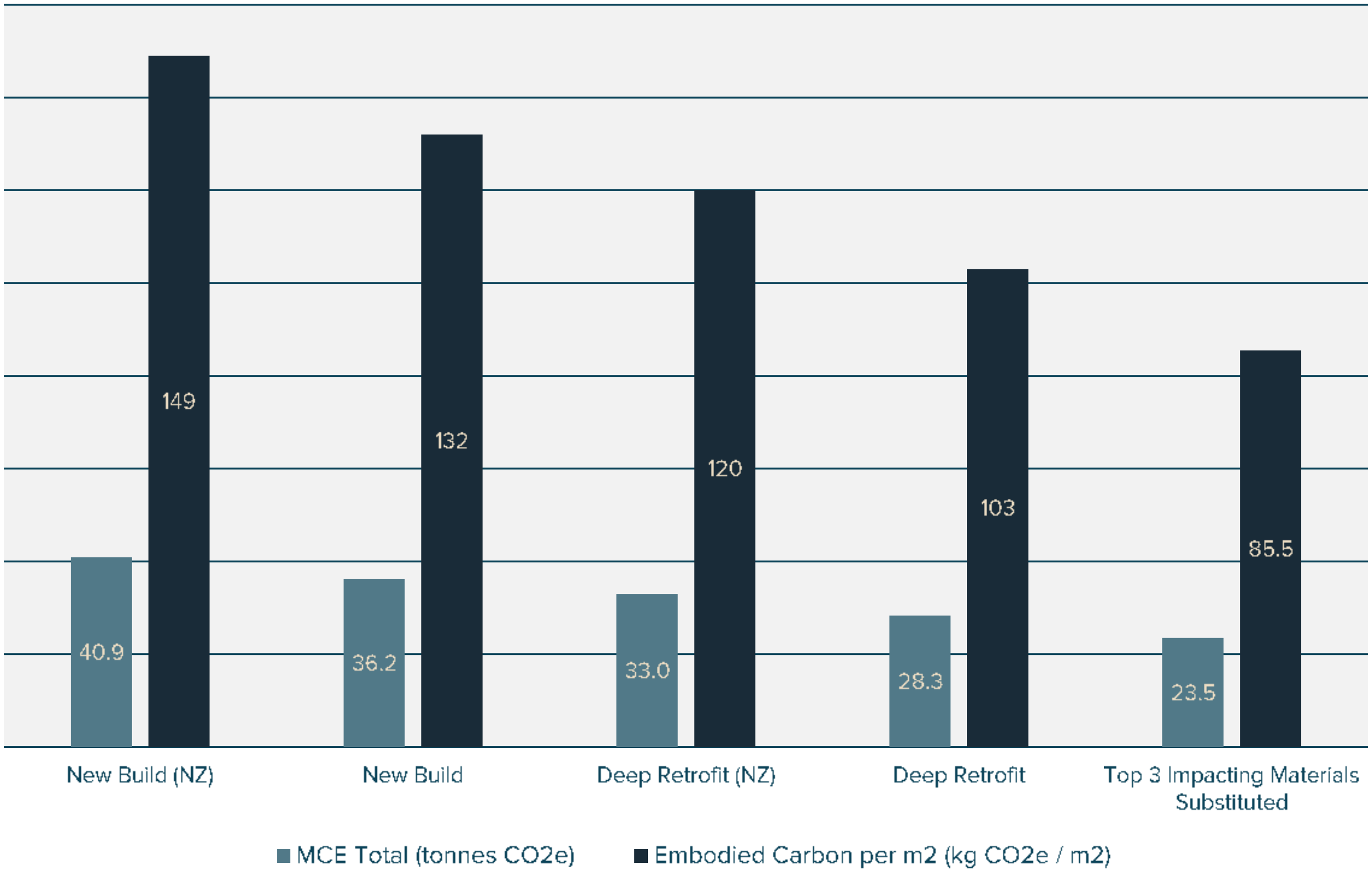
| Original Material | Embodied Emissions $kgCO_2e$ | Material Substitution | Embodied emissions $kgCO_2e$ | % Reduction |
|---|---|---|---|---|
| Steel Panels - Roofing - AVERAGE | 5,733 | Asphalt Shingles / Owens Corning / Supreme / | 829 | 85.5% |
| Window - triple pane / Vinyl frame generic | 4,679 | Window - triple pane / Wood frame/ EU (best performer) | 2,992 | 36% |
| Fiberglass batt - Roof Insulation - AVERAGE | 1,258 | Fiberglass batt / Owens Corning / EcoTouch Pink batt | 870 | 30.8% |

The selections presented here were chosen according to their embodied emissions performance and availability of EPD data informing the software used. Consideration was not paid to the availability of these products. The steel roof is the largest impactor and can be a substitution with an asphalt alternative for an 85% savings in embodied emissions. Windows were changed to lower-impact wood alternatives. It should be noted that the options selected are European products as no domestic alternatives with comparable glazing were available with distinctly lower impacts.

Further, the impacts related to transportation are beyond the scope of this research and do not factor into these numbers. Finally, the selection of the EcoTouch product from Owens Corning represented the lowest impacting equivalent to the industry average ceiling insulation data used in the scenarios considered above, resulting in a reduction of the embodied carbon of 30.8% for that component.

When these substitutions are integrated into the home design the total embodied emissions can be seen below to drop as low as 23.5 tonnes of $CO_2e$, with a carbon intensity of 85.5 kg $CO_2e/m2$. This assumes the substitution of the top impacting materials into scenario 2a, where the home undergoes a deep energy retrofit but with no PV solar installed.

# Discussion




This reduction of 4.8 tonnes of $CO_2$e over even the scenario with the lowest embodied carbon associated with it, **demonstrates the significance of considering the impacts of material choices and making strategic substitutions whenever possible.**

# Conclusions

The data gathered here supports the conclusion that, for homes with poor operational energy performance, net energy savings can be realized in a relatively short timeframe through either a demolition and reconstruction or deep energy retrofit. The period was five years in this study.

The data also supports the conclusion that a deep retrofit provides many opportunities to lower a building's embodied emissions when compared to building a completely new structure by reusing existing components. This was accomplished with the intent of still arriving at essentially the same structure as a result. That acknowledged, the careful selection of low-carbon building materials remains an essential factor in ensuring these benefits are realized and can be seen when the top impacting materials were substituted to functionally equivalent lower impacting alternatives.

PV systems provide an increasingly common choice for homes to reduce their operational emissions. This study quantifies the extent to which this increases the carbon use intensity for this building. This upfront carbon investment was calculated and compared to the annual operational energy use of the building resulting in payback periods equal to or longer than the life of the solar panel.

When compared to the *Material Emissions Benchmark Report for Part 9 Homes in Vancouver*, average net emissions from a home in the City of Vancouver amount to 43t $CO_2e$ with an average emissions intensity of 193 kg$CO_2$e/m2. This study demonstrates that a deep retrofit, particularly one using carefully selected low-carbon materials can result in significantly below-average embodied emissions (120 kg$CO_2$e/m2).

## Further research opportunities

This research offers opportunities to expand on and answer many questions which remain. Some of these include but are not limited to:

- Research encompassing a wider range of housing types, sizes, and geometries.
- Embodied emissions of mechanical and PV systems.
- Embodied emissions of home repair and home improvement practices to support the estimation of maintenance and replacement flows.
- Expanded production and distribution of EPDs to expand the body of material knowledge and to inform LCA tools with improved materials selection.
- Best practices for developing Embodied Carbon benchmarks.
- Policy frameworks supporting transitions in the building industry and housing inventory to lower embodied carbon models.

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# Annex 1: Procedures followed

Modules A1-A3 + B6:

An initial examination of the proposed renovation plans was conducted using Bluebeam software for analysis and geometry takeoffs. These were then entered into the BEAM tool as a first-run assessment of the embodied emissions in the whole building.

At this point, an operational energy model of the building was produced using Hot2000 V11.11 following standard ERS modeling procedures. This model was intended to represent the home as though it were a new construction and so some small adjustments to the basement height were incorporated to represent the building if it were built to current standards. This allowed for the determination of the operational energy consumption of the proposed home.

This energy model was then modified to meet Net Zero operational energy performance by CHBA NZ modeling guidelines, through the introduction of a 22-panel PV system. This also provided the material quantities necessary to calculate the Embodied emissions of the solar panels.

At this point Embodied emissions modeling was moved to the NRCan MCE2 tool to make the best use of the Hot2000 import function introduced by NRCan. Because MCE2 and BEAM are essentially the same tool and should produce comparable results the initial BEAM model was used to corroborate the MCE2 model. Only very small variations in geometry and material calculations were noted. After being imported into MCE2 the necessary auxiliary user input data was entered to complete the baseline model of this home, which in this case represents the home as if built new.

The embodied emissions associated with the 22 solar panels needed to reach Net zero was then calculated by extrapolating an average from the available EPD data on PV solar panels, of which 3 were found to be relevant and to have been conducted with sufficient scope and rigor to justify adequate confidence. Several secondary studies were also consulted and the averages presented by Elementa consulting were found to be comparable and therefore accepted as representative of an industry average of embodied emissions in PV solar panels at this time (Elementa Consulting and Wilmott Dixon, 2022) (Worboys, 2021). Because EPD data is not included in BEAM or MCE2 databases, this value was entered into the baseline model as a user-defined code to be incorporated into the embodied emissions of the home if constructed to net-zero.

From the original data, a slightly modified set of building geometries and related material quantities were derived. These were adjusted to reflect the realities of renovating an existing building vs. a new construction. Geometry distinctions are related largely to the slab and foundation. These were adjusted in Hot2000 and the operational energy load of the building was recalculated. This model was then imported into MCE2 for embodied emissions analysis.

It was determined that the operational energy difference between the two scenarios was close enough that the calculated solar array was appropriate in both scenarios to meet the CHBA NZ standard, and that the slightly higher operational energy demand of the renovation scenario did not affect the number of panels that would need to be installed.

Because in a renovation scenario some building components are wholly new material, some are removed completely, some are partially retained and some are left wholly intact. Each of these situations implies a different level of embodied emissions and so were considered individually in relation to the household component. Isolating new, retained, and upgraded components were accomplished by manually calculating the surface areas using Bluebeam liftoffs. Removed components are considered in modules C and D.

# Annex 1: Procedures followed

Entirely new components were consistent with the new build scenario, and so did not require adjustment in the way they were evaluated, but needed to be extracted from the other material quantity data. Some components like the roof assembly were consistent across scenarios, and so did not require alteration. Components such as exterior walls which were in part new and in part upgraded were separated into appropriate categories. A separate MCE2 calculator was established and populated with only entirely new material components. The output in CO2e for each was retained separately.

The original MCE2 calculations of the new build scenario were then altered to form a renovation scenario. User inputs informing material quantifies were altered to reflect the removal of components composed of wholly new material. The building components were then adjusted at the material level to reflect new vs reused material. The percentage function was used to accomplish this. (For example, it was assumed all insulation and drywall would be replaced so these were left at 100%, studs that were furred out were adjusted to reflect the percentage of new material used). The previously retained all new material component data was then reintroduced as a user-defined material.

The inverse proportion of material retained in each category was also calculated and retained as an estimate of CO2e storage which could be attributed to the materials reused in the renovation scenario as compared to the new build, where these would need to be produced anew.

# Annex 2: Impacts by building Material – New Build (Scenario 1B)

| Building Component | CATEGORY | MATERIAL | NET CARBON FOOTPRINT [kg $CO_2e$] | CARBON EMISSIONS [kg $CO_2e$] | CARBON STORAGE [kg $CO_2e$] |
|---|---|---|---|---|---|
| Footings & Slabs | CRUSHED STONE BASE | Aggregate / / / Avg construction aggregate (gravel & sand) | 7 | 7 | 0 |
| Footings & Slabs | FOOTINGS & PADS | Concrete - 0-25 MPa, Industry Average Benchmark / CRMCA / Can. Avg. / | 1,362 | 1,362 | 0 |
| Footings & Slabs | SLAB FLOOR(S) | Concrete - 0-25 MPa, Industry Average Benchmark / CRMCA / Can. Avg. / | 3,418 | 3,418 | 0 |
| Footings & Slabs | SUB-SLAB INSULATION | EPS foam board with graphite / BASF / Neopor / R 4.7/inch, Type IX | 798 | 798 | 0 |
| Foundation Walls | CONCRETE FOUNDATION WALLS | Concrete - 0-25 MPa, Industry Average Benchmark / CRMCA / Can. Avg. / | 2,975 | 2,975 | 0 |
| Foundation Walls | FOUNDATION WALL CONTINUOUS INSULATION | EPS foam board with graphite / BASF / Neopor / R 4.7/inch, Type II, 15 psi (Type 2, 110 kPa) | 234 | 234 | 0 |
| Foundation Walls | INTERIOR FOUNDATION WALL FRAMING - WOOD | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 59 | 59 | 0 |
| Foundation Walls | FOUNDATION WALL INSULATION | Fiberglass batt - Foundation Wall Insulation - AVERAGE | 80 | 80 | 0 |
| Foundation Walls | INTERIOR FOUNDATION WALL CLADDING | Drywall 1/2" - AVERAGE | 117 | 117 | 0 |
| Structural Elements | MASS TIMBER | Heavy Timber Framing - AVERAGE | 8 | 8 | 0 |
| Structural Elements | MASS TIMBER | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 15 | 15 | 0 |
| Structural Elements | HEAVY STEEL COMPONENTS | Steel post / Generic / / 3.5 x 0.216" (89 x 5.5 mm), Sched 40 STD | 73 | 73 | 0 |
| Ext. Walls | WOOD FRAME WALLS | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 458 | 458 | 0 |
| Ext. Walls | STRUCTURAL SHEATHING | Plywood / American Wood Council & Canadian Wood Council / / 1/2" | 544 | 544 | 0 |
| Ext. Walls | CAVITY INSULATION | Fiberglass batt - AVERAGE | 554 | 554 | 0 |
| Cladding | EXTERIOR CLADDING | Fiber Cement siding - AVERAGE | 3,133 | 3,351 | 218 |
| Cladding | INTERIOR CLADDING for EXTERIOR WALLS | Drywall 1/2" Typical - Interior Cladding for Exterior Walls - AVERAGE | 339 | 339 | 0 |
| Windows | TRIPLE PANE WINDOWS - GENERIC | Window - triple pane / Vinyl frame / / USA & CAN | 4,679 | 4,679 | 0 |
| Int. Walls | INTERIOR WALL FRAMING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 366 | 366 | 0 |
| Int. Walls | INTERIOR WALL CLADDING | Drywall 1/2" Typical - Interior Walls - AVERAGE | 850 | 850 | 0 |
| Int. Walls | INTERIOR WALL INSULATION | Fiberglass batt - AVERAGE | 73 | 73 | 0 |
| Floors | WOOD FLOOR FRAMING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 611 | 611 | 0 |
| Floors | SUBFLOORING | Plywood / American Wood Council & Canadian Wood Council / / 3/4" | 689 | 689 | 0 |
| Floors | FLOOR CAVITY INSULATION | Fiberglass batt - Floor Insulation - AVERAGE | 109 | 109 | 0 |
| Ceilings | CLADDING | Drywall 1/2" - Ceilings - AVERAGE | 670 | 670 | 0 |

# Annex 2: Impacts by building Material – New Build (Scenario 1B)

| | | | | | |
|---|---|---|---|---|---|
| Roof | WOOD FRAME ROOF | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 191 | 191 | 0 |
| Roof | WOOD FRAME ROOF | Wood roof truss - prefabricated / Quebec Wood Export Bureau / Common (Double Howe) Gabrel Roof / 2x6 Chords, 2x4 Webs, 4:12 Pitch, 40 ft span, 20" overhang | 1,050 | 1,050 | 0 |
| Roof | ROOF DECKING | Plywood / American Wood Council & Canadian Wood Council / / 5/8" | 841 | 841 | 0 |
| Roof | ROOF STRAPPING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 159 | 159 | 0 |
| Roof | ROOFING | Steel Panels - Roofing - AVERAGE | 5,733 | 5,733 | 0 |
| Roof | ROOF INSULATION | Fiberglass batt - Roof Insulation - AVERAGE | 1,258 | 1,258 | 0 |
| Roof | ROOF INSULATION | Fiberglass loose fill - Roof Insulation - AVERAGE | 1,576 | 1,576 | 0 |
| Garage | GARAGE CRUSHED STONE BASE | Aggregate / / / Avg construction aggregate (gravel & sand) | 2 | 2 | 0 |
| Garage | GARAGE SLAB FLOOR | Concrete - 0-25 MPa, Industry Average Benchmark / CRMCA / Can. Avg. / | 804 | 804 | 0 |
| Garage | GARAGE CONCRETE WALLS | Concrete - 0-25 MPa, Industry Average Benchmark / CRMCA / Can. Avg. / | 538 | 538 | 0 |
| Garage | GARAGE MASS TIMBER | Heavy Timber Framing - AVERAGE | 829 | 829 | 0 |
| Garage | GARAGE WOOD FRAME WALLS | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 65 | 65 | 0 |
| Garage | GARAGE WALL SHEATHING | Plywood / American Wood Council & Canadian Wood Council / / 1/2" | 82 | 82 | 0 |
| Garage | EXTERIOR GARAGE WALL INSULATION | Fiberglass batt - AVERAGE | 83 | 83 | 0 |
| Garage | GARAGE ATTACHMENT WALL INSULATION | Fiberglass batt - AVERAGE | 36 | 36 | 0 |
| Garage | GARAGE EXTERIOR CLADDING | Fiber Cement siding - AVERAGE | 503 | 535 | 33 |
| Garage | INTERIOR CLADDING of GARAGE WALLS | Drywall 1/2" Typical - Interior Cladding for Exterior Walls - AVERAGE | 68 | 68 | 0 |
| Garage | GARAGE WINDOWS | Window - double pane / Fiberglass frame / / USA & CAN | 125 | 125 | 0 |
| Garage | GARAGE CEILING CLADDING | Drywall 1/2" - Ceilings - AVERAGE | 63 | 63 | 0 |
| Garage | GARAGE WOOD ROOF FRAMING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 29 | 29 | 0 |
| Garage | GARAGE ROOF DECKING | Plywood / American Wood Council & Canadian Wood Council / / 5/8" | 23 | 23 | 0 |
| Garage | GARAGE ROOFING MEMBRANE | PVC Roofing Membrane / CIFA / Includes: Canadian General-Tower, Duro-Last, FiberTite / 48 mils | 28 | 28 | 0 |
| Garage | GARAGE ROOF STRAPPING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 3 | 3 | 0 |
| Floors | Floors | EPS foam board with graphite / BASF / Neopor / R 4.7/inch, Type IX | 132 | 132 | 0 |
| Floors | Floors | Spray polyurethane foam - Closed Cell (HFC) / SPFA / / R 6.6/inch | 71 | 71 | 0 |
| Roof | Roof | Fiberglass loose fill / CertainTeed / InsulSafe, Optima, TruComfort / R 2.6/inch | 566 | 566 | 0 |
| Solar Generation | PV Panels | PV Solar panels | 4,680 | 4,680 | 0 |

# Impacts by building Material – Renovation (Scenario 2B)

| Building Component | CATEGORY | MATERIAL | NET CARBON FOOTPRINT [kg $CO_2$e] | CARBON EMISSIONS [kg $CO_2$e] | CARBON STORAGE [kg $CO_2$e] |
|---|---|---|---|---|---|
| Foundation Walls | CONCRETE FOUNDATION WALLS | Concrete - 0-25 MPa, Industry Average Benchmark / CRMCA / Can. Avg. / | 208 | 208 | 0 |
| Foundation Walls | FOUNDATION WALL CONTINUOUS INSULATION | EPS foam board with graphite / BASF / Neopor / R 4.7/inch, Type II, 15 psi (Type 2, 110 kPa) | 234 | 234 | 0 |
| Foundation Walls | INTERIOR FOUNDATION WALL FRAMING - WOOD | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 59 | 59 | 0 |
| Foundation Walls | FOUNDATION WALL INSULATION | Fiberglass batt - Foundation Wall Insulation - AVERAGE | 80 | 80 | 0 |
| Foundation Walls | INTERIOR FOUNDATION WALL CLADDING | Drywall 1/2" - AVERAGE | 117 | 117 | 0 |
| Structural Elements | MASS TIMBER | Heavy Timber Framing - AVERAGE | 8 | 8 | 0 |
| Structural Elements | MASS TIMBER | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 15 | 15 | 0 |
| Structural Elements | HEAVY STEEL COMPONENTS | Steel post / Generic / / 3.5 x 0.216" (89 x 5.5 mm), Sched 40 STD | 73 | 73 | 0 |
| Upgraded Ext. Walls | FURRING IN WOOD FRAME WALLS | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 167 | 167 | 0 |
| Upgraded Ext. Walls | STRUCTURAL SHEATHING | Plywood / American Wood Council & Canadian Wood Council / / 1/2" | 544 | 544 | 0 |
| Upgraded Ext. Walls | CAVITY INSULATION | Fiberglass batt - AVERAGE | 554 | 554 | 0 |
| New Ext. Walls | WOOD FRAME WALLS | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 245 | 245 | 0 |
| New Ext. Walls | STRUCTURAL SHEATHING | Plywood / American Wood Council & Canadian Wood Council / / 1/2" | 275 | 275 | 0 |
| New Ext. Walls | CAVITY INSULATION | Fiberglass batt - AVERAGE | 280 | 280 | 0 |
| Cladding | EXTERIOR CLADDING | Fiber Cement siding - AVERAGE | 3,133 | 3,351 | 218 |
| Cladding | INTERIOR CLADDING for EXTERIOR WALLS | Drywall 1/2" Typical - Interior Cladding for Exterior Walls - AVERAGE | 339 | 339 | 0 |
| Windows | TRIPLE PANE WINDOWS - GENERIC | Window - triple pane / Vinyl frame / / USA & CAN | 4,679 | 4,679 | 0 |
| Int. Walls | INTERIOR WALL FRAMING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 330 | 330 | 0 |
| Int. Walls | INTERIOR WALL CLADDING | Drywall 1/2" Typical - Interior Walls - AVERAGE | 765 | 765 | 0 |
| Int. Walls | INTERIOR WALL INSULATION | Fiberglass batt - AVERAGE | 73 | 73 | 0 |
| Floors | WOOD FLOOR FRAMING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 611 | 611 | 0 |
| Floors | SUBFLOORING | Plywood / American Wood Council & Canadian Wood Council / / 3/4" | 689 | 689 | 0 |
| Floors | FLOOR CAVITY INSULATION | Fiberglass batt - Floor Insulation - AVERAGE | 109 | 109 | 0 |
| Ceilings | CLADDING | Drywall 1/2" - Ceilings - AVERAGE | 670 | 670 | 0 |
| Roof | WOOD FRAME ROOF | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 191 | 191 | 0 |

# Impacts by building Material – Renovation (Scenario 2B)

| | | | | | |
|---|---|---|---|---|---|
| oof | WOOD FRAME ROOF | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 191 | 191 | 0 |
| oof | WOOD FRAME ROOF | Wood roof truss - prefabricated / Quebec Wood Export Bureau / Common (Double Howe) Gabrel Roof / 2x6 Chords, 2x4 Webs, 4:12 Pitch, 40 ft span, 20" overhang | 1,050 | 1,050 | 0 |
| oof | ROOF DECKING | Plywood / American Wood Council & Canadian Wood Council / / 5/8" | 841 | 841 | 0 |
| oof | ROOF STRAPPING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 159 | 159 | 0 |
| oof | ROOFING | Steel Panels - Roofing - AVERAGE | 5,733 | 5,733 | 0 |
| oof | ROOF INSULATION | Fiberglass batt - Roof Insulation - AVERAGE | 1,258 | 1,258 | 0 |
| oof | ROOF INSULATION | Fiberglass loose fill - Roof Insulation - AVERAGE | 1,576 | 1,576 | 0 |
| arage | GARAGE CRUSHED STONE BASE | Aggregate / / / Avg construction aggregate (gravel & sand) | 2 | 2 | 0 |
| arage | GARAGE SLAB FLOOR | Concrete - 0-25 MPa, Industry Average Benchmark / CRMCA / Can. Avg. / | 804 | 804 | 0 |
| arage | GARAGE CONCRETE WALLS | Concrete - 0-25 MPa, Industry Average Benchmark / CRMCA / Can. Avg. / | 538 | 538 | 0 |
| arage | GARAGE MASS TIMBER | Heavy Timber Framing - AVERAGE | 829 | 829 | 0 |
| arage | GARAGE WOOD FRAME WALLS | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 65 | 65 | 0 |
| arage | GARAGE WALL SHEATHING | Plywood / American Wood Council & Canadian Wood Council / / 1/2" | 82 | 82 | 0 |
| arage | EXTERIOR GARAGE WALL INSULATION | Fiberglass batt - AVERAGE | 83 | 83 | 0 |
| arage | GARAGE ATTACHMENT WALL INSULATION | Fiberglass batt - AVERAGE | 36 | 36 | 0 |
| arage | GARAGE EXTERIOR CLADDING | Fiber Cement siding - AVERAGE | 503 | 535 | 33 |
| arage | INTERIOR CLADDING of GARAGE WALLS | Drywall 1/2" Typical - Interior Cladding for Exterior Walls - AVERAGE | 68 | 68 | 0 |
| arage | GARAGE WINDOWS | Window - double pane / Fiberglass frame / / USA & CAN | 125 | 125 | 0 |
| arage | GARAGE CEILING CLADDING | Drywall 1/2" - Ceilings - AVERAGE | 63 | 63 | 0 |
| arage | GARAGE WOOD ROOF FRAMING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 29 | 29 | 0 |
| arage | GARAGE ROOF DECKING | Plywood / American Wood Council & Canadian Wood Council / / 5/8" | 23 | 23 | 0 |
| arage | GARAGE ROOFING MEMBRANE | PVC Roofing Membrane / CIFA / Includes: Canadian General-Tower, Duro-Last, FiberTite / 48 mils | 28 | 28 | 0 |
| arage | GARAGE ROOF STRAPPING | Wood framing & siding - SPF / American Wood Council & Canadian Wood Council / / | 3 | 3 | 0 |
| loors | Floors | EPS foam board with graphite / BASF / Neopor / R 4.7/inch, Type IX | 132 | 132 | 0 |
| loors | Floors | Spray polyurethane foam - Closed Cell (HFC) / SPFA / / R 6.6/inch | 71 | 71 | 0 |
| oof | Roof | Fiberglass loose fill / CertainTeed / InsulSafe, Optima, TruComfort / R 2.6/inch | 566 | 566 | 0 |
| olar Generation | PV Panels | PV Solar panels | 4,680 | 4,680 | 0 |

# Annex 3: Building Construction specs



| House Component | Assembly or Description | New Build Implementation | Renovation Implementation |
|---|---|---|---|
| **Attic** | Standing seam metal sheeting, self-adhesive roofing membrane, ½" sheathing, 2x4@16o/c cross strapping, engineered truss (2x6 top chord/2x4 bot. chord) @24 o/c, R50 fiberglass batt insulation, ½" GWB | All new material. Trusses manufactured off-site and assembled in place. | All new material. Trusses manufactured off-site and assembled in place. |
| **Flat Roof** | Standing seam metal sheeting, self-adhesive roofing membrane, ½" sheathing, 2x4@16o/c cross strapping, 2x12 @24o/c, R40 fiberglass batt insulation, ½" GWB | All new material is assembled in place. | All new material is assembled in place. |
| **Exterior Above Grade Walls** | Hardie plank, mesh rainscreen, ½" sheathing, 2x6@16o/c, R24 fiberglass batt insulation, ½" GWB | All new material is assembled in place. | Entirely new walls (including enclosed garage walls)<br>Upgraded existing walls<br>513 Sq ft (23.6%) Calculated separately and added.<br>16,625 Sq ft (76.4%)<br>All new materials used<br>All new cladding, insulation and GWB. Existing 2x4 framing furred to 2x6 (36.4% new / 63.6% existing wood) |
| **Entirely new walls (including enclosed garage walls)** | Upgraded existing walls | | |
| **513 Sq ft (23.6%) Calculated separately and added.** | 16,625 Sq ft (76.4%) | | |
| **All new materials used** | All new cladding, insulation and GWB. Existing 2x4 framing furred to 2x6 (36.4% new / 63.6% existing wood) | | |
| **Interior Walls (Using typical wall height slightly different if vault end walls are taken into account.)** | ½" GWB, 2x4@16o/c, ½" GWB (8% is insulated for sound) | 351 LF (2808 SF Approx.) All new material is assembled in place. 172 LF or (1376 SF approx.) existing interior walls removed. | 10% or 38 LF or (304 SF approx.) interior walls reused. 90% or 313LF (2504 SF approx.) All new material is assembled in place. 172 LF or (1376 SF approx.) existing interior walls removed. |
| **Below Grade Walls (Avg ht. of 4 ft.)** | 8" reinforced concrete, 2" GPS rigid insulation, 2x4@ 24"o/c R14 fiberglass batt, ½ GWB. Note* Assumed that new build will be built to 8 ft height, where reno is limited to existing 7.5 ft. | 145LF (approx. 580 sf) of All new material assembled in place. | Reuse of existing concrete walls for 93% of below-grade wall. New framing, insulation, and finishes are to be used. (7% new concrete used primarily to infill unwanted RO's.) |
| **Slab and Footings** | The major difference in construction | New slab with R12 Rigid EPS below | Existing slab with no added insulation |
| **PV** | 12kW system (60m2) on standard metal racking system with industry avg inverters. | All new material is assembled in place. | All new material is assembled in place. |



Source: Takeoff data from proposed building plans combined with H2k / MCE2 software outputs carbon wise

# Questions?

## Contact us

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