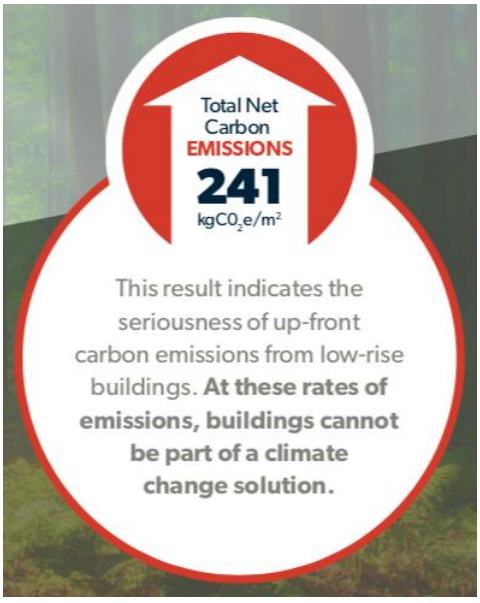
Welcome to the Builders for Climate Action

MATERIAL CARBON EMISSIONS (MCE) CALCULATOR

for the Triple Decker Design Challenge!

This version of the Builders for Climate Action Material Emissions Calculator was designed specifically for the Triple Decker Challenge. We created this calculator to be an easy-to-use tool to compare the greenhouse gas emissions (GHGs) of different building material options in many configurations. The comparative results can help you to make material selections to meet your carbon footprint targets. The calculator allows you to compare materials on a component-by-component basis, as well by whole assemblies. The majority of a building's mass is represented here: we've included a wide range of enclosure assemblies, as well as the main cladding, sheathing and finishing materials for residential construction.

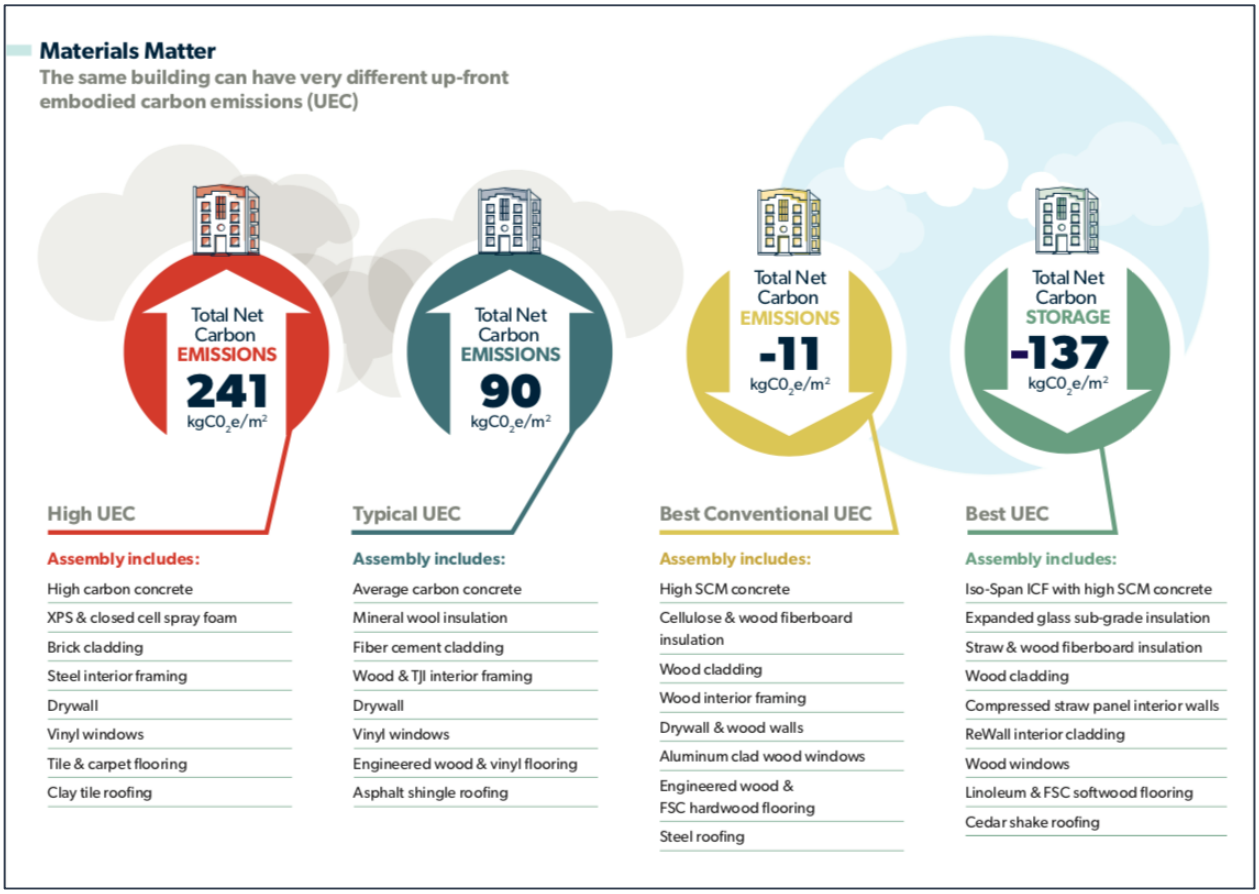
This calculator focuses on ***material carbon emissions*** or ***MCEs*** (often referred to as "embodied carbon") because the high volume of emissions arising directly from the harvesting and production of building materials represents a key opportunity to drive major emission reductions. Our research has indicated that standard low-rise residential buildings can be responsible for 175-400 kg of GHGs per square meter of floor area (32-75 tonnes for a 2,000 square foot home).



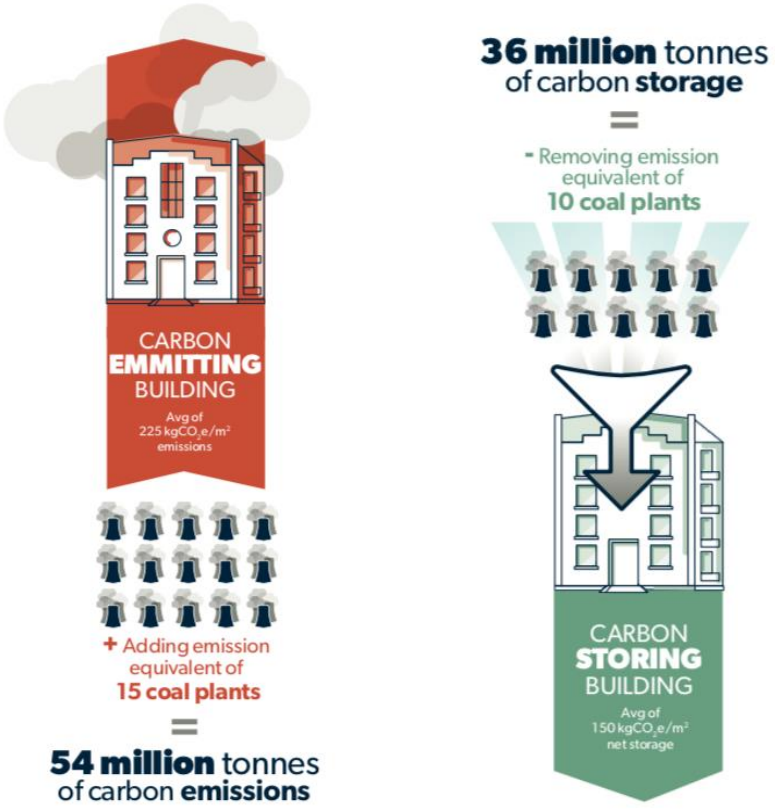
It is critically important that we immediately and dramatically reduce this vast source of GHGs that are being emitted right now. Reductions in emissions today have a greater impact on slowing climate change than reductions we might achieve in upcoming years and decades. In the building industry, we can do this by addressing our material emissions as quickly as possible.

Although the scale of the problem is huge, we are fortunate that there is a lot that the building industry can do to make a big dent in material emissions. In our 2019 study we found

that material selection can play a major role in achieving major emission reductions immediately.



By making informed material choices, a building with the same size, functionality and energy efficiency can dramatically reduce its material emissions. In fact, it is possible with materials available and affordable today to get the MCEs of building close to – and even below – zero. The North American low-rise building industry has the opportunity to achieve the equivalent of closing down 17 coal plants annually and possibly even drawing down the emissions from a further 11 coal plants! There is no other industry that can have an impact of this size on climate change with manageable and achievable actions.

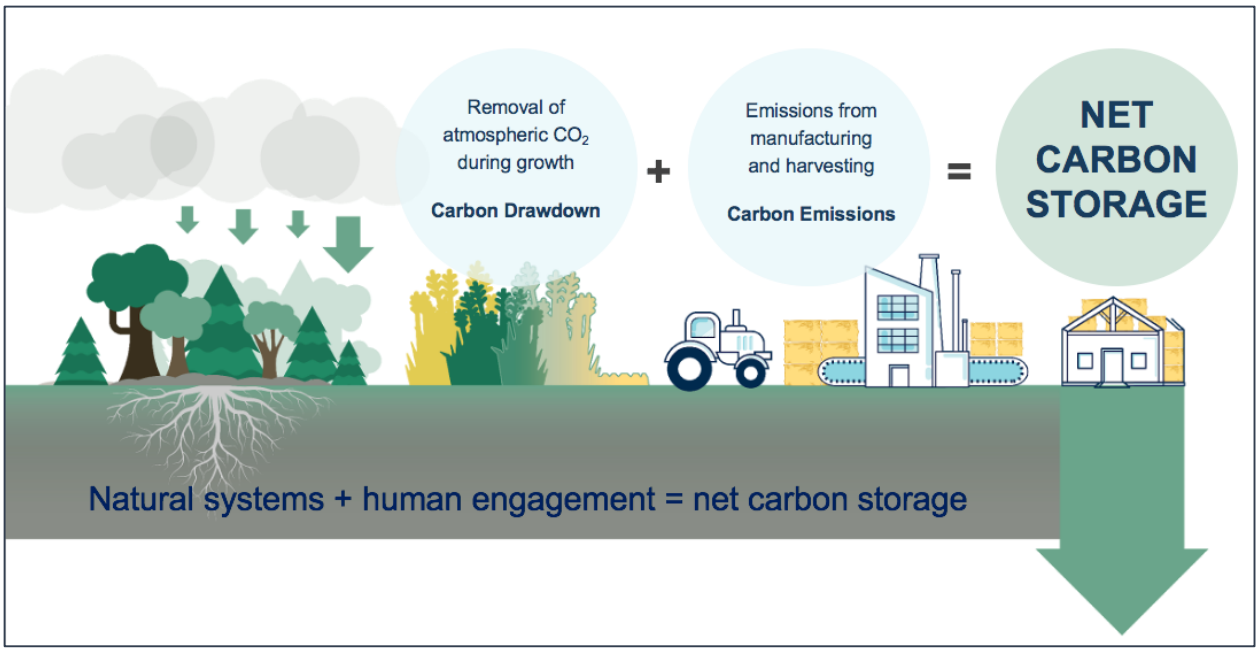


It is our sincere hope that this calculator will play a role in moving the residential building industry from a leading driver of climate change to a leading driver of climate drawdown.

Drawdown Buildings?

This calculator gives some results that are expressed as negative numbers, indicating that the selected material is responsible for net carbon drawdown rather than net GHG emissions. How does this work?

Plant-based materials soak up atmospheric CO_2 during photosynthesis. As plants grow, they take CO_2 out of the atmosphere and use the carbon as essential building blocks for their own structure (and release the oxygen as a by-product). When a plant dies or is harvested, anywhere from 30-60% of the weight of the material is made of carbon that was recently in the atmosphere… the plants have performed the drawdown we so desperately need to control climate change.



Humans harvest billions of tonnes of plant-based carbon each year from our farms and forests and throw away tonnes more as landfill and recycling "waste." Today, we let most of that carbon go back into the atmosphere when we burn these residues or let them rot. We also produce a lot of single-use products from plant-based material and then throw them away and let the carbon go back into the atmosphere.

We see a remarkable opportunity to turn these sources of *biogenic carbon* into building materials and to use these materials to turn buildings into *carbon banks*. Some biogenic materials are already in wide use in the building industry, while others are ready for adoption as quickly as possible.

Data for Calculations

The source data for this calculator comes from Environmental Product Declarations (EPDs). These documents express the results of a "life cycle analysis" (LCA) that has been performed and reported according to product category rules (PCRs). EPDs are performed or verified by a third party. EPDs cannot compare materials intended for different uses (e.g. we can't compare a 2x4 to a floor tile). Even within the same product category, it can be difficult to compare EPD figures because the values expressed for each material may not be directly comparable (e.g. kilograms of brick can't be compared to square meters of wood siding). This calculator normalizes all of the values expressed in EPDs to ensure that appropriate types of

materials are being compared in appropriate quantities (e.g. square meters of brick and square meters of wood siding).

We have taken every measure to ensure that all of our material comparisons are equivalent, using standard product sizes, code norms and best practice to make this an "apples to apples" comparison. There are limitations to the information in this calculator, and we encourage you to read the **"Limitations"** section of this guide to better understand what you will (and won't) learn from this calculator.

It is our aim that this calculator will inspire us to move toward a culture of carbon banking buildings. We encourage you to aim for the lowest MCE numbers you can achieve, and to work toward getting that number *below* zero. We are capable of making buildings that don't just do less harm, but actually do good.

How to Use This Calculator

The steps to use the calculator are fairly simple. Inputs are required in any area in the spreadsheet that is highlighted in yellow. Follow the instructions below to work your way through the spreadsheet:

1) **On the main sheet, you input your project information.**

   This information is for the use of the Triple Decker Challenge team to identify your project. The "total floor area" is used to calculate the total Material Carbon Emissions per square foot of the project, and should include the habitable floor area of the entire building.

SECTION 1 ➜	PROJECT INFORMATION
PROJECT TITLE	Triple Decker Winner
BUILDING TYPE	Three-level multi-unit res
COMPANY NAME	
PROJECT MANAGER	
CITY/ PROV/STATE/COUNTR	Boston, MA, USA
DATE OF CONSTRUCTION	
CONTACT INFORMATION	
PROJECT CERTIFICATIONS	
TOTAL FLOOR AREA (ft2)	1000

Figure 1. Project information area on Main Sheet

2) **On the Main Sheet tab, input the basic dimensions of your building.**

   There are 8 fields on the Main Sheet tab to fill out with your project building dimensions. MCE results will show up on each of the tab pages based on these initial dimension inputs.

   Note that the calculator will not catch errors in logic regarding dimensions. For example, your foundation slab may be mistakenly input at twice the size of your roof and you will get MCE figures that reflect this discrepancy. The accuracy of the calculator is dependent on the accuracy of the dimensions that you enter.

SECTION 2 →	BUILDING DIMENSION CALCULATOR		YOUR DATA		
COMPONENT	CALCULATION APPLIES TO THESE ELEMENTS	REQUIRED UNITS FOR YOUR CALCULATION	UNITS		TOTAL kg of CO2e
					Information carries over from TABS
WINDOW AREA	Windows, including frames (full unit)	Square feet (full dimensions of glazing units)		ft2	0
ROOF SURFACE AREA	Roof framing, roof sheathing, roof insulation (flat or slope), roofing	Square feet (include total surface area)		ft2	0
THIRD LEVEL CEILING AREA	Third level ceiling	Square feet (excluding stair openings)		ft2	0
EXTERIOR WALL AREA	Framing, insulation, exterior continuous insulation, structural sheathing, cladding	Total wall area (include gable area, exclude window & door openings)		ft2	0
FOUNDATION WALL AREA	Foundation wall, exterior continuous insulation, interior framing, interior insulation	Total wall area (not including windows and doors)		ft2	0
FOUNDATION SLAB AREA	Basement slab, sub-slab insulation	Square feet		ft2	0
FOOTING	Footing (Can be found on the Foundation Wall Tab)	Cubic feet - lineal feet x thickness x width		ft3	0
ADDITIONS	Additions - see Additions tab for inputs	Additions - see Additions tab for inputs			0

Figure 2. Building dimension input areas on Main Sheet

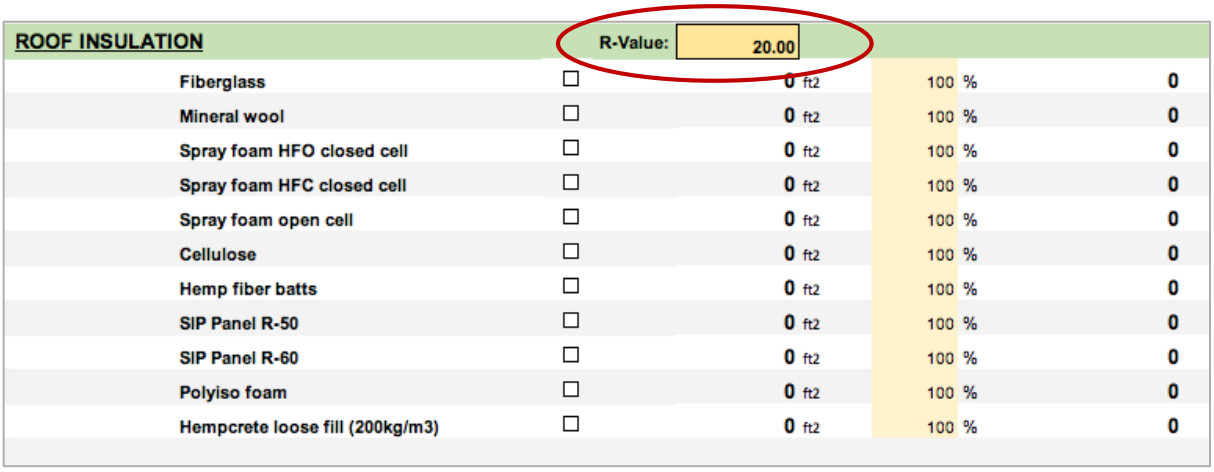
3) Work your way through each tab of the spreadsheet.

The tabs are arranged to reflect the main building elements.
Use the navigation at the bottom of the calculator to move between each page until you have completed all the required areas.

Figure 3. Tab selection menu at bottom of each calculator page

4) Input the desired R-value for the insulation options.

Wherever insulation products are compared, you will need to type the intended R-value for that component of the building into the yellow box. Enter the R-value of the full depth of insulation; do not enter a net R-value inclusive of framing or other losses.
Note that the calculator will allow you to type in any number for R-value. It is up to you to ensure that you are using R-values that are practical and match what is intended for the building and appropriate to the product type.
If R-values will not be identical for different products, you can either choose a nominal value that will help you compare options or you can input one R-value and note the results for the appropriate material, and then change the value and note the results again.

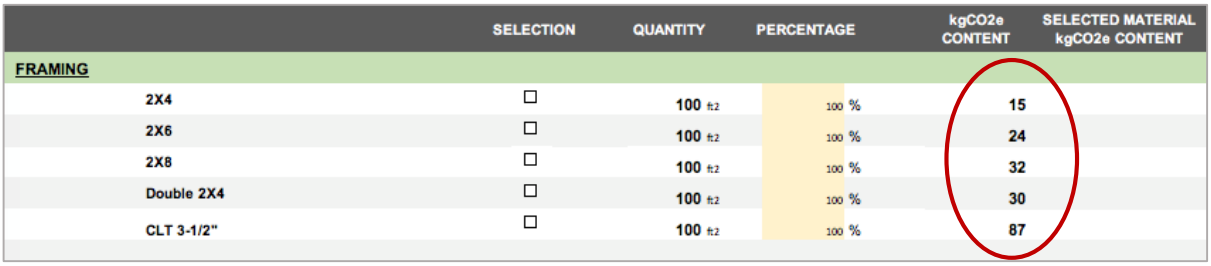


ROOF INSULATION		R-Value: 20.00		
Fiberglass	☐	0 ft2	100 %	0
Mineral wool	☐	0 ft2	100 %	0
Spray foam HFO closed cell	☐	0 ft2	100 %	0
Spray foam HFC closed cell	☐	0 ft2	100 %	0
Spray foam open cell	☐	0 ft2	100 %	0
Cellulose	☐	0 ft2	100 %	0
Hemp fiber batts	☐	0 ft2	100 %	0
SIP Panel R-50	☐	0 ft2	100 %	0
SIP Panel R-60	☐	0 ft2	100 %	0
Polyiso foam	☐	0 ft2	100 %	0
Hempcrete loose fill (200kg/m3)	☐	0 ft2	100 %	0

Figure 4. R-Value input area for each insulation material

5) Use the check box to select the material option you wish to use in your project.

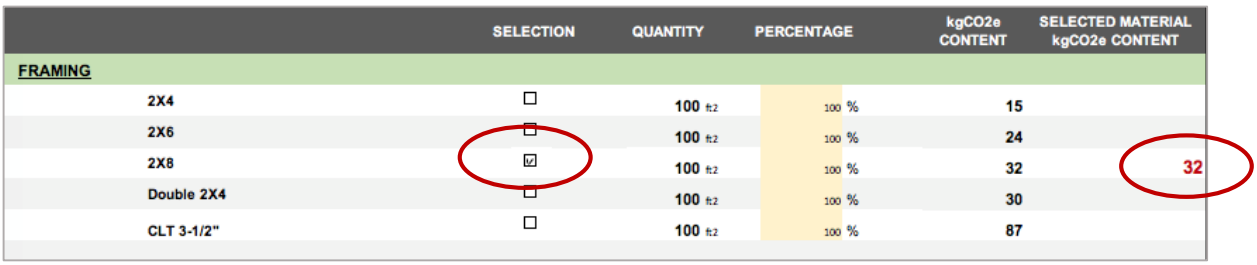
Column K in each tab will show you the material carbon emissions for each of the material options included in the calculator. This enables you to quickly scan the results and determine comparative values for the materials you might consider. *Note that these results are expressed in metric values of kgCO_2e.*



	SELECTION	QUANTITY	PERCENTAGE	kgCO2e CONTENT	SELECTED MATERIAL kgCO2e CONTENT
FRAMING					
2X4	☐	100 ft2	100 %	15	
2X6	☐	100 ft2	100 %	24	
2X8	☐	100 ft2	100 %	32	
Double 2X4	☐	100 ft2	100 %	30	
CLT 3-1/2"	☐	100 ft2	100 %	87	

Figure 5. MCE results for the indicated area/volume of each material

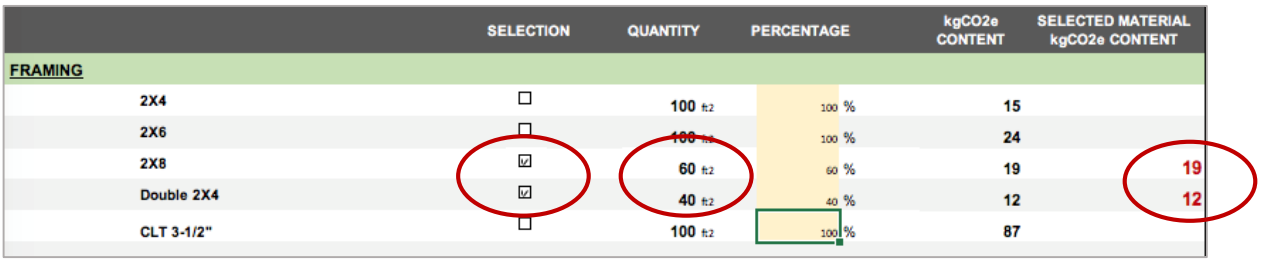
Column D contains check boxes for selecting the material(s) you want to choose for this element of your building. Clicking on a check box will put the MCE value for that particular material into Column L where it appears in red text. *Note that you can make more than one selection in a category and all values will contribute to your total. If you select more than one option in error, your final total emissions will reflect this additionality.*



	SELECTION	QUANTITY	PERCENTAGE	kgCO2e CONTENT	SELECTED MATERIAL kgCO2e CONTENT
FRAMING					
2X4	☐	100 ft2	100 %	15	
2X6	☐	100 ft2	100 %	24	
2X8	☑	100 ft2	100 %	32	32
Double 2X4	☐	100 ft2	100 %	30	
CLT 3-1/2"	☐	100 ft2	100 %	87	

Figure 6. Check box selection and MCE result for checked material

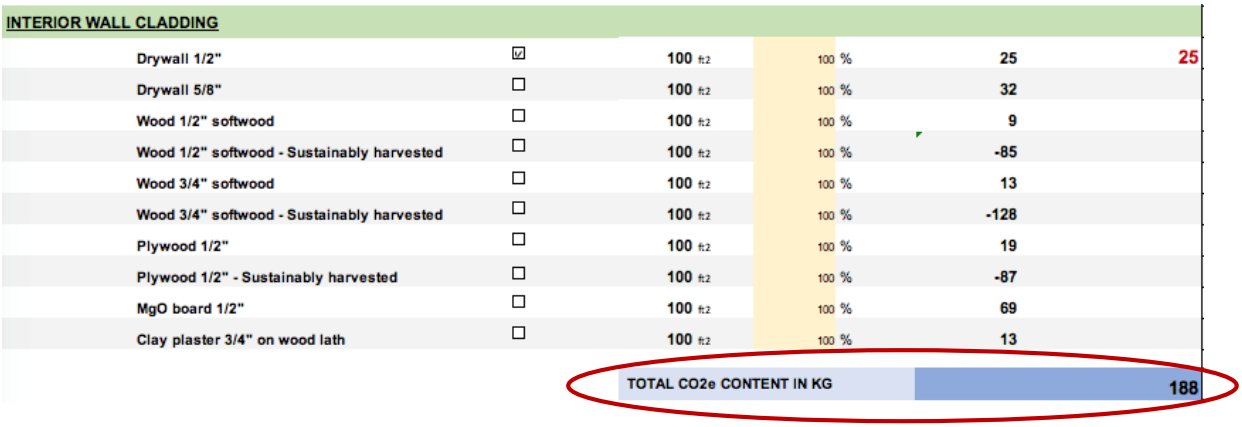
If you intend to use more than one type of material within a category (for example, two or more framing lumber dimensions) you can input the percentage of area associated with each material and the results will update based on the percentage you assign. *Note that the calculator will not ensure that your percentages are accurate nor that they add up to 100%.*



	SELECTION	QUANTITY	PERCENTAGE	kgCO2e CONTENT	SELECTED MATERIAL kgCO2e CONTENT
FRAMING					
2X4	☐	100 ft2	100 %	15	
2X6	☐	100 ft2	100 %	24	
2X8	☑	60 ft2	60 %	19	19
Double 2X4	☑	40 ft2	40 %	12	12
CLT 3-1/2"	☐	100 ft2	100 %	87	

Figure 7. Multiple check box selections with associated percentages.

Each check box selection value contributes to a subtotal at the bottom of the page. This subtotal reflects the emissions of all the selected components on the page.



INTERIOR WALL CLADDING					
Drywall 1/2"	☑	100 ft2	100 %	25	25
Drywall 5/8"	☐	100 ft2	100 %	32	
Wood 1/2" softwood	☐	100 ft2	100 %	9	
Wood 1/2" softwood - Sustainably harvested	☐	100 ft2	100 %	-85	
Wood 3/4" softwood	☐	100 ft2	100 %	13	
Wood 3/4" softwood - Sustainably harvested	☐	100 ft2	100 %	-128	
Plywood 1/2"	☐	100 ft2	100 %	19	
Plywood 1/2" - Sustainably harvested	☐	100 ft2	100 %	-87	
MgO board 1/2"	☐	100 ft2	100 %	69	
Clay plaster 3/4" on wood lath	☐	100 ft2	100 %	13	
		TOTAL CO2e CONTENT IN KG			188

Figure 8. Tab page subtotal for all selected MCE values

There is no limit to the number of times that you can check and uncheck boxes in the calculator. You can revise and fine-tune your selections until you are satisfied with your results.

6) **Return to the Main Sheet to see your MATERIAL CARBON EMISSIONS and COMPONENT SUBTOTALS when all tabs have been completed to your satisfaction.**

Your total results will appear in two forms. The first value is a total of all CO_2e emissions expressed in kilograms (see Fig. 9: 1700 $kgCO_2e$). The second value is expressed as kilograms per square meter of habitable floor area (see Fig. 9: 2 $kgCO_2e/ft^2$).

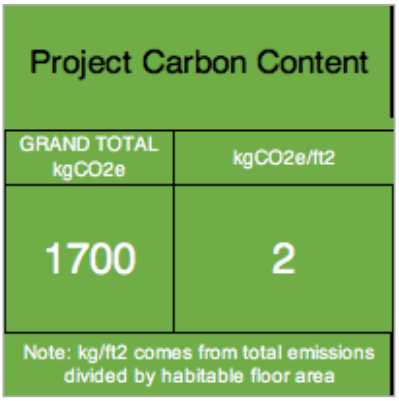


Figure 9. Main Sheet totals in gross $kgCO_2e$ emissions and $kgCO_2e/m^2$

Habitable floor area is calculated from the input you made on Row 20 of the Main Sheet.

If you are using the calculator to achieve a particular MCE threshold you can examine your preliminary results and see if you have met the target. If not, you can revisit any or all of the tabs and choose different materials to see if you can adjust the results to meet your goal.

On the Main Sheet, you will also be able to see a summary of your results per component of your building. These subtotals will allow you see "hot spots" you may want to address by revisiting the appropriate tab and choosing material alternatives that will help meet your targets. *Note that any area of the building not being affected by the design can be left at a zero value.*

SECTION 2 ➜	BUILDING DIMENSION CALCULATOR		YOUR DATA		
COMPONENT	CALCULATION APPLIES TO THESE ELEMENT	REQUIRED UNITS FOR YOUR CALCULATION	UNITS		TOTAL kg of CO2e
					Information carries over from TABS
WINDOW AREA	Windows	Square Feet (full dimensions of glazing units)	100.00	ft2	762
ROOF SURFACE AREA	Roof framing, roof sheathing, roof insulation (flat or slope), roofing	Square feet, (include total surface area)	100.00	ft2	216
THIRD LEVEL CEILING AREA	Third level ceiling	Square feet (excluding stair openings)	100.00	ft2	32
EXTERIOR WALL AREA	Framing, insulation, exterior continuous insulation, structural sheathing, cladding	Total wall area (include gable area, exclude window & door	100.00	ft2	188
FOUNDATION WALL AREA	Foundation wall, exterior continuous insulation, interior framing, interior insulation	Total wall area (not including windows and doors)	100.00	ft2	501
FOUNDATION SLAB AREA	Basement slab, sub-slab insulation	Square feet	100.00	ft2	0
FOOTING	Footing (Can be found on the Foundation Wall T	Cubic feet - Lineal feet x thickness x width	100.00	ft3	0
ADDITIONS	Additions - see Additions tab for inputs	Additions - see Additions tab for inputs			0

Figure 10. Main Sheet subtotals by building area in gross kgCO_2e emissions

7) Save the spreadsheet file for submission.

You will submit a copy of your worksheet as part of your application. Please follow competition rules and guidelines for preparing your submission.

Limitations of This Calculator

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 and understand the results you are achieving.*

The results from this calculator are not intended to be a precise reflection of the actual material carbon emissions (MCEs) of your finished building. There are several factors to understand about this calculator and its relative accuracy:

1) **All the data is based on averages for material types.**

   We've either used industry-wide average EPDs or we have averaged the results from as many product specific EPDs as we could access. This means you will get a clear sense of the difference between types of materials, but you won't know the actual carbon footprint of the actual product you install. In some cases, different manufacturers (or even different plants from the same manufacturer) can have variations in material emissions up to 35%.

   After using this calculator, it is our hope that your procurement process will include comparing EPDs within the product categories you have chosen. You may wish to visit the EC3 tool by BuildingTransparency.org, a growing repository of building material EPDs in order to find specific products with the lowest material emissions.

   It is our hope that more manufacturers will soon provide product specific EPDs, which will allow us to provide more granularity in the data. We encourage you to tell manufacturers that you will be selecting materials with the lowest possible carbon footprint based on their EPDs. We look forward to the day when there is enough data that we can provide you with a range of options within each product category.

2) **We have made assumptions in our quantity calculations that may not reflect your practices.**

   In order to make the calculator simple to use and to minimize the number of inputs you must enter we have made numerous assumptions about material quantities. To the best of our ability we have chosen quantity takeoff 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, we assume 16" O.C. framing for all stud wall construction, and 24" O.C. framing for all floor and roof construction. While this may not match your framing plan, the relative difference between your framing options in each category will be accurate. You can adjust the percentages for each framing selection to better reflect your particular design.

3) **No waste factor for materials is included.**

Every construction project generates off-cuts and waste. For the purpose of this competition, none of our calculations assume any waste factors in the material quantities, as we felt unwilling to rely on any standard factors due to the wide variation in material types and on-site practices.

If you would like your MCEs to reflect the fact that you will order more material than is calculated here, you can add an appropriate percentage to each material category. In fact, we would encourage you to do this to generate more accurate figures for your project.

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/vapor 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 these categories. 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 MCEs of the building. Even a result showing some net carbon-banking may actually be a net emitter if all of these materials were included in the total.

5) **We have only included data for "cradle-to-gate" emissions, not transportation to site or job site emissions.**

Getting building materials from the factory to the job site will add emissions to the overall project. However, we didn't feel we could provide transportation estimates with enough degree of accuracy to be meaningful. EPDs and LCA software programs attempt to provide averages but we found the degree of assumptions and generalizations did not give us enough confidence that these figures would be useful to you.

We encourage you to understand your supply chains and to attempt to do your own transportation emission calculations. There are various sources for estimates of emissions for different transportation types that can be used, such as this table from Wikipedia:

Mode of Transport	kg of CO_2 per Ton-Mile
Air cargo	0.8063
Truck	0.1693
Train	0.1048
Sea freight	0.0403

The emissions from a construction site are likewise difficult to estimate. There is a big difference between a job site powered by relatively clean electricity compared to a diesel generator. Heavy equipment operation time, the need for job site heating and even the commuting distances can all have significant impact. Again, we encourage you to be conscious of these factors and to do your best to both calculate and mitigate these emissions.

It should be noted that job site emissions (A5) have been included in our MCE calculations for those materials that have a necessary, sizable and very predictable volume of emissions created on site. Examples include emissions from site-mixed foam insulation and from concrete poured into insulated concrete forms. These types of emissions are included in A5 in many EPDs but are more related to the static emission profile of the product than to construction site-specific activity.

6) No end-of-life emissions calculated

There are certainly 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. It is our position that the decades from 2020-2050 are absolutely crucial for us to reign in the worst effects of climate change. While we acknowledge that there will be emissions released when these materials reach the end of their service life, we must

concentrate our efforts on immediate emission reductions and not make decisions based on amortizing up-front materials emissions over 50-100 years, as this can lead us to make decisions that will not help us achieve our near term climate goals. All the materials we've 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). We believe that if we are able to make enough good decisions to avoid the worst impacts of climate change, we will also be able to make good decisions about end-of-life pathways for buildings and materials.

- End-of-life for buildings and materials is hard to predict. We are unsatisfied with "standard" life expectancy figures, as it is too difficult to predict whether a building will last 20 years or 200 years. 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.
- End-of-life options in LCA are generally limited to landfill, incineration or recycling. The move to a more carbon positive world must inherently include a move toward better end-of-life treatment for all materials. It doesn't seem prescient to make decisions about material choices today based on end of life options that are unlikely to make sense in the future.

7) No costing information.

We have not attempted to include material costs as a comparative factor in this calculator. This is obviously important to builders and their clients, but we did not feel we could effectively capture costing data that would be relevant across North America, nor that would remain current in the face of market fluctuations and product development. We leave it to builders to use their own costing information to bring that lens to these material carbon emission results.

We are pleased that the MassCEC is including material emissions in the criteria for the Triple Decker Design Challenge. We hope that the results you obtain from this material emissions calculator are informative and help to shape an approach to the challenge that recognizes the opportunities for meaningful emission impacts from the materials as well as the energy efficiency of these retrofits.