Missoula Public Library | photo by Heidi Long

Embodied Carbon in Casework and Countertops

A Case Study and Materials Recommendations

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MSRDesign

Paper Mill House | photo by Lara Swimmer Photography

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Executive Summary

As awareness within the building industry about the global warming potential (GWP) of building materials and products grows, digital tools have become available to help architects model and estimate the embodied carbon footprint of architectural assemblies.

However, finish materials, such as casework and countertops, are typically not included in modeling tools, which emphasize core, shell and partition wall elements. This gap makes it difficult to generate a complete embodied carbon footprint for multiunit housing, hospitality spaces, and other project types where finishes, such as millwork elements, comprise a significant volume of materials used in the interior architecture.

This report presents a method for modeling the GWP of casework and countertop materials using Tally, an embodied carbon modeling plug-in for Revit, and available data from product-specific environmental product declarations (EPDs), resulting findings, and a spreadsheet-based calculator for calculating the GWP of casework on a project.

Findings and recommendations
The carbon impact of casework and countertops can be significant compared to core and shell, especially in project typologies that involve frequent turnover or in which casework forms a significant proportion of the interior fit-out.

Designers should consider the GWP of casework and countertops along with material health, durability, and other selection factors. Manufacturers should continue to improve standardization and transparency of GWP information related to these products.

Four Seasons Private Residences Kitchen | photo by Spacecrafting

Background and Method

The omission of interior finish materials, including millwork elements such as casework and countertops, from existing modeling tools, is also significant due to the frequency of renovation compared to new construction. Two studies published by the [Carbon Leadership Forum (CLF)](), including "[Embodied Carbon Benchmark Study, LCA for Low Carbon Construction (2017)]()" and "[LCA of Tenant Improvement in Commercial Office Buildings (2019)]()", estimate that the embodied carbon for tenant improvement (TI) elements averages 40—140 kg CO2eq/m2, compared to commercial office building structures, foundations, and enclosures, which fall in the range of 200—500 kg CO2eq/m2. However, the typical recurrence interval of TI is every 10—20 years. Therefore, over a building's lifetime, the cumulative impact of recurring TI may reach the same order of magnitude as the embodied carbon of the entire core and shell.

Modeling method

As a catalyst for this study, a Tally assessment of two multiunit residential projects modeled in Revit revealed that the casework and countertop model objects were not included in Tally's estimated carbon footprint. The casework and countertop Revit families are not recognized by the current version of the Tally software (Figure 1). As a result, the plug-in could not assign materials from the LCA database, and no GWP was recorded for these modeled objects.

As a workaround to make the casework and countertops visible to Tally, the research team modeled a new series of cabinets in Revit using wall and floor families, modified in terms of thickness and assembly, with typical casework substrate and finish materials assigned from the Tally library (Figures 2 and 4). Countertops were modeled using floor families modified with layers to represent the substrate and finish layers in the appropriate thicknesses.

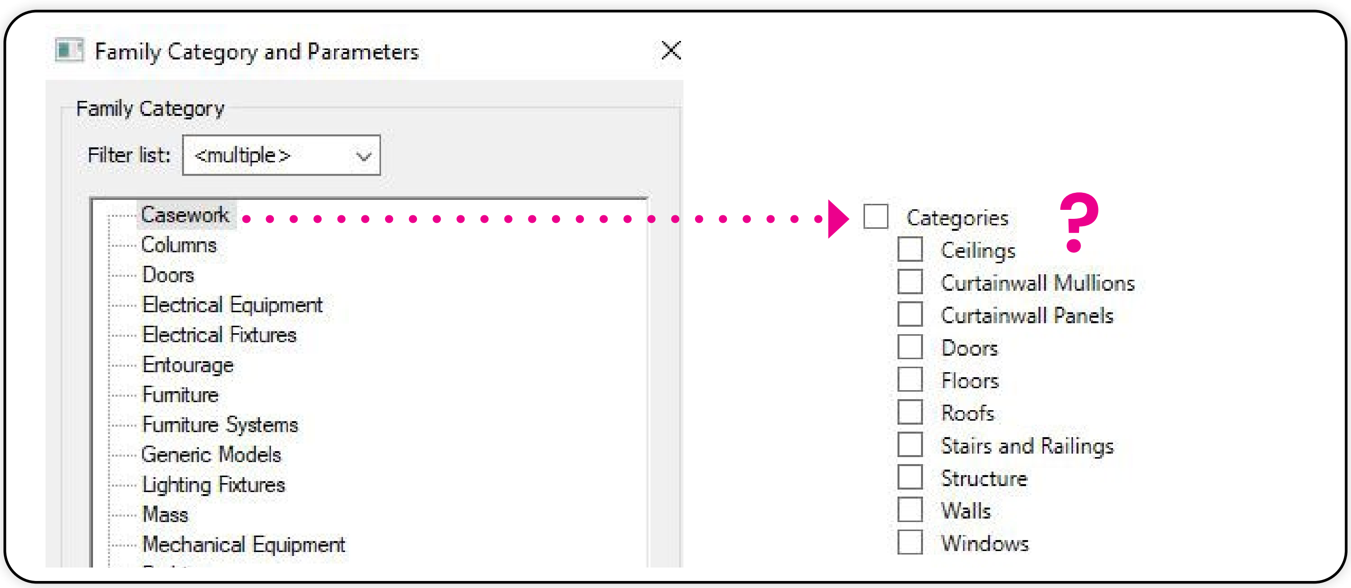


Figure 1 | Revit includes casework families, but these families are not among the categories recognized by Tally or other embodied carbon modeling tools.

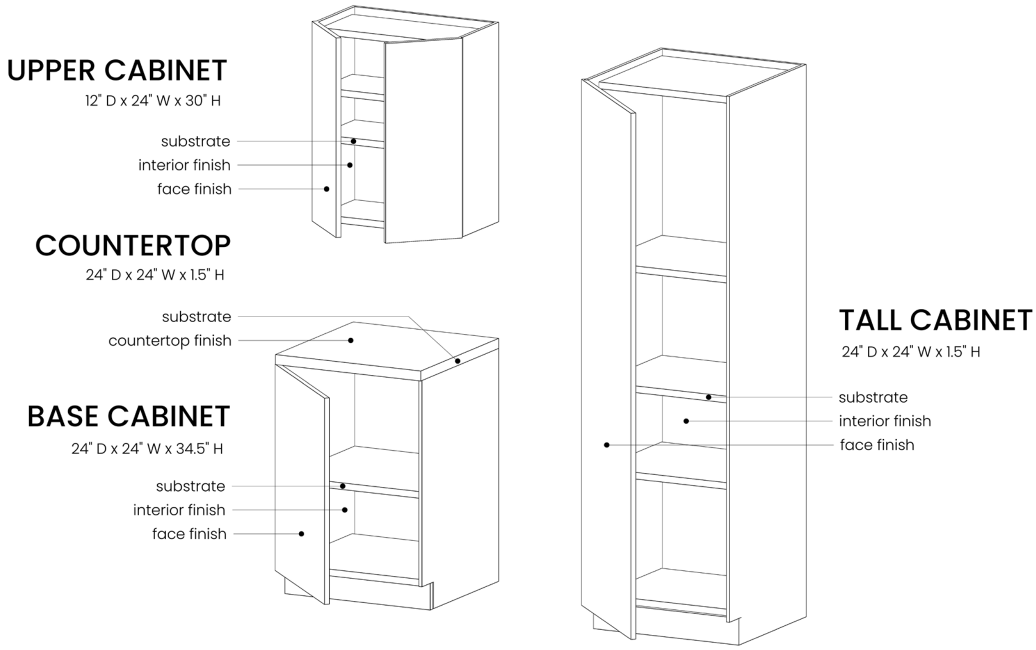


Figure 2 | Casework components modeled in Revit include a base cabinet and countertop (24" depth), upper cabinet (12" depth), and tall cabinet (24" depth).

Casework was represented by modifying a wall family to include a substrate plus interior and exterior finish layers. Where applicable, adhesives and finish coatings were included as accessory materials. We also modeled a standard module of 2 linear feet for each assembly, then divided by 2 to arrive at a quantity of embodied carbon per linear foot.

The products and material types represented in the modeling exercise are listed in Figure 3.

Comparing Tally and EPD data

- Overall, Tally GWP numbers were similar to EPD-obtained GWP numbers for the same or similar product, with some exceptions. Some materials, such as plywood and OSB, had similar results using both methods. In other cases, such as for cement-bonded particleboard, the Tally results were double.
- To get individual material A1-A3 impacts from Tally and view them separately in the automatically generated report, different materials were modeled as design options.
- Standardizing the data from manufacturer-provided EPDs to make products comparable was a challenge. Although the number of EPDs has increased in recent years, as of 2024, some big brand names still do not provide them. Some material categories such as natural stone tend to rely on industry-average data. It was often necessary to convert units and extract A1-A3 from a range of different included scopes. Some EPDs include the substrate in the data without itemizing it, so it was not possible to seperate out. Units ranged from kilograms to square feet to square meter to "per unit."

Materials and sample products compared, with substrate where applicable

Casework

- Solid wood
- Plywood
- Color-through wood fiber board (e.g. Forescolor, Valchromat)
- Cement bonded particle board (e.g. Viroc)
- Oriented strand board (OSB)
- Linoleum, furniture or flooring grade (e.g. Forbo)
- HPL (high pressure laminate, e.g. Wilsonart, Formica)
- CHPL (compact high pressure laminate, e.g. Wilsonart, Formica)
- Wood veneer

Countertop

- Solid surface resinous (e.g. Formica Everform, Avonite)
- Engineered stone/quartz (e.g. Dupont Corian, Caeserstone)
- Stone, natural quarried
- Concrete with wire mesh structure
- Cement bonded particle board (note that the EPD from Cetris is used to represent Viroc)
- Color-thru wood fiber board (e.g. Forescolor, Valchromat)
- Paper composite with phenolic resin (e.g. Paperstone)
- Butcher block
- Sintered stone (note there are three thicknesses, e.g. Lapitec)
- Porcelain
- Stainless steel
- HPL and CHPL (plastic laminate, e.g. Wilsonart or Formica)
- Linoleum (e.g. Forbo)

Figure 3 | Products and materials modeled for comparison

Olbrich Botantical Gardens Frautschi Family Learning Center | photo by Gaffer Photography

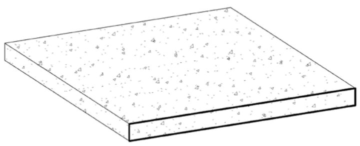
Notes on modeling and limitations

Tally reports and Excel tables are available upon request.

- In Tally, a one-time install was assumed. LCA scopes beyond A1-A3 were excluded (no A4 transportation or A5 install, no B replacement cycle and use, no C recycling or end of life). However, it should be noted that on commercial projects and some residential, countertops may be replaced every 10-15 years, regardless of wear.
- The models did not include a countertop backsplash. To model natural stone countertops, grout was removed from the existing Tally profile, and the material thickness was adjusted to be true to the way materials are specified.
- Biogenic carbon was excluded from both Tally modeling results and EPD data.

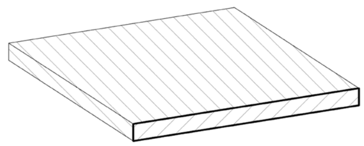
CONCRETE

FINISH: concrete - 1-1/2"



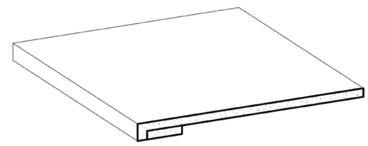
STONE

FINISH: natural stone - 1-1/2"



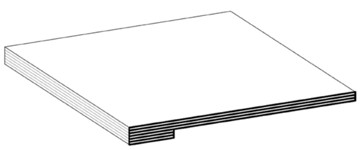
PLAM

FINISH: plastic laminate
3/4" MDF substrate
PVC Edgebanding



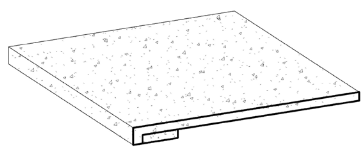
LINOLEUM

FINISH: linoleum
3/4" Plywood substrate
Sealed exposed edge



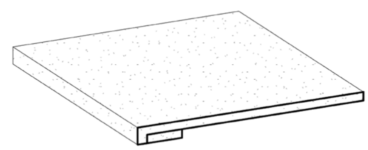
CEMENT BONDED PARTICLE BOARD

FINISH: cement bonded particle board - 3/4"
Exposed edge



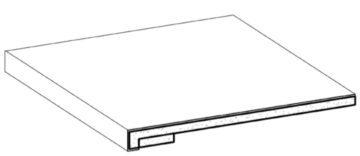
COLOR-THRU WOOD FIBER BOARD

FINISH: color-thru wood fiber board - 3/4"
Sealed exposed edge



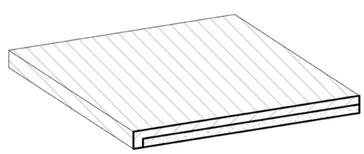
STAINLESS

FINISH: stainless steel- 16 ga.
3/4" MDF substrate



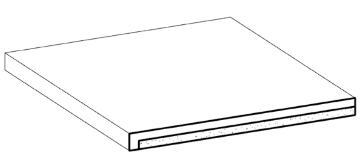
ENGINEERED STONE

FINISH: engineered stone - 3/4"
3/4" MDF substrate



SOLID SURFACE

FINISH: solid surface - 3/4"
3/4" MDF substrate



WOOD

FINISH: solid hardwood - 1-1/2"

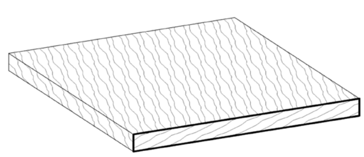


Figure 4 | Countertop assemblies with finish and substrate layers called out.

Countertop Results

Countertop GWP results
Countertop assemblies are shown in figure 5, with the green miniature chart showing the addition of different substrates where required for installation.

Per square area, the GWP of solid surface countertop (defined as resinous with natural or synthetic aggregate) and the thickest sintered stone option measured the highest, followed by thinner sintered stone, engineered stone (with plastic resin), compact HPL (CHPL, resin and melamine without paper), stainless steel and natural stone.

The lowest-GWP materials starting at the bottom were linoleum, regular HPL with kraft paper (not compact HPL which is plastic only), cement particleboard, concrete (including wire mesh), porcelain, glass ceramic (or sintered glass, made without plastic resin), paper composite, and butcher block.

Thickness of material made a big difference in the case of sintered stone.

Countertop design considerations
Linoleum is a natural material that patinas over time. It may not be suitable or durable for wet locations. Flooring-grade linoleum is a more durable option than furniture-grade.

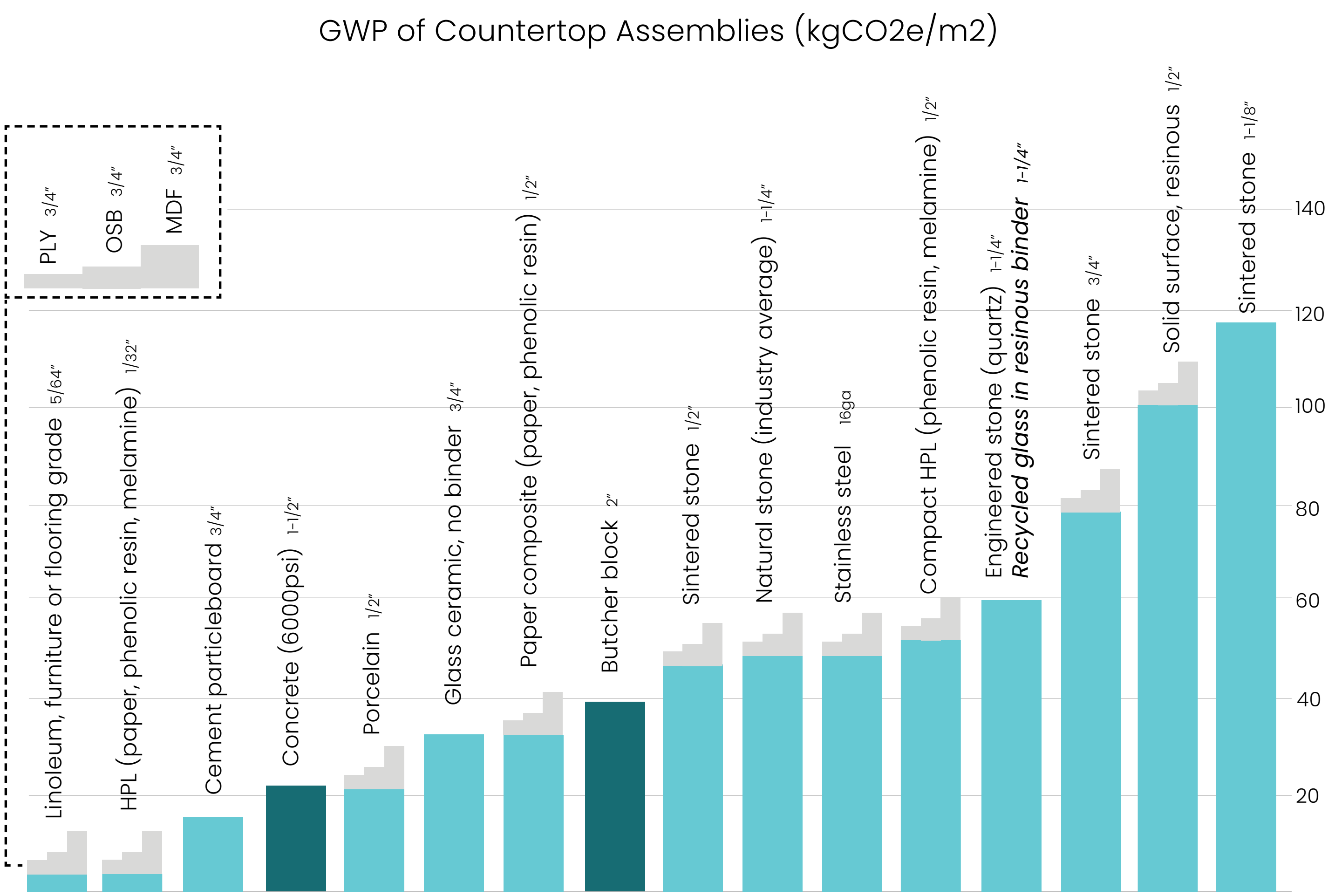


Figure 5 | GWP of countertop shown in kg CO2 equivalent per m2

In addition to the high carbon footprint demonstrated in this analysis, many designers are moving away from durable options such as quartz and solid surfaces that contain silica. Silica is emerging as a primary health concern in engineered stone materials. While there are provisions to protect miners and workers in factories from silicosis, installation crews often have inadaquate protection when working with these materials.

The carbon footprint of solid-surface or engineered-stone/quartz alternatives, such as recycled glass in epoxy resin matrix, are likely to be similar to the high carbon in solid surface and quartz due to the footprint of the resinous binder, regardless of what aggregate is added. Unfortunately recycled glass in resin could not be modeled in this analysis due to the lack of EPD data and suitable method for modeling in Tally. This material is noted in italics in the chart as an educated estimate.

In this study, porcelain emerged as a possible large-format slab option that does not contain silica or epoxy resin. Selecting a thinner material such as 1/2" sintered stone is also a way to save carbon by reducing material. Sintered glass or glass ceramic is an emerging material to monitor.

Concrete offers flexibility, but it requires a skilled trades person to build a custom mold and use a mix design that will remain smooth and durable over time. Concrete can be prone to staining.

Notes for countertop manufacturers

- It would benefit the industry to reduce the GWP of solid surface. TIt may be possible to reduce the GWP byvusing bio-based resins, but at this time, no transparency documentation exists to verify the precise reduction in GWP from using bio-based resins. Manufacturers using and developing resins should develop an EPD as soon as possible to verify any claims of reduced carbon footprint.
- Different formulations of plastic laminate, including HPL and CHPL, have widely differing carbon footprints. Paper content is helping to reduce the GWP of HPL compared to CHPL. However, to improve transparency, manufacturers should break out the GWP of components such as melamine, phenolic resin, and biobased resin content in their EPDs.

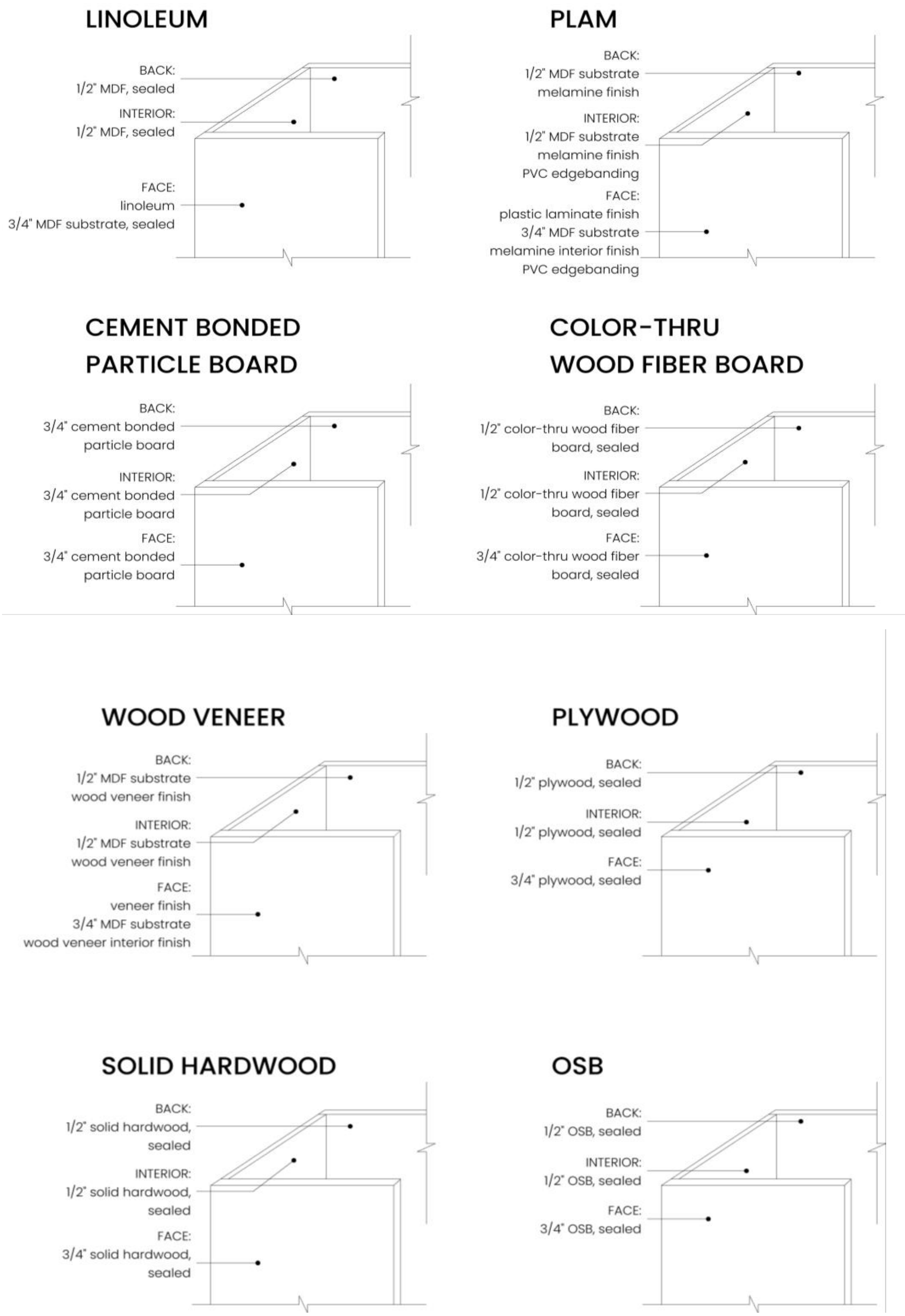


Figure 6 | Casework assemblies modeled with finish and substrate layers

Casework Results

Casework GWP results
Casework assemblies are shown in figure 6. Results are shown in figure 7, with LCA scope A1-A3 modeled data from Tally alongside data from product-specific EPDs.

As noted in the modeling methodology discussion, Tally and EPD data sources yielded generally similar trends with a few differences. The highest-GWP casework materials as measured by Tally were wood veneer and cement bonded particle board, compared to the highest per EPD data of CHPL and HPL with substrates.

The lowest GWP materials were plywood, OSB (included for the sake of comparison and questions regarding binder), thru-color wood fiber board, solid wood, and linoleum with substrate.

The use of binders appears to be a key differentiator in GWP calculation. EPDs automatically include binders, but not every EPD differentiates the percent content. Glue content, ingredients and footprint as a whole is not very transparent, which is probably true across the building industry. In addition, some manufacturers describe a portion of their binder or adhesive as bio-based, but the proportion is often not given, so it is difficult to understand the contributing portion of GWP.

In general, solid materials performed better than multi-layer materials in this analysis.

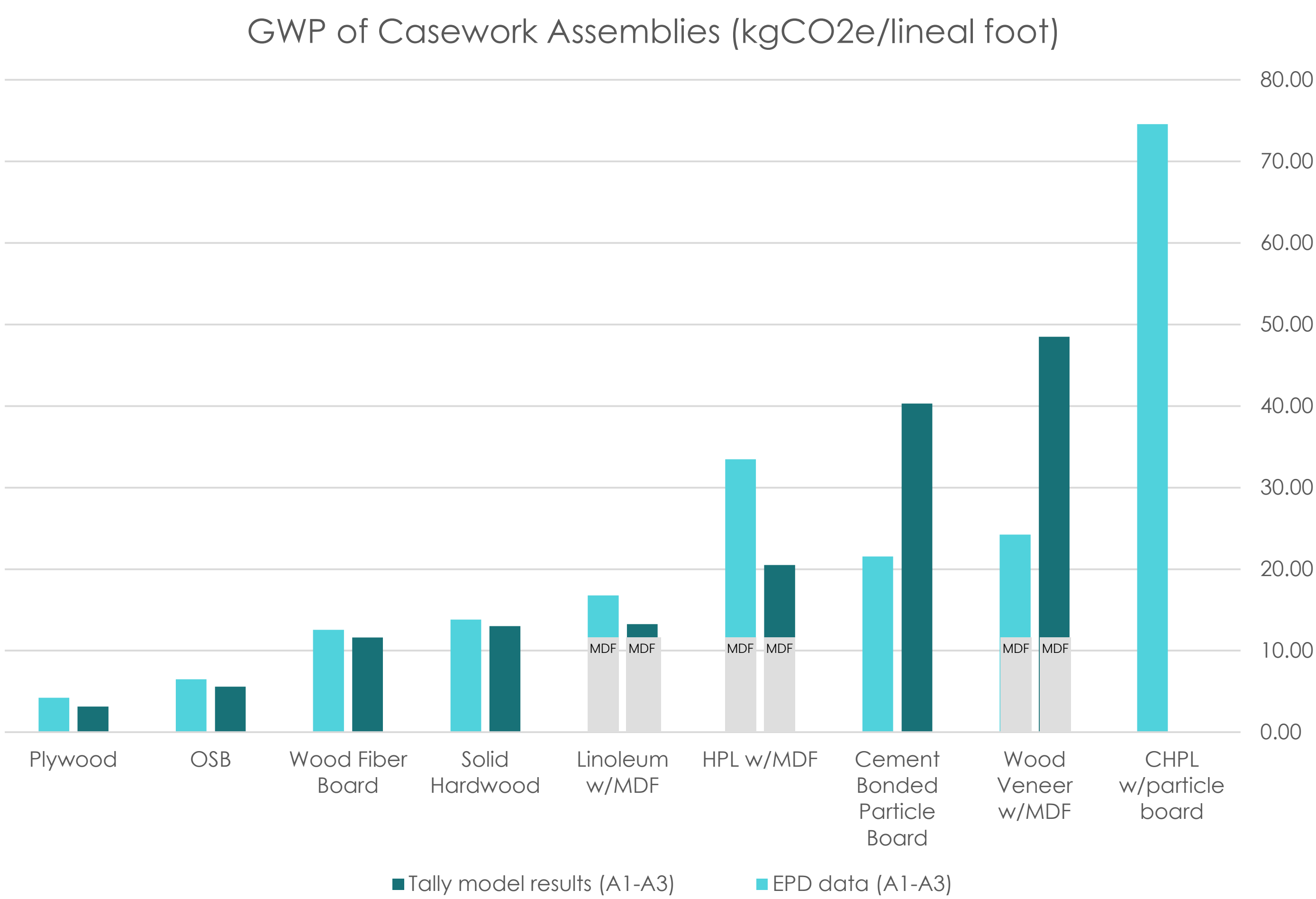


Figure 7 | GWP of countertop shown in kg CO2 equivalent per m2

Casework design considerations

Durability is always a primary concern with casework. Natural materials tend to develop a patina, compared to plastic-coated or glued materials that chip or peel.

Emerging blended bio/plastic polymer casework materials are interesting to consider. But as with countertops, depending on the percentage of bio-based content and degree of permanent or inextricable binding with the plastic components, it is unclear what aspect of sustainability is being improved by blended materials. For example, in the world of furniture and finishes, blended textiles such as polyester-cotton are increasingly recognized as end-of-life materials, because the fused composition cannot be recycled with plastics or composted with other natural materials.

For a sustainable future, it is necessary to discuss the appropriate use of plastic.

Notes for casework manufacturers

Reducing the use of glues and binders generally appears to correlate to lower-GWP casework products.

Regarding EPDs and reporting:

- Manufacturers should transparently report glue and binder content and differentiate the GWP of these components. Bio-based content may contribute to a lower GWP, but it is difficult to confirm without knowing the % and source of the bio-based material.
- Units should be standardized across EPDs. This may require revisions to the product category rules (PCR). The PCR for all countertops should be the same.
- Manufacturers should start including scope B, C, and D in LCAs again with a standard PCR for all countertops.
- Packaging should not be included in the GWP number, and especially not as a way to sneak in biogenic carbon. Biogenic carbon (e.g. a negative GWP number implying sequestration of atmospheric carbon) should be itemized separately from the manufacturing footprint scope A-D and should never be disguized as a net GWP for the product.
- Manufacturers should include substrates in LCA modeling where needed for product functionality and also itemize the footprint.

Case study

A spreadsheet-based calculator was used to calculate the total GWP impact of casework and countertops in a 14,000 sf office tenant improvement project (figure 8), compared to an 84,000 sf multinunit housing renovation (figure 9).

The GWP of these components in the tenant improvement project was found to be relatively low (approximately 2%) compared to other finishes, including floors, ceilings, new walls, doors, and interior glazing. This result is due to the relatively small volume of casework compared to the size of the space and the specific products that were selected. For the office project, the cabinets were made of FSC-certified plywood, and the natural stone countertop was a salvaged material.

By contrast, in the multiunit housing interior renovation, casework and countertops were found to be 33% of a total GWP calculation, which included floors, ceilings, walls, doors and interior glazing.

MSR Design's 510 Marquette Office | photo by Lara Swimmer

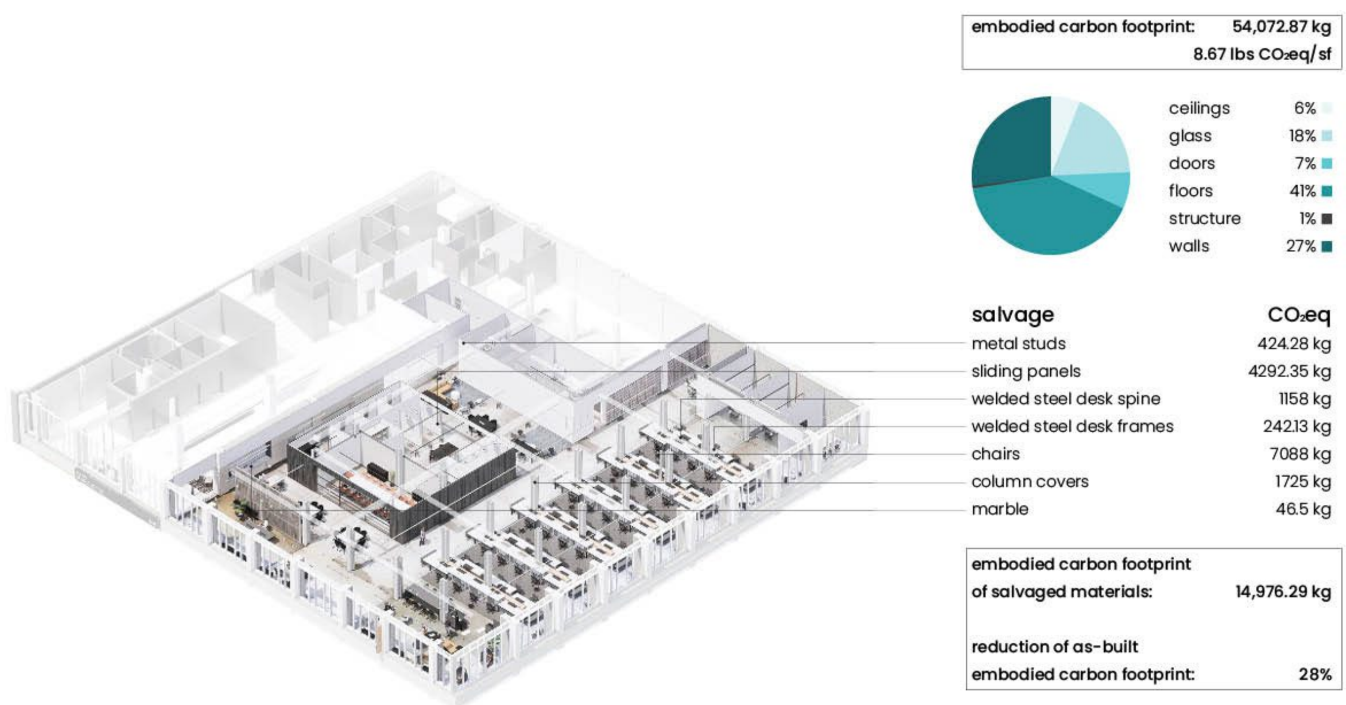


Figure 8 | Office TI embodied carbon footprint calculation.

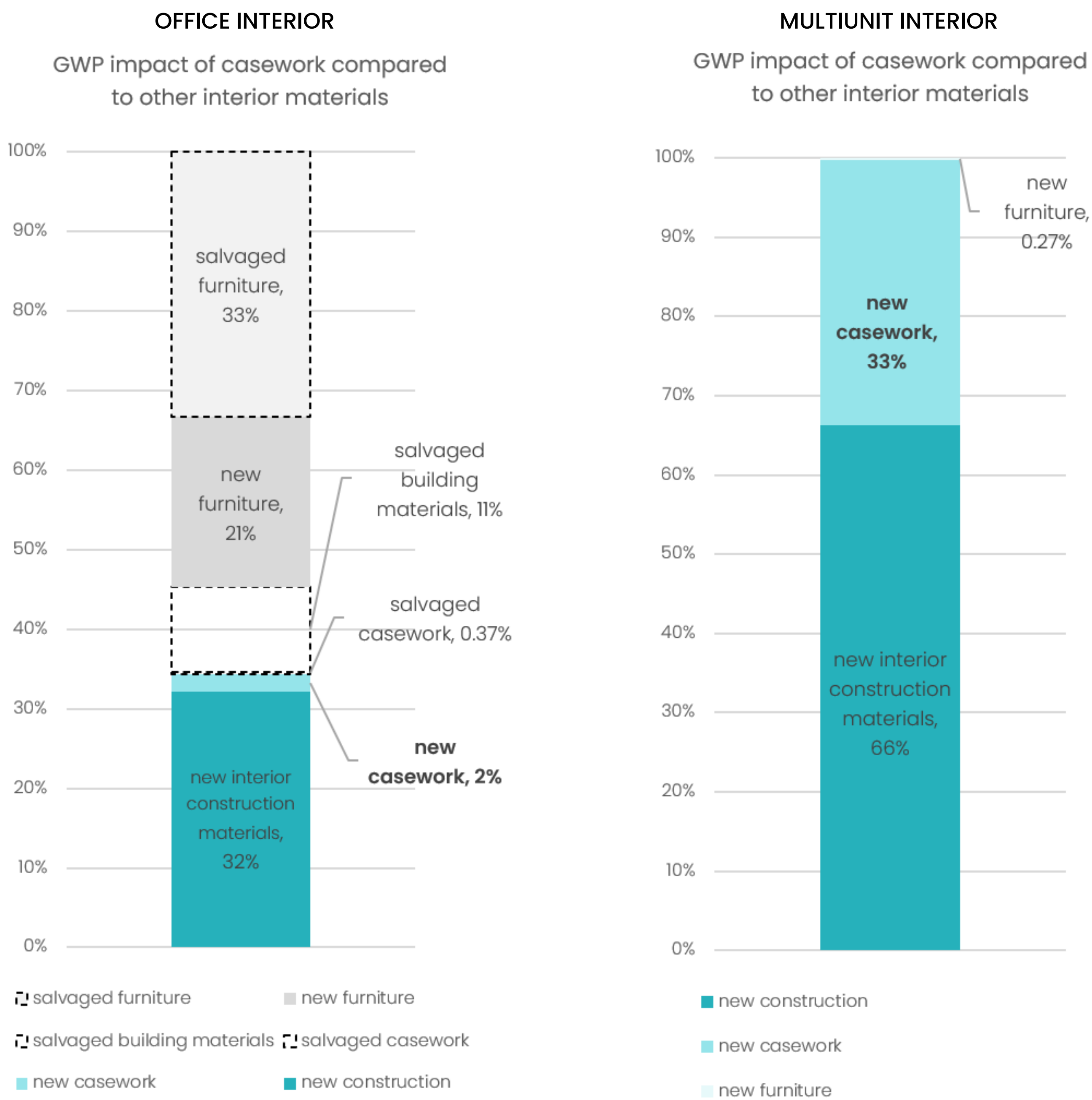


Figure 9 | Office TI versus market rate multiunit housing interior-only renovation, % GWP impact of casework and countertops.

In both interior-only case studies, the proportional impact of casework and countertops is higher than it would be in a new construction or major renovation project with a new envelope and structure. For multiunit housing, hospitality, healthcare, laboratory, and other project typologies with built-in work surfaces and storage, the volume of casework and countertops is likely to be proportionally high, even in the case of new construction, and the GWP impact significant. Based on these findings, casework and millwork should not be overlooked when considering the GWP of both new and renovation projects.

Carbon Calculator for Casework and Countertops

A quantity takeoff of casework, measured in linear feet (LF), is typically done during the construction documentation phase to estimate material costs. This takeoff number can be used to calculate the embodied carbon impact of casework. For convenience, a Revit schedule could be formatted to display LF per casework component automatically.

The casework calculator is available as part of the "MSR Design Sustainability Tracker" tool, which can be downloaded from the MSR Design [website](#).

Enter building area	10,000

Total GWP Summary | Casework		
	kg CO2e	**kg CO2e per SF**
New casework	445.04	0.045
Salvaged casework	192.46	0.019
New + Salvaged casewc	637.50	0.064

GWP Calculator | Casework Group Breakout	Casework and Countertop Materials			GWP per LF, kg CO2e		Subtotal GWP with QTO, kg CO2e	
	New	**Salvaged**	**enter QTO in LF**	**New**	**Salvaged**	**New**	**Salvaged**
Casework Group 1	*input group description here*					445.039	192.464
base cabinets	LINO w/plywood substrate	N/A	50.00	8.901	0.000	445.039	0.000
upper cabinets	N/A	LINO w/plywood substrate	30.00	0.000	6.415	0.000	192.464
tall cabinets	N/A	N/A		0.000	0.000	0.000	0.000
countertop	N/A	N/A		0.000	0.000	0.000	0.000
Casework Group 2	*input group description here*					0.00	0.00
base cabinets	N/A	N/A		0.000	0.000	0.000	0.000
upper cabinets	N/A	N/A		0.000	0.000	0.000	0.000
tall cabinets	N/A	N/A		0.000	0.000	0.000	0.000
countertop	N/A	N/A		0.000	0.000	0.000	0.000
Casework Group 3	*input group description here*					0.00	0.00
base cabinets	N/A	N/A		0.000	0.000	0.000	0.000
upper cabinets	N/A	N/A		0.000	0.000	0.000	0.000

Figure 10 | Casework and countertop spreadsheet calculator is used to estimate GWP impact of these materials in total and per square foot of project area. The calculator is available at msrdesign.com as part of the MSR Design Sustainability Tracker.

Paper Mill House | photo by Lara Swimmer Photography

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The furniture calculator is available as part of the MSR Design Sustainability Tracker, which can be downloaded from the MSR Design website. Tally reports and Excel tables are available upon request.

One10 Office | photo by Farm Kid Studios

101 Dupont Place | photo by Halkin Mason Photography

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