LCA for Low Carbon Construction

Estimates of Embodied Carbon for Mechanical, Electrical, Plumbing and Tenant Improvements

Summary Document

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INTRODUCTION

The building industry is expanding its ability to understand and mitigate the environmental impacts of buildings through the application of life cycle assessment (LCA). Most building LCAs focus on structure and enclosure (core and shell) but rarely assess interior work such as mechanical, electrical, and plumbing (MEP) and tenant improvements (TI). MEP and TI impacts can be difficult to quantify, but it is important to assess the prevalence and potential intensity of these impacts because these components are often installed multiple times over the lifetime of a building and they may be environmentally-intensive to produce. The environmental impacts of MEP and TI appear to be significant, but more data and research are needed in order to better understand these impacts.

GOAL

This study aimed to establish a preliminary range of likely embodied carbon impacts for MEP and TI components, focusing on commercial office buildings in the Pacific Northwest. This document summarizes the study results, compares findings with other benchmark studies, and discusses their implications. For more information about the research data, methods, results, and analysis, please refer to the respective MEP and TI reports, available on the Carbon Leadership Forum website.

This study is part of the Low Carbon Construction Project, funded by the Charles Pankow Foundation, the Oregon Department of Environmental Quality, and Skanska USA.

SCOPE

Scope of MEP

Components of MEP in this study included:

- Mechanical: Equipment and ductwork for Heating, Ventilation, and Air-Conditioning (HVAC) systems
- Electrical: Generators, batteries, electrical service and distribution, wiring devices, and lighting fixtures
- Plumbing: Domestic water piping and sanitary sewer piping

Scope of TI

Components of TI in this study included:

- Finishes: Ceiling, flooring, painting, and interior glazing
- Furniture: Chairs, cubicles, tables, private offices, sofas, and shelving
- Fixtures: Cabinets, counters, doors, and partition walls (both fixed and operable)

INVENTORY

Material quantities

The MEP study estimated material quantities by developing eight hypothetical buildings in consultation with local mechanical and electrical engineers and contractors. The eight hypothetical buildings were distinguished by four size categories and two energy performance categories. The TI study estimated material quantities by performing quantity take-offs on architectural drawings of five office projects in the Pacific Northwest.

LCA data

The MEP study used publicly-available data sources and EPDs to gather LCA data for equipment and material impacts. Many sources were European because there were very few North American EPDs for the MEP products of interest. The TI study used LCA data sources from EPDs (mostly from North America, a few from Europe) and North American building industry databases (Athena and Quartz). Generally, the selection of available and geographically appropriate LCA data for MEP and TI products was limited.

RESULTS AND DISCUSSION

Material mass and impact assessment

Mass estimates ranged from 16 - 23 kg/m² for MEP and 17 - 43 kg/m² for TI. **Figure 1** presents the low, medium, and high mass estimates. Embodied carbon estimates ranged from 40 - 75 kg CO_2e/m^2 for MEP and 45 - 135 kg CO_2e/m^2 for TI. **Figure 2** presents the low, medium, and high embodied carbon estimates. Note that MEP estimates did not include the impacts of refrigerants, which could be significant, nor plumbing fixtures and fittings.

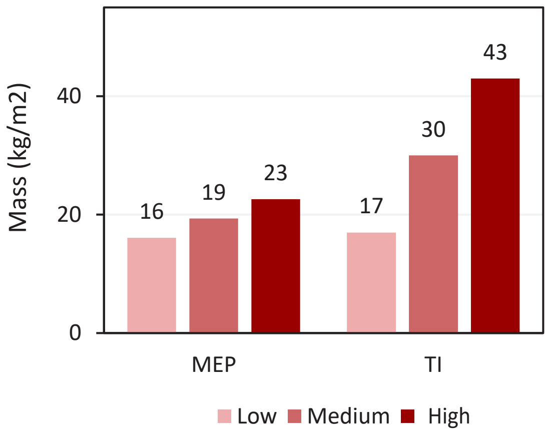

Figure 1. Mass estimates for MEP and TI at low, medium, and high estimate levels.

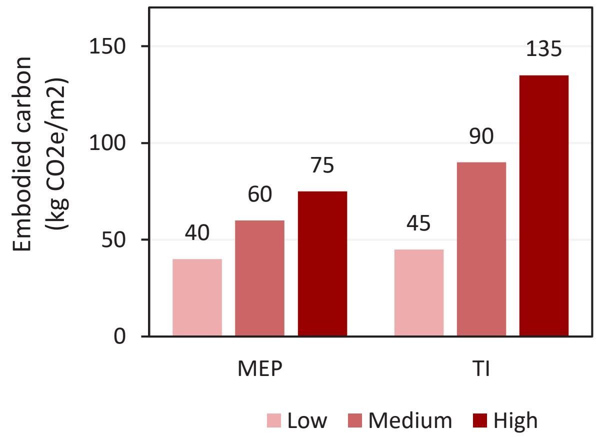

Figure 2. Embodied carbon estimates for MEP and TI at low, medium, and high estimate levels.

Comparison to Embodied Carbon Benchmark Study

The Carbon Leadership Forum's Embodied Carbon Benchmark (ECB) Study collected embodied carbon data for life cycle stage A (cradle-to-gate and/or cradle-to-construction) for approximately 1,000 buildings. **Figure 3 (a)** presents the embodied carbon impacts of building construction for office buildings with building scopes limited to structure, foundation, and enclosure. The central 50% of values, represented by the box in the box-plot, ranged from approximately 300 – 500 kg CO_2e/m^2. **Figure 3 (b)** and **(c)** depict the results of adding the low and high estimates for MEP and TI (85 and 210 kg CO_2e/m^2 respectively) to the results from the ECB study. This figure shows that including MEP and TI estimates in initial construction estimates could increase life cycle stage A impacts by 30% or more. However, a whole building LCA that considers other life cycle stages, including operational impacts, would provide a more comprehensive understanding of MEP and TI impacts.

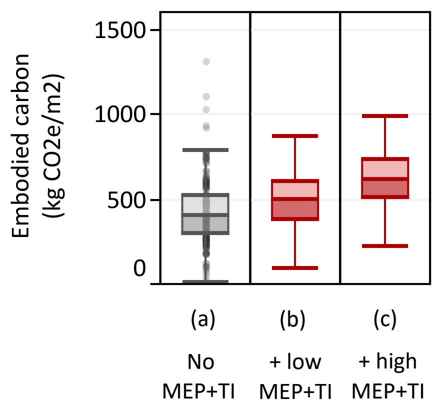

Figure 3. Results from the Embodied Carbon Benchmark Study, filtered for building use type = office buildings; scope = structure, foundation, and enclosure; life cycle stages = A1-A5. Three variations are shown: (a) the original ECB values; (b) original values + low MEP TI estimates; and (c) original values + high MEP TI estimates.

Lifetime impacts

The recurring nature of MEP and TI installments are important to consider, especially in the context of the full building lifespan. MEP and TI are often replaced every 10 – 20 years, and the accumulated impacts can be significant.

Figure 4 presents three scenarios showing the combined impacts of initial construction, MEP, and TI over a building lifespan of 60 years. Each scenario reflects the low, medium, and high estimates of each contribution, assuming a recurrence interval of 15 years. Initial construction impacts are shown as 300, 400, and 500 kg CO_2e/m^2, approximating the 25th, 50th, and 75th percentile values of office buildings from the ECB study, respectively. During the first 15 years of a building's lifespan, MEP and TI impacts are a small fraction of the initial construction estimates. However, when replacements of MEP and TI begin to accumulate, the combined impacts can exceed the initial construction impacts, depending on the estimate level. For example, after 60 years in the 'high estimate' scenario, the combined impacts of MEP and TI exceed the initial construction impacts. **Table 1** summarizes the values used in Figure 4.

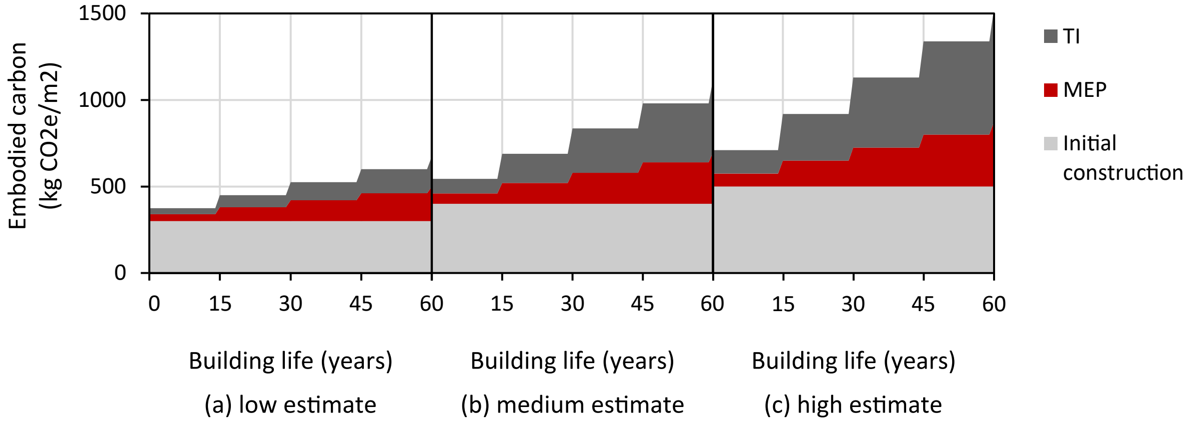

Figure 4. Cumulative embodied carbon impacts of initial construction, MEP, TI, and use (operational) at low, medium, and high estimate levels over 60 years.

Table 1. Initial embodied carbon impacts at low, medium, and high estimate levels.

	Embodied carbon (kg CO_2e/m^2)		
Component	**Low estimate**	**Medium estimate**	**High estimate**
Initial MEP	40	60	75
Initial TI	45	90	135
Initial construction	300	400	500
Initial construction + MEP+TI	385	550	710

As an example from Figure 4, **Table 2** uses the medium estimate level to present the total impacts of recurring MEP and TI at 45 years.

Table 2. Total embodied carbon due to recurring installations at the medium estimate level.

	Embodied carbon (kg CO_2e/m^2), medium estimate			
Component	**Year 0**	**Year 15**	**Year 30**	**Year 45**
Recurring MEP	60	120	180	240
Recurring TI	90	180	270	360
Initial construction	400	400	400	400
Initial construction + recurring MEP+TI	550	700	850	1000

Overall, these findings suggest that the environmental impacts of TI and MEP are significant, especially when the full building lifespan is considered. Note that some results are part of ongoing dissertation research and therefore is subject to change based on future work, including the potential impacts of refrigerants in HVAC systems.

HIGH-IMPACT ITEMS

Some MEP and TI items were associated with high embodied carbon values due to the combined effects of their carbon intensities and their quantities assessed in buildings. Based on the data collected in this preliminary study, high-impact items (per unit floor area) included:

MEP:

- Air-handling units (AHUs) and other large, heavy units
- Galvanized sheet metal for ductwork
- Light fixtures
- Cast iron piping for wastewater and ventilation
- Refrigerants (more data is needed)

TI:

- Cubicles
- Furniture
- Flooring, which depended on the flooring type
- Ceiling panel suspension system

The material quantities of some high-impact items varied significantly. For MEP, highly variable items were those that were either present or absent depending on the building model (e.g. batteries were included some electrical systems and not in others) and ductwork (the quantity of ductwork varied by a factor of 2 depending on the building size and system). For TI, highly variable items included flooring and ceiling finishes (because design choices affected the material types and quantities) and furniture, especially cubicles (because furniture quantities depended on the number of occupants).

NEXT STEPS

This preliminary study provides a basis for additional work that will be needed to advance the state of knowledge on MEP and TI environmental impacts. The data and research needs are:

- More EPDs specific to MEP and TI in North America
- Building case studies to compare actual embodied carbon estimates to the generic models created for this study
- Quantification of refrigerant use in buildings for different HVAC systems
- Accurate estimations on refrigerant charges, leakages, and recovery during end-of-life

In practice, to reduce the embodied carbon impacts of MEP and TI, the following strategies can be employed:

- Reuse as much as possible, especially furniture
- If new materials are needed, source low-impact products
- Use less materials overall. This can be done by minimizing use of finishes, partitions, interior glazing, etc.

REFERENCES

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PROJECT TEAM

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