Sustainable Markets Initiative

Decarbonization in the Built Environment: Addressing Embodied Carbon in Mechanical, Electrical and Plumbing (MEP) Systems

Sustainable Buildings Task Force

1. Executive Summary

Decarbonization is critical to combating climate change and creating a sustainable future. With buildings accounting for nearly 40% of the world's greenhouse gas emissions, there is no decarbonizing our future without decarbonizing buildings.[1] The good news is we have technology available today to get to net-zero operations through efficiency, electrification, and digitalization. Cutting carbon is not only good for the planet, but saves operational costs as well. During COP27, the Sustainable Markets Initiative's Sustainable Buildings Task Force released a report that outlines best practices and recommendations for reducing operational carbon in the built environment through technology adoption, supported by smart policies and innovative partnerships and incentives.[2]

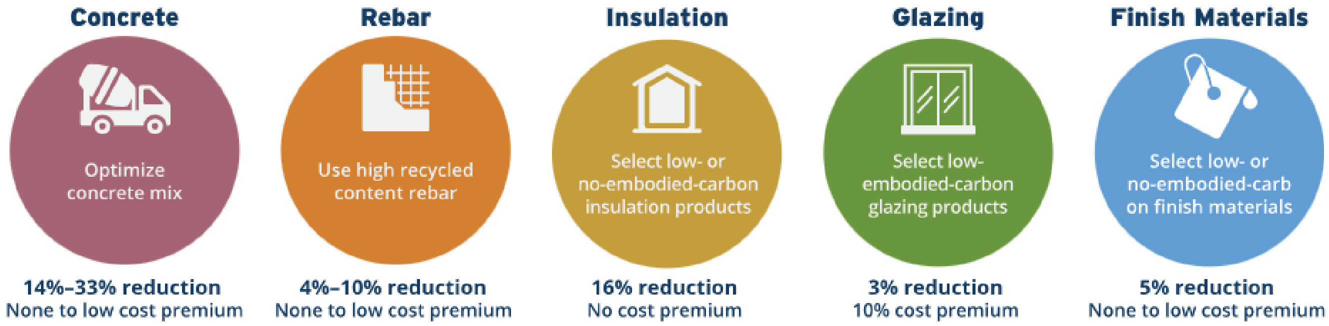
Policymakers, contractors, designers, engineers, and architects are now moving to implement strategies aimed at capturing the significant low hanging fruit of reducing the operational carbon associated with the built environment. To date, much less has been done to address embodied carbon.

Where embodied carbon is considered, the bulk of the research has been around building materials like concrete and steel. While these structural materials do make up a large portion of embodied carbon in buildings, a 2019 study by the Chartered Institution of Building Services Engineers (CIBSE) found embodied carbon from building services make up 15-50% of embodied carbon in new builds and upwards of 70% in refurbishment projects.[3] A building's mechanical, electrical and plumbing (MEP) systems are a significant, but often ignored, component of a building's overall emissions.

As the industry shifts from an operational carbon to a Whole-Life Carbon (WLC) view of greenhouse gas (GHG) emissions, the question of a standard for measuring whole life carbon becomes more important than ever. This paper charts new territory by spotlighting the carbon associated with embodied carbon in operating systems in buildings, identifying the many opportunities to cut that carbon, and highlighting the emerging approaches to track and identify that carbon.

1. *International Energy Agency (2019): "Global Status Report for Buildings and Construction 2019"*
2. *Sustainable Markets Initiative. "Sustainable Buildings Task Force." Sustainable Markets Initiative*
3. *CIBSE Technical Symposium (2019): "Understanding the importance of Whole Life Carbon in the selection of heat-generation equipment"*

2. How did we get here?



Ref: RMI (2021); "Reducing Embodied Carbon in Buildings Low-Cost, High-Value Opportunities

2.1 Historical approach and research gaps

To date, building embodied carbon research and reduction goals have focused on either the primary materials (e.g., concrete, steel, etc.) or primary systems (e.g., architecture, structural and civil, etc.). Landmark studies and reports, such as those published by RMI[4], highlighting top cost-effective embodied carbon reduction strategies for buildings, and the Carbon Leadership Forum[5], benchmarking embodied carbon per square foot, did not include MEP systems. The World Green Buildings Council's report "Bringing Embodied Carbon Upfront",[6] emphasizes the contribution to, and potential reduction of, embodied carbon by building materials such as cement, steel, gypsum, glass, aluminum, plastic, and wood.

It's reasonable such research has been heavily focused on building materials. Structural elements, in particular concrete and steel, tend to be embodied carbon hotspots; such materials also have readily available lower carbon alternatives on the market today, making them compelling decarbonization solutions.

The World Business Council for Sustainable Development's report "Halving Construction Emissions Today"[7] included estimates and reduction strategies for building systems' embodied carbon as part of the building's total carbon emissions. In 2019, a Carbon Leadership Forum study[8] focused exclusively on estimating the embodied carbon of MEP, generating low, medium and high estimates of embodied carbon in kgCO_2-eq/m^2 of building area.
In Europe, the Greater London Authority published whole life carbon assessment guidance and benchmarks estimating that building services account for an estimated 20% of the whole life carbon of a typical office building. Also out of Europe, "Towards EU embodied carbon benchmarks for buildings in Europe"[9] published by Ramboll found that building services contributed to an estimated 27% of building embodied carbon emissions.

A recent report from the USGBS and RMI, "Driving Action on Embodied Carbon in Buildings"[10], highlights persistent data gaps in reporting of embodied carbon data, noting that many whole building lifecycle assessments omit MEP entirely because of this data gap.

As such, there is an opportunity for future studies to consider, measure, and report the impact of MEP systems on whole building embodied carbon. There is also a need for studies that highlight the potential solutions, and successful case studies, for MEP embodied carbon reduction.

4. RMI (2021); "Reducing Embodied Carbon in Buildings Low-Cost, High-Value Opportunities"
5. The Carbon Leadership Forum Department of Architecture University of Washington (2017) Embodied Carbon Benchmark Study
6. World Green Building Council (2022); "Bringing Embodied Carbon Upfront"
7. World Business Council for Sustainable Development; "Net-zero buildings Halving construction emissions today"
8. Benke, B., Lewis, M., Carlisle, S., Huang, M., and Simonen, K. (2022). "Developing an Embodied Carbon Policy Reduction Calculator" Carbon Leadership Forum, University of Washington. Seattle, WA.
9. Ramboll (2022), "Towards EU embodied carbon benchmarks for buildings in Europe"
10. USGBS and RMI (2023), "Driving Action on Embodied Carbon in Buildings"

2.2 Definitions

2.2.1 Embodied Carbon

Embodied carbon refers to the total GHG emissions from the construction process. This includes raw material extraction, manufacturing, transportation, installation, maintenance, replacement, and end of life for a system.

2.2.2 Operational Carbon

Operational carbon refers to emissions released continuously from both operational energy consumptions, for example the system's heating, cooling, and powering a building over its lifetime, and the operational water use. As referenced earlier, the International Energy Agency (IEA) reports that buildings account for around 39% of global energy-related emissions: 28% from operational carbon and 11% from the embodied carbon associated with manufacturing materials and products.

While operational emissions make up a higher percentage, those emissions can be reduced over time through efficiency upgrades and transitioning to renewable energy sources. Conversely, embodied carbon emissions must be addressed in the near-term if we hope to achieve net-zero by 2050 to limit global warming. Additionally, as the grid greens and building operations become more efficient, the split between embodied and operational emissions in the built environment will skew toward embodied carbon.

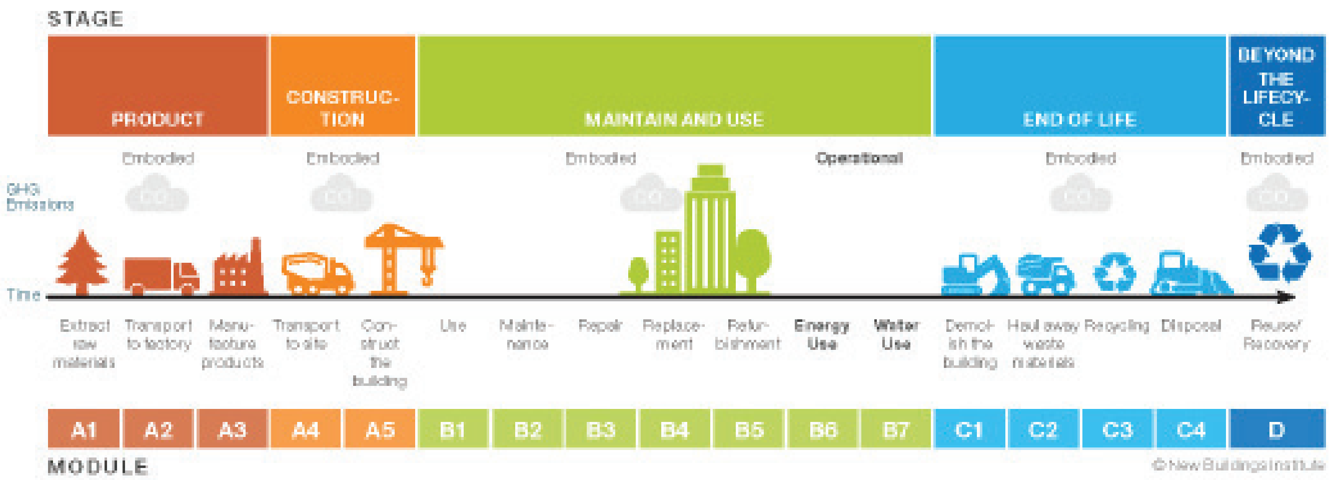
2.2.3 Whole-Life Carbon

As the name implies, Whole-Life Carbon (WLC) considers operational and embodied carbon emissions together to understand their combined impact.

2.2.4 Lifecycle Assessments (LCA)

LCAs calculate the environmental impact of a product or service throughout its entire lifecycle. In addition to transparent, comprehensive reporting, this holistic view can help avoid burden-shifting – when a reduction in one lifecycle stage results in an unintended consequence in another – in pursuit of product footprint reduction.

FIGURE 1: LIFECYCLE STAGES
Data source: BS EN 15978:2011



3. Opportunities in addressing embodied carbon in MEP systems

3.1 Sustainability Goals

With the increase in energy-efficient buildings, addressing embodied carbon is becoming an increasingly critical factor in driving toward net-zero and carbon-neutral buildings. Embodied carbon can represent up to 50% of overall lifecycle emissions in new, energy efficient buildings, making it a key factor in reducing GHG emissions.[11] The World Green Buildings Council outlined its vision that:

> *By 2030, all new buildings, infrastructure and renovations will have at least 40% less embodied carbon with significant upfront carbon reduction, and all new buildings must be net-zero operational carbon.*
>
> *By 2050, new buildings, infrastructure and renovations will have net-zero embodied carbon, and all buildings, including existing buildings, must be net-zero operational carbon.*

Developing net-zero carbon assets requires reducing embodied carbon to an absolute minimum. Solutions are readily available and are actively being implemented to reduce operational emissions (renewable energy, electrification of building systems, energy-efficient appliances and systems, etc.). Efforts to abate embodied carbon will be more complex, due to the need to involve multiple parties to decarbonize across the entire supply chain, and more challenging as it will require reducing emissions from carbon-intensive industrial and manufacturing processes.

3.2 Decarbonizing Materials

Promoting low-carbon materials, such as those with high recycled content, bio-based materials and alternatives produced using low-emission manufacturing processes, can reduce embodied carbon up to 80% in buildings.[12] Use of low carbon materials may support decarbonization of certain materials typically used in MEP systems such as aluminium, which is typically used in heating/cooling and ventilation systems. Similar techniques are currently used in other building products, for example an aluminium window frame has 20% and 45% lower embodied carbon when using 30% recycled content and low carbon aluminum respectively.[13] However, designers and specifiers must be conscious of the scarcity of scrap, which means it cannot meet global demands. This challenge is demonstrated by 70% of the total metallic input to steel production being derived from iron ore.[14]

11. *Lützkendorf, T. and Balouktsi, M., 2022. "Embodied carbon emissions in buildings: explanations, interpretations, recommendations." Buildings and Cities, 3(1), p.964–973.DOI*
12. *Industry Transition Report (2023): "Accelerating Decarbonization in Hard-to-Abate Sectors"*
13. *One-Click LCA: Whitepaper "Low-carbon Aluminium. Solution for construction and renovation"*
14. *World Steel Factsheet (2021): "Scrap use in the steel industry"*

Another commonly used material in MEP systems is steel, which can be highly carbon intensive. Electric arc furnaces (EAF) are a key technology to greatly lower steel's carbon intensity. A recent study released by the Steel Manufacturers Association found that steel produced using EAF technology has a carbon intensity that is approximately 75% lower than steel produced using traditional blast furnaces.[15] However, global EAF steelmaking capacity is limited, with the majority being available in the US. To make meaningful progress in the decarbonization of steel, more needs to be done to expand EAF capacity globally.

The opportunity for lower carbon MEP materials is ripe for innovation and materially important to overall building decarbonization. A study focused on embodied carbon benchmarks for buildings in Europe found that out of six different building categories (Ground, Load-bearing structure, Envelope, Internal, Services and Appliances), building services were the single largest lifecycle contributor of embodied carbon, contributing to 27% of the total with a mean value of around 190 kg CO_2eq/meter squared floor area. The materials used to make the systems which include aluminum (e.g. motors, heat exchangers), copper (e.g., pipework, wiring), rare earth metals (e.g. batteries, solar photovoltaics, and heat pumps), steel (e.g. enclosures, support rails, ductwork), cast iron (e.g. piping) and combinations of metals (boilers, chillers, pumps), combined with the need for frequent replacement and challenges in breaking down and recycling multi-material components that make up MEP equipment, contribute significantly to MEP system carbon intensity.

Reaching net-zero embodied carbon for MEP systems will require the development of low-carbon material alternatives at scale globally, an increase in the operational lifetimes of the systems themselves and the creation of more circular supply chains that allow for adaptive reuse or effective recycling.

15. *Clean Technica (2022): Independent Study Validates that Steelmaking by Electric Arc Furnace Manufacturers in U.S. Produces 75% Lower Carbon Emissions*

4. Opportunities for reducing embodied carbon in MEP systems

4.1 Data collection

Collecting embodied carbon metrics needs an established and widely followed approach to calculating the carbon footprint of raw materials or manufactured goods. Lifecycle Assessments (LCAs) are the most accepted method for quantifying and reporting embodied carbon. LCAs calculate the environmental impact of a product or service throughout its entire lifecycle, including production, construction, use, and end-of-life. In addition to transparent, comprehensive reporting, this holistic view can help avoid burden-shifting – when a reduction in one lifecycle stage results in an unintended consequence in another – in pursuit of product footprint reduction.

LCAs need to be aligned with International Organization for Standardization (ISO) standards 14040 and 14044 because they provide the foundation. ISO standards need to allow for flexibility in the calculation of embodied carbon, such as inclusion or omission of specific lifecycle stages, difference in how and where to account for the benefits of recycled content, use of different background datasets, and how to account for renewable energy credits in product manufacturing facilities.

LCAs serve as a foundation for an Environmental Product Declaration (EPD), which summarizes a product's environmental impact report based on an LCA performed in compliance with a specific set of Product Category Rules (PCRs). Such PCRs are managed by Program Operators (PO), which also set the EPD verification process and house a publicly available database of EPDs published in line with their PCR. ISO 21930 and EN 15084 provide rules for EPDs of construction products and services. Beyond ensuring compliance with specific ISO or EN standards, PCRs can specify study requirements including data sources, cutoff criteria, standard input assumptions where data is lacking, and scenarios for modeling use-stage emissions.

EPDs, which require third-party verification, provide an additional level of standardization for reporting consistency within a certain industry or product area. Critical review is always encouraged for product LCAs but is required when the assessment will be used to compare products.

Global EPD availability for MEP products is currently limited, however the following Program Operators do have PCR and published EPDs for MEP products:

- PEP (Product Environmental Profile) EcoPassport
- UL Environment
- EPD International
- EPD Hub

The data communicated in EPDs and LCAs can help inform embodied carbon reduction strategies throughout the building supply chain. The studies also serve as inputs to whole building licecycle assessment, which itself is gaining popularity and use in the buildings industry. Whole building LCAs can help building owners evaluate various design options and make informed choices to optimize for sustainability by lending insight into product, material, and system choices and their environmental impacts over the entire building licecycle.

The CIBSE Technical Memorandum 65 (TM65) methodology is used to estimate the licecycle embodied carbon of MEP products where no EPD is available. TM65 focuses exclusively on embodied carbon and thus does not include other environmental impact categories (such as ozone depletion or acidification) nor emissions from MEP system use. TM65 outlines data requirements and provides emission factors for major MEP product inputs (e.g., kg CO_2eq/kg steel) based on literature values.

While the methodology was drafted for use by engineers, manufacturers and consultants in the UK and Europe, TM65 principles can be applied in other geographies with adjustments to certain assumptions and emission factors. For example, additional guidance for using TM65 outside of the UK was drafted along with an Australia/New Zealand addendum to the methodology.

TM65 is a starting point for manufacturers who are still developing embodied carbon expertise and those that manufacture complex products with a high barrier to entry for EPDs. According to the CIBSE, the TM65 methodology "does not aim to replace EPDs, but rather allows initial conservative embodied carbon estimates for MEP products to be made, while waiting for EPDs to become available." Certain standard reporting formats are encouraged, but not required, by the methodology. TM65 presents a low barrier to entry to product carbon footprint accounting and can thus play a critical role in increasing embodied carbon transparency for MEP products. It can be a useful option for generating an initial baseline of the embodied carbon footprint for a suite of products, which is more efficient than pursuing full EPDs for all products.

4.2 Role of policy and funding

Policies and funding programs have a real opportunity to drive change in addressing embodied carbon. The year 2022 saw a drastic increase in the number of policies introduced to address embodied carbon reductions in the building and infrastructure sector. Policies and incentives specific to embodied carbon in MEP systems could have a similar and positive effect.

In the US, the Inflation Reduction Act (IRA)[16] aims to reduce total carbon emissions 40% by 2030 and allocates funding to low-carbon procurement for infrastructure projects. The US Environmental Protection Agency (EPA) offers a grant program to encourage manufacturers of construction materials to develop and verify EPDs.[17] Both programs have the potential for significant impact in the US.

In the European Union (EU), the EU Emissions Trading System (ETS)[18] serves to reduce emissions by providing a cap-and-trade system via a carbon market. The cap is reduced annually in line with the EU's climate target. Companies can purchase allowances on the carbon market and trade with each other as needed. Those that do not fully account for their emissions are subject to fines.

Furthermore, the EU have recently announced the introduction of a Carbon Border Adjustment Mechanism (CBAM), which is currently in the transition phase with full enforcement by 1st January 2026. This mechanism levels the playing field for cleaner, more sustainable products, bridging the gap between the EU's ambitious environmental standards and those of its trading partners. This is done via imposing costs on carbon emissions associated with imported goods entering the EU. The CBAM will require importers of certain goods like cement, iron and steel, fertilisers, aluminium, electricity and hydrogen to surrender CBAM certificates. This will affect the supply chain for building services products, amongst others, to address carbon leakage and encourage adoption of greener production methods.

Policymakers can drive efforts toward low embodied carbon building systems by adopting regulations and incentives that drive reductions. Policies can stimulate market demand for low carbon materials and the commercialization of solutions for reducing embodied carbon.

16. *US Inflation Reduction Act 2022*
17. *EPA (2023): New Grant Opportunity Focused on Lower Embodied Carbon Construction Materials Coming Soon!*
18. *EU Emissions Trading System (EU ETS)*

4.3 Market perception

Environmental awareness and consumer preferences must create a strong incentive for businesses to drive decarbonization in building systems. The information used to create this awareness must be transparent and comparable to build trust and prevent indifference among consumers and the market. Therefore, it is critical for industry professionals to educate the public and the market on the parameters that define a sustainable or decarbonized building to enable educated choices regarding the materials and technologies that make a significant contribution towards the goal of decarbonization and the corresponding cost implications.

Francis House, SW1 is a 38,000 square foot warehouse refurbishment in Victoria, London, with an overall upfront embodied carbon 269 kg CO_2eq/m^2. Derwent London worked hand-in-hand with a smaller contractor and their supply chain to learn more, together, about the embodied carbon of mechanical and electrical (M&E) equipment such as air-source heat pumps and chillers. Following industry guidance and with the support from a sustainability consultant, the contractor made great strides in gaining data from its supply chain that enabled a much more accurate estimate of embodied carbon than the benchmark figure typically provided for M&E plant. Generally, industry guidelines suggest building services make up 15% of upfront embodied carbon however, this work found embodied carbon for building services was actually 21% for Francis House. Such assessments highlight areas of focus for reducing emissions on future projects and help the industry in establishing future guidance. Additionally, through early engagement with the occupiers, an agreement was met to not install the Cat A, and to understand the impact of Cat A fit-outs, and how occupiers adapt their space to inform future design and procurement discussions with the contractors. Further, this was a cost and program neutral solution due to Cat A contributions.

At another project, Soho Place, London, analysis estimated the impact a Cat A fit-out - and its associated strip-out – has on embodied carbon. For the occupiers fit-out at Soho Place this equated to between 10 kg CO_2eq/m^2 – 40 kg CO_2eq/m^2 depending on how much of the Cat A was altered, but reinstalled. This analysis has influenced the procurement route for future projects to reduce avoidable carbon.

As an industry we need to understand that even the most adaptable Cat A fit-outs, are likely to incur wastage. There are many ways to avoid this, including augmented reality Cat A designs for occupiers, engaging with manufacturers for take-back schemes (& warranties) of newly installed, but stripped out kit or only installing one floor of Cat A, and engaging with occupiers on how best to adapt and re-use the Cat A fittings.

5. How can we reduce the embodied carbon associated with MEP systems?

5.1 Design considerations

Considering the entire lifecycle of building materials during design and selection is critical to minimize embodied carbon of the building and its systems. As discussed previously, ISO standards governing LCAs and EPDs provide a basis for material and product selection and need to be standardized. Designers can influence a building's final embodied carbon by providing low embodied-carbon options to project stakeholders at key design decision points. This can be done through whole-building design, specification and one-for-one material substitution. Importantly, cutting carbon can also cut costs for example through early design considerations, or when circular economy principles are adopted.

5.1.1 Whole Life Carbon (WLC)

Driving reduction starts with a WLC approach. Considering the product, construction, use and end-of-life stages can inform design comparisons early in the process that can have significant implications in the long-term, e.g., the carbon payback of a complicated metal shading device versus a simpler, more modest glazing ratio in reducing cooling demands of a building. This may therefore reduce both operational carbon, and also lead to a reduction in equipment sizing enabling upfront carbon reductions. Such comparison between upfront carbon cost and the implications on operational emissions can help to inform the process of reducing the carbon impact of buildings.

5.1.2 Refrigerants

In the past, MEP systems have used chlorofluorocarbon (CFC) and hydrofluorocarbon (HFC) refrigerants, which have high global warming potentials (GWP). The industry is aggressively transitioning to low and ultra-low GWP refrigerants including hydrofluoroolefins (HFO), HFC-HFO blends, and natural refrigerants; for most MEP applications, refrigerants that are 75% to 99.9% lower GWP are available today or will be within the next few years. This shift will dramatically reduce the embodied carbon associated with refrigerants in MEP systems. It should be noted that low-GWP refrigerants should be considered alongside potential challenges with flammability, pressure and their carcinogenic risk.

Different system types also have different refrigerant charges (i.e., the mass of refrigerant in a system). Therefore, reducing refrigerant charge as well as reducing the GWP of refrigerants should be prioritised. For example, Variable Refrigerant Flow (VRF) systems typically have a high refrigerant charge due the refrigerant being the transfer fluid. VRF systems also typically have a high leakage rate, leading to these systems having high use-stage emissions.

It is important for MEP engineers to work to reduce refrigerant leakage through preventive maintenance and leak detection. Reclaiming as close to 100% of refrigerant as possible at end-of-life and selecting lower GWP refrigerants can vastly reduce whole life emissions from MEP systems.

5.1.3 Circularity

Buildings are complex, composite ensembles of many items. Frequently, materials with different recycling requirements and capabilities are joined together with adhesives. Polyvinyl chloride extrusions, for example, are recyclable but may become contaminated with other demolition materials or additives.

How can we ensure circularity within our buildings with such complex components? Designing for circularity and disassembly starts with understanding the components themselves. Details already known by manufacturers, suppliers and contractors can be a rich source of information when scaled up to site, city or national levels of usable material. Products designed for circularity reduces the associated waste and contamination of products, components and raw materials to be reused.

5.1.4 Hierarchy of Actions

The following principles[19] should be taken into account when considering MEP and system design:

Build Less

- Minimize loads through passive design and avoid oversizing.
- Eliminate materials – consider integrated design in making aspects of buildings multifunctional or simply reduce material by eschewing unnecessary layers.
- Utilize self-finishing internal surfaces like timber or exposed concrete soffits. This may help reduce carbon associated with raised access floors or suspended ceilings used to hide distribution.
- Design multifunctional spaces for future flexibility.
- Simplify the design in junctions, and maximize the efficiency of service runs, riser arrangements and plant room locations.

Build Clever

- Design for circularity – MEP systems are changed many times throughout the life of the building based on space use, technology updates, occupant preferences and maintenance. Consideration should therefore be given to the accessability of MEP systems and distribution, as well as reuse of systems themselves.
- Ensure comprehensive EPDs, or TM65 data on all products specified and when considering alternatives.
- Consider existing buildings as a source for materials.

Build Efficiently

- Minimize refrigerants, ensure leakage and disposal is considered in life-cycle analysis and where the removal or reduction of refrigerants is not possible, specify those with low GWP.
- Source materials locally where possible to reduce transport of materials to site and disposal off site. Specify products designed for disassembly, repair and reuse that can be replaced, such as mechanical and modular construction over adhesives.

5.1.5 Construction and Manufacturing

5.1.5.1 Modular Construction

Building less frequently and more efficiently can reduce on-site waste and allow efficient manufacturing off-site in controlled conditions. Prefabrication and modular construction also enable integrated design elements, allowing them to perform multiple functions within a building. An integrated approach reduces the number of layers and material within a building along with the associated embodied carbon, sometimes at the expense of simplicity in design coordination and lifetime flexibility.

The selection of building systems can have a significant impact on the WLC of a building, not only in operational emissions but also embodied emissions of the system, the structure and the envelope of the building.

One such example is a comparison of a precast radiant system where heating and cooling pipes are embedded into the structural slab of the building.

When compared to a business-as-usual all-electric office building of a steel structure and an air-source variable refrigerant flow and dedicated outdoor systems, an alternative radiant system has been demonstrated to reduce WLC emissions by 40%. This is achieved primarily by a 30% reduction in operational energy through efficient systems but also through a reduction in the embodied carbon of the structure, mechanical systems and refrigerant volume.

5.1.5.2 Energy-Efficient and Low Carbon Manufacturing

In addition to lower-carbon raw materials, decarbonizing the manufacturing of finished MEP products can be a compelling solution to reduce the carbon intensity of MEP system embodied carbon.

The main decarbonization levers at this stage of the supply chain are:

- Energy efficiency and innovation to achieve productivity gains in the manufacturing process
- Increasing share of renewable energy in electricity production
- Replacing hydrocarbon-based thermal energy with green hydrogen or other renewable fuels
- Electrification of industrial processes when possible

Transforming manufacturing will require upfront capital investments. Policy makers and interested stakeholders should consider how to incentivize and accelerate such investments.

19. *UK Green Building Council (2019): "Net-zero Carbon Buildings: A Framework Definition"*

6. Recommendations and Conclusions

6.1 Industry Partnerships

Collaboration among stakeholders to share knowledge, best practices and innovations is key in reducing embodied carbon. Partnerships can help to align the interests of commercial developers, building owners and manufacturers, which will ultimately drive effective, sustainable decarbonization efforts.

WorldGBC's Whole Life Carbon vision creates a framework for decarbonization across the building sector, complete with key target dates and principles for achieving the targets.[20] The organization views cross-sector collaboration as key to achieving its net-zero vision.

SMI's Sustainable Buildings Task Force is one example of stakeholder collaboration working to accelerate the transition to a sustainable world.[21] Comprised of global CEOs from the building industry, the group promotes the development of coordinated global partnerships to help the built environment industry organize itself around ambitious goals to deliver net-zero buildings.

Originally borne out of the Carbon Leadership Forum but now an independent body, the MEP 2040 Commitment is an initiative with the mission of dramatically reducing the embodied carbon emissions associated with MEP systems. Signatories to the commitment, which is intended for MEP engineering and design firms, agree to establish a company plan, and report annual progress, to reduce operational and embodied carbon across MEP systems on all projects, targeting net-zero by 2040; measure and report progress against that plan annually; request EPDs and low GWP refrigerants from MEP manufacturers; and participate in quarterly MEP2040 forums. Non-engineering firm stakeholders can be recognized as Supporters of the Commitment.

6.2 Supplier Engagement

Supplier engagement is crucial to reducing embodied carbon. Downstream customers can drive sustainable sourcing by working with suppliers to set reduction targets, encouraging investment in clean energy solutions, collaborating on logistics and circularity initiatives and exploring material optimization. Additionally, suppliers and customers can accelerate their understanding of how to best achieve environmental goals through knowledge sharing.

20. *World Green Building Council (2023): "Whole Life Carbon Vision"*
21. *Sustainable Markets Initiative. "Sustainable Buildings Task Force." Sustainable Markets Initiative.*

The first step to effectively engaging suppliers is understanding where they are in their sustainability journey and how their products contribute to your embodied carbon. At this stage, it might be useful to prioritize top suppliers in terms of both potential impact and availability of carbon reduction opportunities.

For example, an "in region" supplier might be a better partner for a circularity initiative like returnable packaging, while a supplier abroad might be better targeted for a freight optimization exercise. Commodity products like steel or aluminum might be an easier initial focus than specialty products that are highly engineered and complex. Low-carbon alternatives are emerging for many raw materials in traditionally carbon-intensive sectors like steel, but significant reductions can be achieved with existing materials through design decision making. It might be possible to use less of the current material or increase the share of recycled material input into the product.

Transforming the value chain will require large investments to adapt new production routes, change energy mix and embrace innovative technologies. Therefore, to effectively address embodied carbon, it is important that suppliers are engaged and supported on sustainability initiatives.

6.3 Conclusion

For efforts to decarbonize the built environment to be successful, assessing the whole impact of building systems must not be forgotten. By addressing the embodied carbon of these systems along with the rest of the building, we can calculate the true impact of the built environment.

Unlike operational carbon emissions which can be continuously impacted through things like relying on renewable energy, embodied carbon emissions are front-loaded. Once a system is built, embodied carbon emissions are already in the atmosphere.

Most of the embodied carbon emissions of the built environment have traditionally been attributed to building materials like concrete and steel. The good news is that investing in and expanding globally in the availability of secondary steel and aluminum will continue to have a positive impact on reducing embodied carbon of this sector's impact on emissions. However, while these structural materials do make up a large portion of embodied carbon in buildings, the embodied carbon from building services has been shown to contribute 15-50% of embodied carbon in new builds and upwards of 70% in refurbishment projects. Therefore, considering the entire lifecycle of building materials during design and selection is critical to minimizing the embodied carbon of the building and its systems. Reaching net-zero embodied carbon for MEP systems will require the implementation of passive design measures, reducing equipment size (and therefore embodied carbon), at-scale development of low-carbon material alternatives and an increase in the operational lifetimes of the systems themselves.

7. References

1. *International Energy Agency (2019): "Global Status Report for Buildings and Construction 2019"*
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