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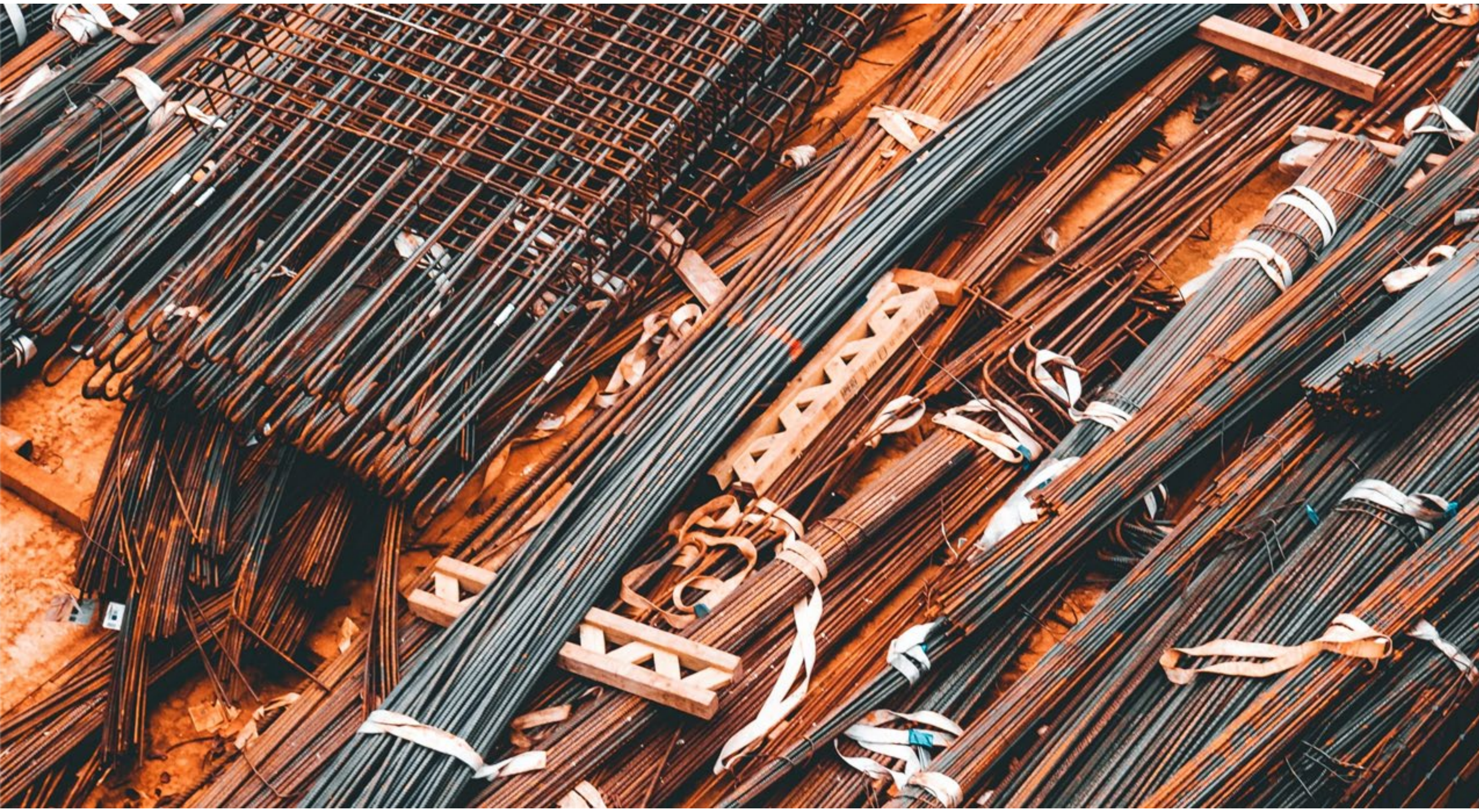
White Paper 5

Embodied Carbon Considerations For Data Centers



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Executive Summary

Climate change continues to affect our environment at an increasing rate while our understanding of the impact between human activities and the increase in measured greenhouse gases (GHG) is becoming clearer. The demand for IT services is contributing to immense growth within the data center sector and this contributes to increasing carbon impacts from construction and operations. In terms of built out area and overall energy usage, data centers currently remain a small subset of commercial and industrial emissions. However, it does not take much imagination to see a future where they are one of the highest consumers of energy and resources. As more systems move online, such as most things leisure, education and work-related, contrasted by a reduction in commercial real estate, an increase in data center carbon footprint can be forecast.

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1. Introduction

Climate change continues to affect our environment at an increasing rate while our understanding of the impact between human activities and the increase in measured greenhouse gases (GHG) is becoming clearer. The demand for IT services is contributing to immense growth within the data center sector and this contributes to increasing carbon impacts from construction and operations. In terms of built out area and overall energy usage, data centers currently remain a small subset of commercial and industrial emissions. However, it does not take much imagination to see a future where they are one of the highest consumers of energy and resources. As more systems move online, such as most things leisure, education and work-related, contrasted by a reduction in commercial real estate, an increase in data center carbon footprint can be forecast.

Early data center design was primarily focused on cost, resiliency and uptime but later evolved to include efficiency and the reduction of operational energy consumption. The economic approach to design decision-making has considered the data center lifecycle, but only in terms of capital and operational expense and total cost of ownership. Increasing the efficiency of the data center or reducing the resources required to build it lessens the GHG impact but there are limitations. There remains the risk of design decisions having unintended consequences if embodied carbon emissions are not considered.

Embodied carbon includes all emissions not attributed to operations and the use of electrical energy and water in the day to day running of the data center. These include those from extraction, manufacturing, and transportation, as well as installation of materials and components used to create the built environment. It also includes the lifetime emissions from in-use activities including maintenance, repair, replacement and the end-of-life activities of deconstruction, transportation, waste processing and disposal. Reducing the GHG emissions in support of a carbon neutral goal for the data center industry must be performed with a comprehensive approach. Embodied carbon is the sum of GHG emissions normalized to an equivalent CO_2 number.

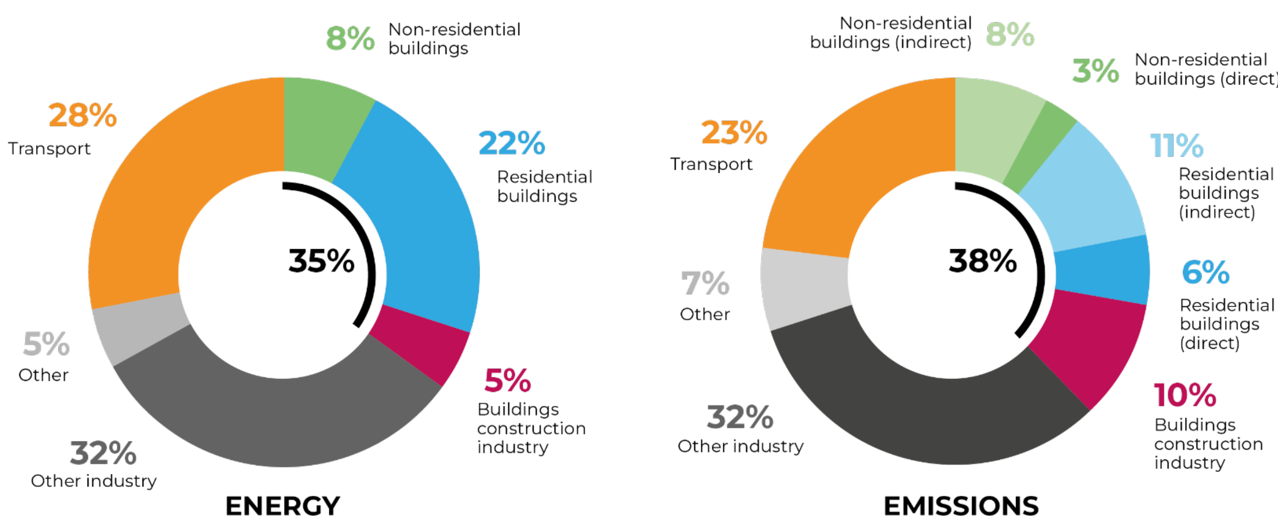
Including the Whole Life Carbon approach to the design process can identify which design selections achieve the lowest carbon emissions over the entire lifecycle of the data center, where focusing solely on operational emissions may fall short.

2. Data Center Scale

According to the Jones Lang LaSalle (JLL) research group, there was 611.3 MW of data center capacity under construction in 2020 in North America, and another 418.2 MW under construction in EMEA[1]. This is an increase from 549.8 MW at the end of 2018. Density is still increasing, however, the amount of building area required to keep up with demand for the services continues to increase.

The United Nations Environment Programme (UNEP) Global Alliance for Buildings and Construction (GlobalABC) publishes an annual global status report in which the two trends were highlighted[2]. "CO_2 emissions from the building sector are the highest ever recorded" and "new GlobalABC tracker finds sector is losing momentum toward decarbonization." These are both concerning trends with the percentage of global emissions and energy of 38% that can be attributed to the overall building sector. To decrease the share of global emissions that can be attributed to building operations, it requires continued effort on efficiencies and especially for data centers, the expedited decarbonization of the electric power grid. The opportunities exist to improve these on new builds and continue in the future through technology innovation and equipment retrofits as advances become available.

Global share of buildings and construction final energy and emissions, 2019



Notes: Buildings construction industry is the portion (estimated) of overall industry devoted to manufacturing building construction materials such as steel, cement, and glass. Indirect emissions are emissions from power generation for electricity and commercial heat.
Sources: (IEA 2020d; IEA 2020b). All rights reserved. Adapted from "IEA World Energy Statistics and Balances" and "Energy Technology Perspectives".

There is an additional 10% of global emissions attributed to the construction of buildings. These emissions, created at the beginning of the building lifecycle, cannot be reduced over time. Addressing the sources of these emissions during design and procurement are an important consideration and contribute to immediate embodied carbon reductions. Another perspective to highlight the importance of embodied carbon in relation to operational carbon is grid decarbonization. If the grid providing the operational energy is decarbonized over time, and the embodied carbon emissions remain the same, the embodied carbon relative to operational carbon will increase.

3. Embodied Carbon vs Operational Carbon

There are terms available which we need to understand to ensure we all are speaking the same language. The Language of Carbon[3]. Greenhouse gases (GHG) trap heat in the atmosphere and include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (NO_2). Release of these gases occurs while burning fossil fuels or biological materials, in chemical reactions during materials production, in the transportation of fossil fuels, from agricultural activities and treatment of wastewater, among others.

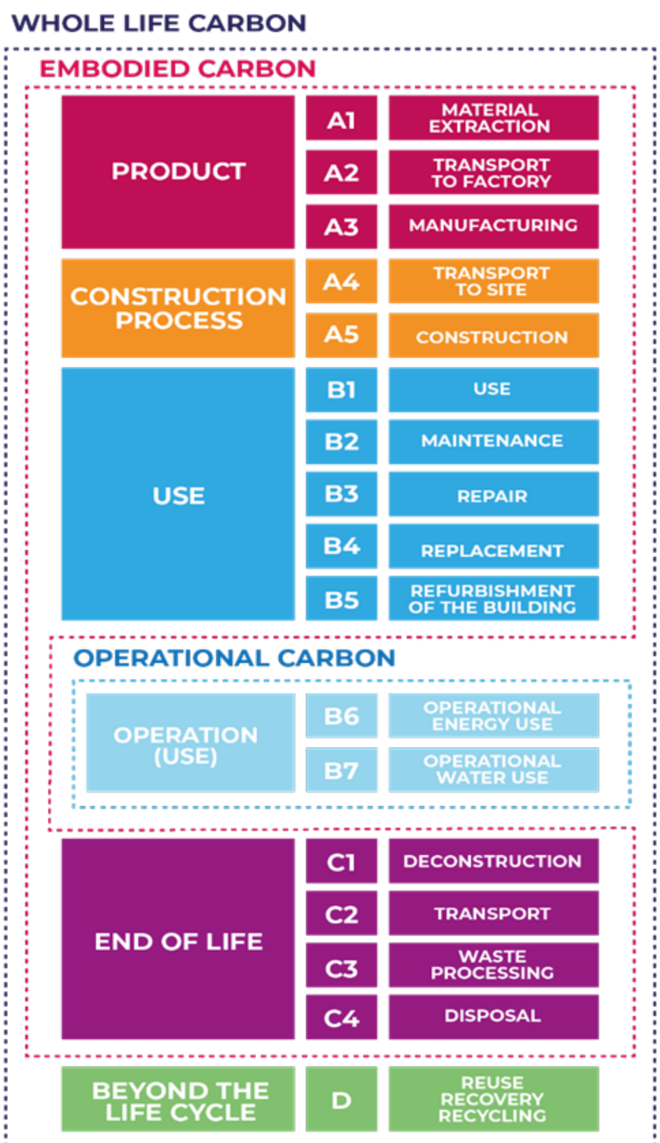
Although synthetic, fluorinated gases are also considered to be GHG and are synthetic gases which have widespread use as substitutes for ozone-depleting substances in refrigerants, as well as industrial processes such as manufacturing of aluminum and semiconductors. About 92%[4] of these gases are in the substitution of ozone-depleting substances and are often used in data center cooling systems. Although typically emitted in small quantities, they are extremely potent greenhouse gases and deemed to hold high Global Warming Potential (GWP).

GWP is a metric used to allow comparisons of the global warming impacts of different gases. A high GWP means that small atmospheric concentrations can have disproportionately large effects on global temperatures. GWP and Carbon Dioxide Equivalent (CO_2e) are used to normalize the emissions calculations.

Embodied + Operational = Whole Life Carbon

Significant efforts have been invested in data center operational efficiencies. And rightly so, because the energy use density for data centers per unit area is much higher than other types of buildings. Innovations have reduced the amount of additional energy that is required to support the critical load and can be seen by the reduction of average PUE (Power Utilization Effectiveness) over the last decade. There are also efforts underway to apply the excess heat and energy produced by the facility to offset the energy used by the critical IT load. This is termed waste heat reuse, and it is measured by ERE (Energy Reuse Effectiveness).

Investments to reduce the operational energy of the facility are recouped over time during the lifecycle of the facility. Therefore, such reductions are not accounted for until 5, 10, 30 years into the future. Embodied carbon on the other hand is mostly spent up front when the building is constructed. This is a major reason to include the embodied carbon within analyses and design decisions. Understanding embodied and operational carbon is needed to allocate and account for each appropriately.



Adapted from EN 15978:2011

Combining embodied and operational emissions to analyze the entire lifecycle of a building throughout its useful life and beyond is the Whole Life Carbon approach. This ensures that the embodied carbon (CO_2e emissions) together with embodied carbon of materials, components and construction activities are calculated and available to allow comparisons between different design and construction methods.
The terms carbon and energy are often used interchangeably but they are not the same. They follow similar paths but can have different measurements depending on several factors e.g., the source of energy and the emissions associated with the production and use of that energy. The emissions associated with energy can vary depending on geographic location and grid energy supply mix.

In the measurement of embodied carbon, Cradle is referenced as the earth or ground from which raw materials are extracted. The following provide boundaries to measure the embodied carbon and emissions of a building at different points in the construction and operating lifecycle.

- Cradle to Gate - extraction, transportation, processing, manufacturing up to the factory gate.

- Cradle to Site - adds transportation to the site for installation.

- Cradle to Use - adds installation activities.

- Cradle to Grave - adds use factors including maintenance, repair, replacements along with the end-of-life factors including deconstruction, transportation, waste processing, and disposal.

However, there is an additional boundary definition that views the holistic impact and benefit of design choices called Cradle to Cradle. Its scope considers the reuse, recovery, and recycling of the materials installed in the building, even the building itself and other activities beyond the lifecycle. Like the Energy Reuse Effectiveness (ERE) metric for operational energy, it assesses the circularity of the building and its components in terms of reuse or recycling. This is the Whole Life Carbon approach.

4. Measuring Embodied Carbon for a Whole Life Carbon Approach

The most prevalent and accepted method to calculate the environmental impacts of buildings is EN 15987:2011 Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method. This standard defines the methods to perform a Life Cycle Assessment (LCA). EN 15987:2011 is part of a suite of standards that assesses sustainability at the product component and building level. Embodied carbon is included in Scope 3 of the GHG Protocol standards and a simplified description of these is:

- Scope 1: Direct emissions from owned operations including onsite combustion and fugitive emissions of greenhouse gases
- Scope 2: Indirect emissions from owned operations including emissions produced by the providers of purchased electrical energy and water
- Scope 3: Indirect emissions from unowned upstream and downstream activities

Scope 3 is also referred to as Value-Chain emissions and could be significant depending on the breadth of operations and the lifecycle of products produced. Focusing on the data center facility, much of the Scope 3 emissions will be produced by upstream activities. These activities include the materials for construction but also include those for ongoing maintenance and replacement of the facility equipment.

Data Center Scope

A data center facility has unique aspects compared to traditional facilities. This is seen in the creation of addendums and exceptions by standards and codes organizations specifically for data centers because they do not fit into existing building types. In comparison to commercial buildings, their size and shape mimics warehouses whereas their MEP systems are similar to office buildings. However, there are significant differences. The limited number of publicly available data center case studies and reports creates challenges for owners, architects, and engineers to develop the practice of LCA.

That is not to say that performing an LCA on data center facilities is a challenge that cannot be overcome. If anything, it is a challenge that should be overcome. The knowledge and skills should be developed by the firms specializing in mission critical facilities design. The best practices and contributions should be shared. The advantage of performing a full scope LCA is the ability to identify hot spots among the sources of impact. This will allow the team to focus on the areas of most benefit for reductions. There are also advantages to performing a partial LCA on a select boundary or system. This allows the comparison of two equivalent solutions with embodied energy included in the decision matrix. The ServerFarm Whole Building Life-Cycle Analysis Report[5] illustrates the value that an LCA can bring to the design process.

Performing an LCA for a data center construction project requires data from trusted sources and an accurate model of the building to be able to calculate the embodied carbon and energy. The architectural, structural, and civil disciplines materials data will be available in generic form from a database. Multiple of these databases have been created and continue to be maintained, and appropriate selections should be made to ensure the data is accurate to the project location. Mechanical, electrical, and plumbing data will be available generically within an ICE (Inventory of Carbon and Energy) or specifically within the EPD or Environmental Product Declaration for a piece of equipment or component. LCA consultants are available and software packages have been created to streamline the assessment process.

Tools for Assessment

Performing an LCA requires an information database and methods for calculating and analyzing the results. The most widely referenced information database is the ICE database, researched and published by the University of Bath. Several academic, non-profit organizations, and government entities have also created and maintained databases. These datasets only cover the cradle to gate scope. Although no single database includes data for every geographical location, product, or situation, they are improving over time as more manufacturers and suppliers develop EPD's in the standardized format.

A few examples of available tools include BIM360 from Autodesk, which allows the integration of data from the EC3 tool developed in partnership between the Carbon Leadership Forum[6] and Building Transparency[7]. The EC3 tool is an EPD database and Building Transparency provides the Tally software to assist in the analysis and reporting of results. Other organizations with available tools are the Athena Sustainable Materials Institute[8] and EDGE[9] (Excellence in Design for Greater Efficiencies). These organizations are industry groups or academic partnerships. On the commercial side, there are companies such as OneClick LCA[10] that provide full-service support for performing LCA.

The available databases, tools, and knowledgeable resources required to accurately perform an LCA are growing, but the undertaking of performing a full LCA requires a considerable amount of time and resources.

5. Solutions

Each data center and design is unique, but research suggests that 10-20% of embodied carbon can be eliminated from construction projects with no increase in cost, and that embodied carbon accounts for 20-50% of the whole life energy and carbon of commercial buildings when operational energy is considered[11]. Although this value is far lower for data centers, embodied carbon should be considered in conjunction with operational energy and water savings benefits that may be gained by design choices.

Less is more

Reducing embodied carbon in MEP disciplines can be accomplished by reducing the equipment and materials in the systems. Maximizing utilization of equipment and reducing complexity achieve the reduction in building area required and weight of the equipment, in turn the embodied carbon required.

Increase density

Supporting an increased power density in the IT environment contributes to performing the same amount of “work” in a smaller area. The reduction in floor area required as well as the amount of IT equipment required affects the overall impact.

Life cycle assessment

Performing a lifecycle assessment on the data center design provides the opportunity to compare alternate design choices and allow for more informed decisions to be made. Choosing the design with the lowest carbon impact and shortest carbon payback period requires this measurement and analysis.

Material substitution

Including sustainability and embodied carbon reduction options in specifications directs designers and contractors to select materials with positive impacts. Recycled content and material substitution should be specified for reduced embodied carbon while achieving design requirements.

Equipment selection

Equipment manufacturers play a role in achieving sustainability goals. Selecting manufacturers with developed EPD allow for the LCA to be performed effectively. Product lifecycle and service life play a key role in the longevity of the subsystems. End of life activities including recyclability can have a positive or negative impact on the viability of the equipment.

Building reuse/retrofit

Reusing existing structures, commercial buildings, and warehouses to retrofit and reuse to meet new data center requirements or upgrading legacy data centers provides a significant reduction in overall embodied carbon. Designing data center buildings that may be used for other purposes in the future also contributes to the reduced future impacts. The Preservation Leadership Forum sums up the advantages here, "when comparing buildings of equivalent size and function, building reuse almost always offers environmental savings over demolition and new construction." [12]

6. Conclusion

Performing deliberate analysis and making design decisions using the Whole Life Carbon approach, considering both Embodied Carbon/Energy and Operational Carbon/Energy, provides the opportunity to contribute positively to the global goal to reduce greenhouse gas emissions. The opportune time to create this positive impact and reduce the embodied carbon emissions occurs during planning, design, and procurement or in other words, now.

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About Author

Brevan Reyher, EIT is an Electrical Engineer and Consultant at EYP Mission Critical Facilities.

Brevan's experience starts in 2007 with the development of standard and maintenance operating procedures, raised floor area design, analysis of electrical usage data and equipment operating parameters.

Brevan's experience also includes serving as the lead project engineer designing and implementing multiple data center infrastructure buildouts in different territories, including in Ashburn, Chicago, Dallas, London, Sydney, Hong Kong and Frankfurt. His work during the design phase included focusing on the customer's requirements gathering and design integration into development of specifications and documentation.

Brevan has advised and mentored operations personnel in development and implementation of preventive maintenance programs on mission-critical data center systems and technical change management efforts to mitigate risk and business impact during construction and maintenance operations.

He holds a Bachelor of Science degree in electrical engineering, and a Bachelor of Arts in Business Administration from Trinity University.

He is a team member of the recently launched EYP Mission Critical Facilities and I3 Solutions Group Sustainability Initiative to offer a practical roadmap towards a Carbon Net-Zero data center by 2030.

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