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Impact of Technology Network Design on Building Sustainability: How a Fiber to the Edge network can reduce carbon footprint.

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Abstract

The building sector accounts for nearly 39% of annual greenhouse gas emissions globally, with 28% resulting from building operations (operational carbon or resultant emissions from energy and fuel consumption) and 11% from building materials and construction — this is typically referred to as embodied carbon. Although focusing on operational carbon has resulted in technological efficiency advances and environmental policies, it only represents a part of the net-zero solution; the missing piece being the embodied carbon associated with raw material extraction, manufacturing, delivery, construction methods, as well as end-of-life disposal or recycling of building infrastructure. As more companies adopt an Environmental, Social, and Governance (ESG) framework, beginning to explore the impact of embodied carbon in their real-estate investments will be an important component of achieving their net-zero goals. Life Cycle Assessment (LCA) is used by designers, architects, manufacturers, and consultants for various purposes, including ESG risk evaluations. However, for those in the construction industry, its use has been adopted to include the entire building footprint, leading to a Whole-Building Life Cycle Assessment (WBLCA) methodology.

This white paper analyzes and discloses the estimated operational and embodied carbon impacts of integrating a building-wide, fiber to the edge (FTTE) network at the Corning Optical Communications (COC) headquarters by conducting a WBLCA. This retroactive appraisal attempts to promote decarbonization in early building design — especially when considering data network infrastructure — for strategic planning and even policymaking in reducing carbon emissions while responding to and complying with an organization's ESG strategy. The environmental advantage of integrating Corning's developed composite cable solution and FTTE network design presents itself as a lower-carbon, climate-resilient development solution in building design, amounting to a 6.8% reduction in whole-building life cycle carbon over a 30-year life.

- Buildings represent 39% of annual greenhouse gas emissions globally, 28% from operational carbon and 11% from building materials and construction or embodied carbon.
- Energy efficiency advances and environmental policies continue to improve operational carbon
- Reduction in embodied carbon must be designed into the building infrastructure to have meaningful impact. This includes network infrastructure that supports the ever-increasing technologies being deployed in buildings
- Fiber to the edge creates future-ready networks with virtually unlimited bandwidth and ultra-high reliability, requiring less materials, space and energy than traditional copper-based networks
- Fiber to the edge networks can also significantly reduce the whole-building life cycle carbon of a building

Introduction

The Global Status Report 2017 reconfirms the influence that building operations, building materials, and construction can have on annual global emissions. Nearly 39% of global carbon dioxide emissions come from buildings, 28% associated with operations typically referred to as operational carbon, while building materials and construction, typically referred to as embodied carbon, are responsible for an additional 11% annually. Furthermore, the global floor area of new construction is expected to double by 2060. The smart building market, a driving factor in this exponential growth, will require a future-ready backbone to leverage Internet of Things (IoT) advancements to efficiently manage assets, resources, and services. This will lend itself to reduced energy consumption and improvements to the overall occupant experience. A future-limiting factor of IoT technology within smart buildings will be bandwidth, especially when increased network agility will be needed to support integrated artificial intelligence (AI).

A building-wide FTTE network provides a future-ready state that supports over 1,000 times more bandwidth than copper, with the added benefit of lower operational and embodied carbon (measured as Global Warming Potential in CO^2e). According to The Autorité de Régulation des Communications Électroniques (ARCEP), a French communications regulator, an optical fiber network uses 3.6 times less energy than a copper one. Providing high-throughput connectivity within a building has a direct influence on operational carbon and is expected to increase within the smart building market.

While choosing to opt for a building-wide FTTE network is clearly beneficial for minimizing operational environmental impacts, the life cycle of cabling infrastructure in terms of embodied carbon, including "rip-and-replace" upgrades, has yet to be disclosed. Therefore, as more high-performance smart buildings look to make more informed material procurement choices, the building's infrastructure, specifically telecommunication/data communication systems, should not be overlooked as an opportunity to further decarbonize the building's total carbon footprint. Fiber will be a primary technology that will enable the decarbonization of smart buildings.

This white paper explores the embodied and operational carbon impact of integrating a building-wide FTTE network at the new COC headquarters in an attempt to promote decarbonization in early building design for strategic planning and even policymaking in reducing carbon emissions responding and complying to an organization's ESG strategy.

> "I believe that a low carbon future is forged by integrative architecture and engineering and our purpose is to reimagine the built environment as an opportunity to be regenerative and adaptive for a more sustainable tomorrow."
>
> Dr Tommy Zakrzewski, HKS Architects

Current Industry Trends. The current trajectory of greenhouse gas emissions from buildings is not aligned with global climate targets and policies, especially considering that global floor area of new construction is expected to double by 2060. Because of this, reducing embodied carbon and benchmarking using best practices are urgent and critical trends in the architectural, engineering, and construction industries. As more companies adopt an ESG framework — a systematic approach for identifying, assessing, and integrating the economic, environmental, and social impacts of a business on society as well as the environment — realizing the impact of embodied carbon in their real estate investments will be an important component of achieving their net-zero goals. Embodied carbon emissions are associated with construction and infrastructure, impacting our atmosphere from the time the raw materials are extracted up to Day 1 of a building's operational life. Therefore, the acceleration and adoption of low-embodied-carbon construction will impact financial budgets and increasingly become a focus in design in order to identify and reduce risks that negatively impact ESG performance.

Study Methodology

For 171 years, Corning has applied its unparalleled expertise in glass science, ceramic science, and optical physics to develop products and processes that have transformed industries and enhanced people's lives. Recognizing the strive to be a catalyst for positive change to help the world better is a fundamental aspiration for a company paving the way for its next 171 years of success.

When COC decided to build a new, state-of-the-art headquarters in Charlotte, NC (Corning HQ), they knew a future-ready network would be at the heart ofits construction. A retrospective study has since been completed to holistically assess the impact of FTTE concerning the whole-life carbon emissions of this new headquarters.

While a standard LCA comprehensively evaluates the sustainability of products and processes, a WBLCA is a methodology used to assess the environmental impact of a building's entire footprint through its whole life cycle. Often the LCA/WBLCA helps to optimize the selection of environmentally preferable materials and products throughout the design, engineering, and construction process. An ancillary benefit of performing a WBLCA is that it can contribute to the overall LEED certification of a new construction building. WBLCA benchmarking can achieve points for Building Life Cycle Impact Reduction credits under the LEED v4.1 pilot Materials and Resources credit category. Thus, to benchmark the environmental impact of the new Corning HQ, the operational and embodied carbon needed to be quantified.

Quantifying Operational Carbon. Corning used the EPA's ENERGY STAR® Portfolio Manager, an online tool that organizations can use to track and measure energy consumption, water consumption, and GHG emissions, to benchmark the performance of their new headquarters. Operational utility data for the building, including electricity and natural gas, was obtained to generate an annual energy and fuel use profile for the building as it was operated in 2021 (January–December). This data was then benchmarked and assessed using the ENERGY STAR® Portfolio Manager to best understand the operational carbon associated with the historical energy and fuel use data. The building showed consistent energy and fuel utilization over a three-year period. Based on 2021 operational data, the operational carbon of the new headquarters resulted in a Global Warming Potential (GWP) of 959.8 MT-CO^2e.

Quantifying Embodied Carbon. While the ENERGY STAR® Portfolio Manager was able to calculate the building's operational carbon, the remaining life cycle stages of the building, as defined by European standard EN 15978, remained unknown. The embodied carbon of a building is the estimated CO^2e emitted when a building is made and encompasses the extraction of raw material, the manufacturing and refinement of materials, transport, the construction of the product or structure, and the end-of-life deconstruction and disposal of the materials. Tally, an Autodesk Revit plug-in, was used to estimate the embodied carbon of the Corning HQ. The WBLCA within Tally combines environmental impact data with material attributes, assembly details, and specification information translated from the building information model (BIM).

Tools for reporting product-specific life cycle assessment studies include Environmental Product Declarations (EPDs) and material ingredient reporting tools such as a Health Product Declaration. The architecture, engineering, and construction (AEC) industry currently lacks a comprehensive database of materials for embodied carbon analysis specifically associated with MEP systems and data infrastructure. While standards such as CIBSE TM65 Embodied Carbon in Building Services can be used to estimate the embodied carbon of HVAC systems, nothing has been benchmarked for data network infrastructure to date.

Results from Tally considered the contribution of each cycle stage — product stage (A1-A3), construction stage (A4-A5), use stage (B2-B6), end-of-life stage (C1-C4), and benefits and loads beyond the system boundaries (D) — within a 60-year lifetime for architecture, structure, and interiors scope. The new building's construction documents resulted in a GWP of 8,539 MT-CO^2e (excluding cabling infrastructure).

Network Life Cycle Assessment. As part of Corning's commitment to environmental stewardship, COC executed the work to develop LCAs to quantify the environmental impact of several optical fiber network products, including composite fiber-optic cabling. The LCA study and the corresponding report are referenced throughout this white paper alongside Corning's interpretation of the results and relevant material from this study.

FTTE networks leverage a composite fiber-optic cable contains fiber and copper conductors within the same cable jacket and can deliver data and power to the very edge of a network. A key difference between FTTE and legacy LAN deployments is that legacy LAN copper-based networks are limited in bandwidth and distance. Future-ready fiber-optic cabling networks reduce space, provide extended reach, and eliminate the need for future "rip-and-replace" cycles. Table 1 illustrates a few key items about how each network would have been deployed at Corning HQ.

Corning HQ case study	Length of cable required	Width of cable tray required	Length of cable tray required	Rip & replace cycles over 30-yrs
Legacy LAN Copper-based Cabling Network	77,075 meters	24 inches	1,020 meters	3
Fiber Optic Composite Cabling Network	25,000 meters	12 inches	1,020 meters	0

Table 1: Network architecture differences included as part of the LCA analysis

To understand the environmental impact of this composite cable compared to traditional copper cabling, a CAT 6_A UTP plenum cable and corresponding, publicly available EPD was used (EPD CommScope, 2021). CAT 6_A UTP plenum cabling is rated to be laid in the plenum space of buildings and often uses thicker copper conductors and jackets with speeds of at least 500 MHz, allowing 10 Gbp/s (Gigabits per second) up to 328 feet (100 meters). The evaluations provided by Corning and public EPDs both followed the principles of conducting an LCA according to ISO 14040/14044. Corning's LCA study was conducted by Sphera Solutions, Inc. in collaboration with COC, and used Sphera LCA Modeling principles (Sphera GmbH, 2021b) with a Cradle-to-Gate system boundary.

The results, data, methods, assumptions, and limitations have been documented in accordance with the ISO requirements in a peer-reviewed LCA report prepared by Sphera (Diaz, et al., 2022). While multiple impact categories were part of this LCA, the impact category reported here is GWP, or embodied carbon due to its relevance to climate change. GWP was also the focus when using the public EPDs for CAT 6_A UTP Plenum cable.

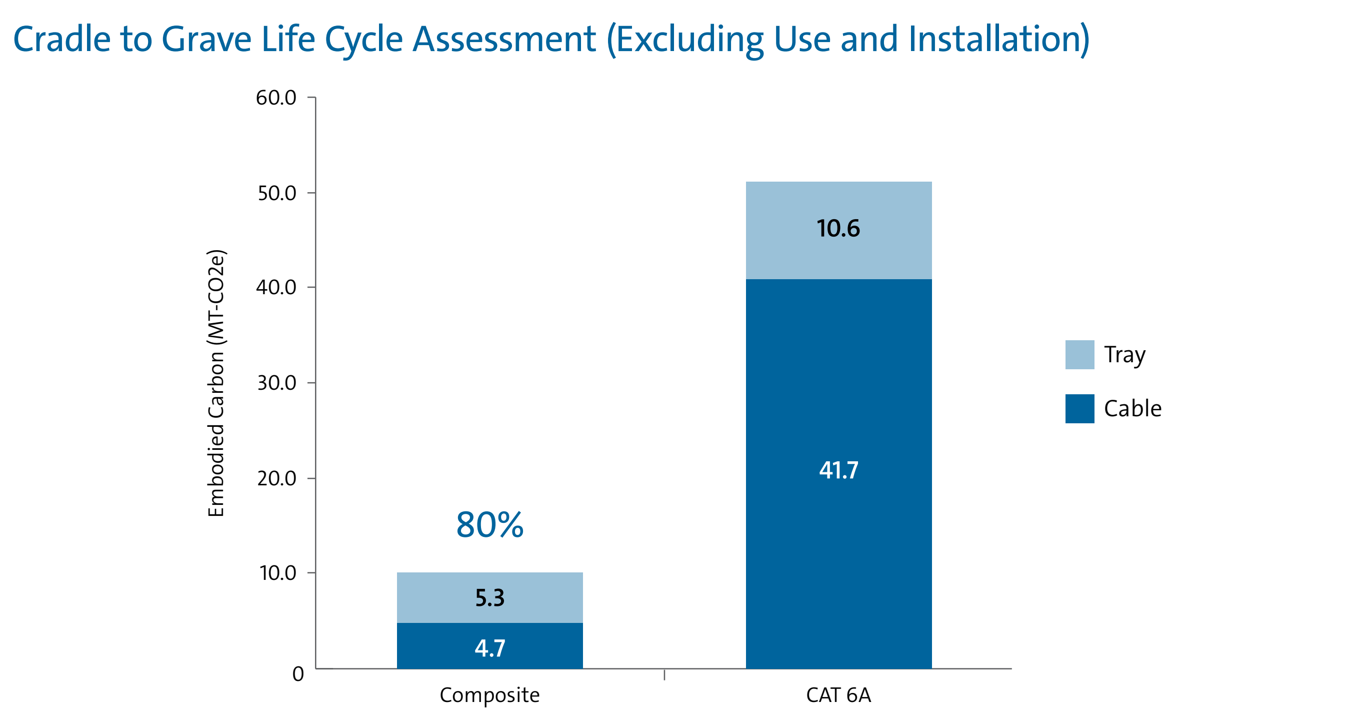

Figure 1: Legacy LAN copper-based cabling network and fiber optic composite cabling network based on Table 1

Corning HQ (Composite) Embodied Carbon

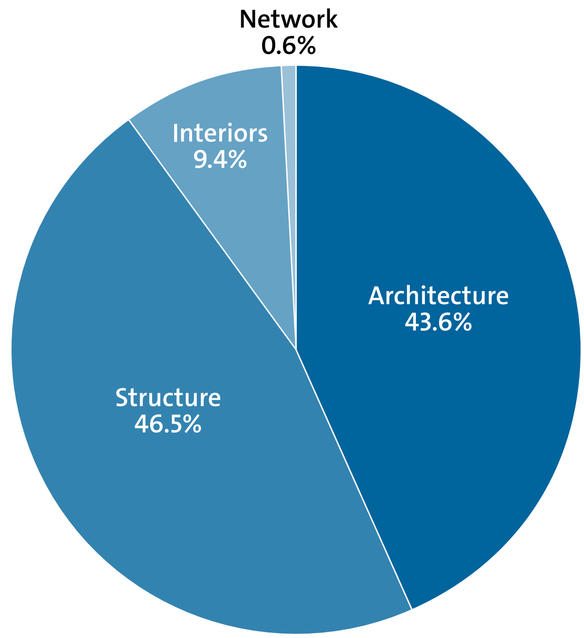

Figure 2: Corning HQ (Composite) Embodied Carbon Distribution

The differences in Table 1 were analyzed to highlight their impact to GWP using Corning's LCA study and public EPDs for cables and cable trays (EPD OBO Bettermann, 2019). The results of the composite (4.7 MT-CO^{2}e) and CAT 6A Plenum cabling comparison (41.7 MT-CO^{2}e), indicated that the embodied carbon was reduced by more than 88%, and with cable trays, by 80% (10.0 MT-CO^{2}e and 52.2 MT-CO^{2}e respectively).

As previously mentioned, using an FTTE network eliminates the need for separate cabling, which reduces the total amount of cable in the building. Furthermore, it reduces the amount of duct and tray space required to house that cabling. From a materials perspective, using a composite (hybrid fiber and power) cable in a zone architecture reduces the linear meters of cable by up to 70%. For a 16,723m^2 building, this equates to 77,075 meters of linear cable. In addition to using less cable, FTTE networks require 40% less rack space and significantly fewer IDF closets, further reducing embodied carbon (although this is not accounted for in this white paper). From an operational perspective, FTTE networks also reduce the energy required for HVAC dramatically, with significantly less power needed to run and cool network electronics. For the Corning HQ, the energy savings delivered were estimated at more than 68,000 kWh per year (accounted for in WBLCA). These savings have a direct financial impact on the bottom line, with a simple payback in three years and a 153% return on investment. In addition to operational savings, the FTTE network was 29% less expensive to install than a legacy copper network.

Whole-Building Life Cycle Analysis. Combining the results from Tally, the total embodied carbon of the Corning HQ with the FTTE network design amounts to more than 8,549 MT-CO^{2}e, with the network cabling and trays considered in the COC study contributing 0.6% to the embodied carbon of the building (Architecture 43.6%, Structure 46.5%, Interiors 9.4%, Network 0.6%). The FTTE network design using composite cabling (8,549 MT-CO^{2}e) compared to CAT 6A Plenum cabling (8,591 MT-CO^{2}e), demonstrates a 0.5% reduction in GWP.

To calculate the WBLCA of the Corning HQ, the one remaining operational carbon component to consider was the energy consumption and demand from six IDFs for the CAT 6A Plenum cabling infrastructure to one main MDF for composite cabling infrastructure. A building energy model (BEM) for the two cabling infrastructure designs was used to estimate energy savings. The Trane TRACE® 700 output demonstrated that the CAT 6A Plenum cabling infrastructure could have increased the operational carbon of the Corning HQ building by more than 84.9 MT-CO^{2}e, a greater than 8% increase from the current FTTE building design.

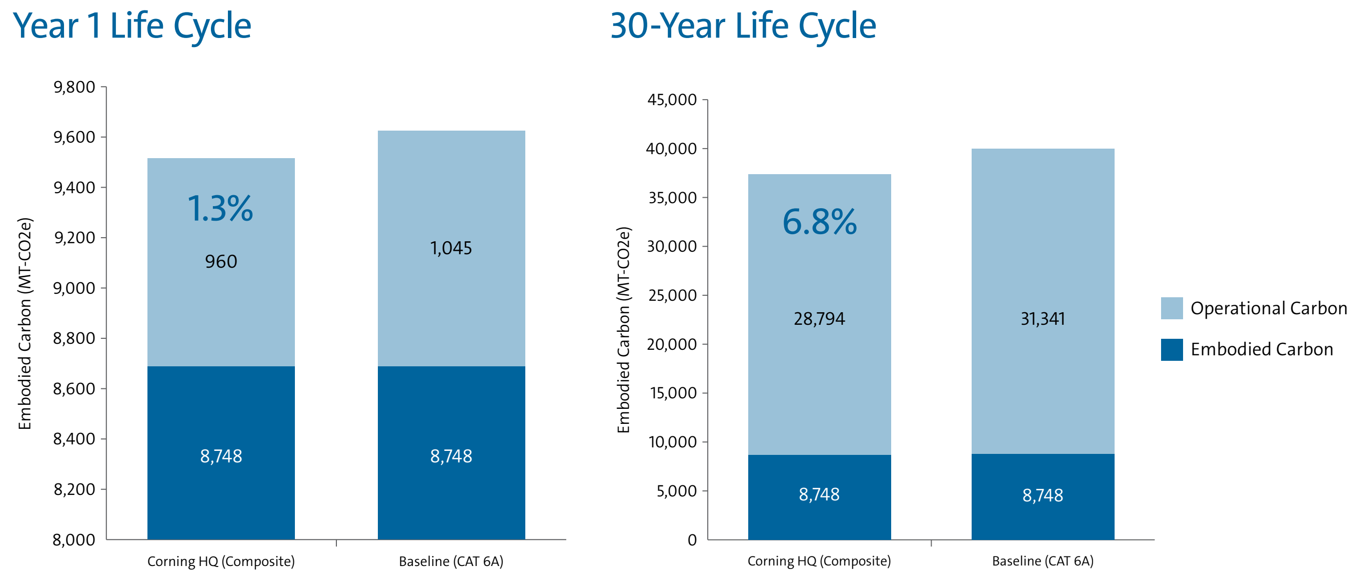

Figure 3: Corning HQ (Composite) and Baseline (CAT 6A) Whole-Building Life Cycle Analysis Comparison

Combining the tabulated results from Tally, the COC LCA study and publicly available EPDs, the ENERGY STAR® Portfolio Manager operational data, and the Trane TRACE® 700 output for the FTTE network design using composite cabling in comparison to CAT 6A UTP Plenum cabling total carbon (Year 1) amounts to 9,509 MT-CO^{2}e for the FTTE network design (960 MT-CO^{2}e operational, 8,549 MT-CO^{2}e embodied) and 9,636 MT-CO^{2}e for the CAT 6A UTP Plenum cabling design (1,045 MT-CO^{2}e operational, 8,591MT-CO^{2}e embodied); yielding a 1.3% reduction. Looking forward, the use of CAT 6A UTP Plenum cabling would require a cable "rip-and-replace" or addition to keep up with technology refresh cycles three times over a 30-year period, which would then increase the WBLCA to 37,343 MT-CO^{2}e for the FTTE network design (28,794 MT-CO^{2}e operational, 8,549 MT-CO^{2}e embodied) and 40,089 MT-CO^{2}e for the CAT 6A UTP Plenum cabling design (31,341 MT-CO^{2}e operational, 8,74 8 MT-CO^{2}e embodied); a 6.8% reduction.

Conclusion

This white paper analyzes and discloses the estimated operational and embodied carbon impacts of integrating a building-wide FTTE network at the Corning HQ by conducting a WBLCA. This retroactive appraisal attempts to promote decarbonization in early building design, especially when considering data network infrastructure, for strategic planning and even policymaking in reducing carbon emissions.

To conduct this analysis, the EPA's ENERGY STAR® Portfolio Manager was used to estimate and quantify the operational carbon associated with measured energy and fuel use data, while Tally was used to estimate the embodied carbon of constructing the Corning HQ. Furthermore, a material and product level LCA was conducted by Sphera in collaboration with COC to understand the environmental impacts of composite cabling.

The combined tabulated results amounted to a 1.3% reduction in whole-building life cycle carbon (Day 1 impact). In anticipation of future network and bandwidth growth, it was estimated that the use of CAT 6A Plenum cabling would require a cable "rip-and-replace" to keep up with technology refresh cycles three times over a 30-year period, which would then increase the operational and embodied carbon of the building, resulting in a 6.8% reduction in whole-building life cycle carbon (over 30 years) when using an FTTE network. Isolating the embodied carbon impact of the FTTE network design using composite compared to CAT 6A Plenum cabling demonstrated a 0.5% reduction in GWP. This could contribute to the overall LEED certification of a new construction building because the WBLCA benchmarking can achieve points for Building Life Cycle Impact Reduction credits under the LEED v4.1 pilot Materials and Resources credit category.

FTTE helps create future-ready networks that will last the lifetime of the building with virtually unlimited bandwidth and ultra-high reliability. This eliminates the endless rip-and-replace network refreshes that are prevalent today — reducing the future total cost of ownership and LCA of the building and positioning the building for generations of future technological advances. The WBLCA provided herein can begin to help define the environmental goals of a project and could help to make decisions regarding the building data network infrastructure in support of ESG. While this white paper focuses on a single building's impact, it also provides a reliable picture of material and building environmental impacts using science-based standardized metrics such as GWP. Using Corning's composite cable solution and FTTE network design presents itself as a lower-carbon, climate-resilient development solution in building design.

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- Environmental Product Declaration: CommScope Cat 6A Plenum Data Networking Cable, EPD 278
- Environmental Product Declaration: OBO Bettermann Produktion, EPD-CRS-BS-17.0
- LCA report prepared by Sphera (Diaz, et al., 2022).
- Trane Trace® 700 output on Corning HQ, 2019
- EPA's ENERGY STAR® Portfolio Manager
- Tally, an Autodesk Revit plug-in

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