How to Futureproof your Business: Achieve Carbon Neutrality with BIM

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About the author

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A prolific author, Aarni has penned several business books and contributed articles to various esteemed technology and business publications. He has an award-winning blog and podcast at AEC-Business.com. In this book on carbon footprint management with BIM, Aarni continues his mission to make the construction industry more efficient, sustainable, and communicative.

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Contents

INTRODUCTION

How to Achieve Carbon Neutrality with BIM

We're witnessing history's most significant building boom from 2020 to 2060. We'll add about 240 billion square meters of new buildings worldwide. That's like building a new city as big as New York every month for 40 years. We also have existing buildings that need repair and care for decades. How can we both build and keep our planet habitable for future generations?

As construction sector professionals, we are responsible and able to make a massive impact on our environment's future. Fortunately, we have the technologies and skills to meet the challenge. In addition, we need commitment and knowledge to transform into an environmentally friendly construction.

This guidebook offers ideas and practical advice on future-proofing our built environment and business with building information modeling and the latest environmental information. We'll focus on the carbon footprint, specifically embodied carbon, of buildings.

The book has four chapters

1. Why managing carbon footprint is a necessity

The first chapter examines why the construction industry must incorporate sustainability in its strategies and operations.

2. How BIM enables carbon emission management

In the second chapter, we focus on how building information modeling is essential in managing the embodied carbon of our projects.

3. Implement BIM-based emissions management

The third chapter offers practical advice on the methods and tools for implementing carbon management with BIM.

4. Future trends and opportunities

The fourth chapter outlines opportunities and trends from which your company can benefit.

This guide will assist you in transitioning toward the modern approach to handling the carbon footprints of buildings.

CHAPTER 1

Why managing carbon footprint is a necessity

The following chapter examines why the construction industry must incorporate sustainability in its strategies and operations.

Sustainability can no longer be an afterthought or mere lip-service. Every architecture, engineering, and construction (AEC) company must incorporate sustainability in its strategy and operations. This section examines what drives the industry toward environmentally sound construction and how it will change your company's future.

Thanks to general climate change worries, the ESG ambitions of companies, and new regulations, sustainability is becoming everybody's business.

Sustainability is a broad and multifaceted concept. It involves meeting our present needs without compromising the ability of future generations to meet their own needs.

In its essence, environmental sustainability is about keeping our planet habitable. It relates to preserving natural resources and ecosystems, minimizing waste and emissions, and mitigating the impact of our activities on the environment. It involves promoting biodiversity, reducing greenhouse gas (GHG) emissions, shifting towards renewable energy sources, and implementing circular principles.

In the following, we'll focus on improving environmental sustainability in the AEC sector by reducing the industry's currently high greenhouse gas emissions.

Types of greenhouse gas emissions

When discussing a building's carbon emissions, there are a few concepts that should be known.

The greenhouse gases generated throughout the life span of a product, building, or infrastructure project can generally be classified into two categories: operational emissions and embodied emissions.

Operational carbon emissions are those generated during the utilization phase of a building. These emissions originate from all the energy sources required for a building's heating, cooling, ventilation, lighting, and other electrical needs.

On the other hand, **embodied carbon emissions** are associated with the materials and products that compose a building, and they can be produced at any stage throughout a building's life cycle.

Emissions generated during a product's manufacturing, transportation, and installation phases before its actual use are **upfront embodied** carbon emissions.

Furthermore, **whole-of-life embodied carbon** encompasses the emissions generated during these initial phases and those produced during the maintenance and decommissioning stages of a building or an infrastructure project.

In the following, we'll focus on the embodied carbon of buildings.

Construction's environmental impact

The built environment is one of the world's largest economic ecosystems. It also considerably impacts the environment, releasing more greenhouse gasses than the transportation or industrial sectors. Consequently, it has a special responsibility and opportunity to decarbonize its processes and products.

The global impact

Let's first look at the size of the opportunity.

These figures illustrate the built environment's emissions on a global level (McKinsey, 2023):

> It accounts for 14.4 metric gigatons, or 26%, of greenhouse gas emissions annually. Its share of CO_2 emissions from fuel consumption is even higher, up to 37%.

> Of the 14.4 gigatons, approximately two-thirds are operational (for example, daily electricity consumption) and one-third are embodied (related to the materials used to build the structures).

If we look in more detail at a typical building stock in the Nordic climate, we obtain this greenhouse gas distribution (Climate 2035 project, 2021):

- Energy consumption of buildings: 76 %
- Construction materials: 15 %
- Logistics and jobsite functions: 7 %
- Deconstruction and waste: 2 %

The environmental impacts of the built environment go beyond GHG emissions. They include material and resource use, waste generation, impact on water systems, habitat harm, biodiversity loss, soil health, and more.

Zooming in on a single building

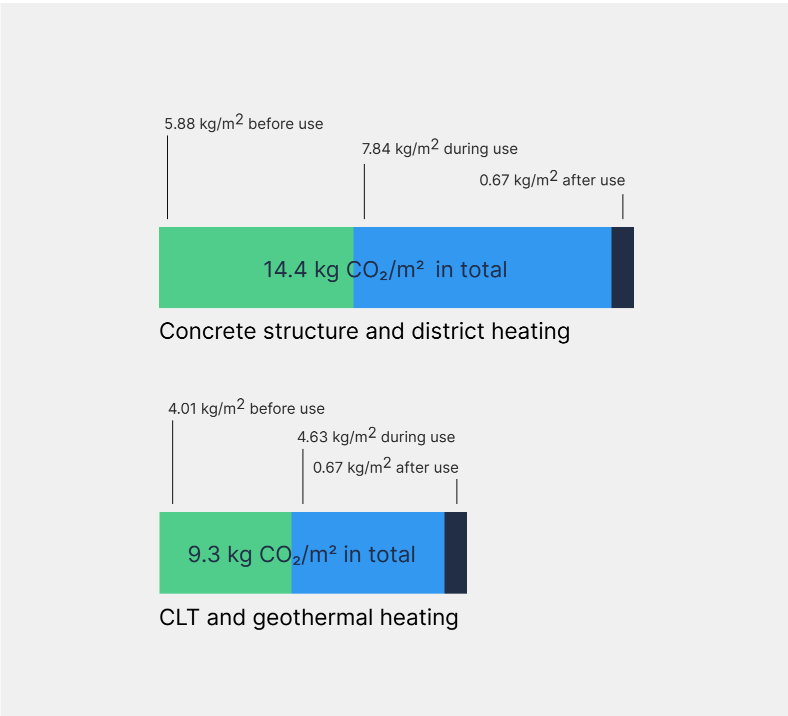
What do these high-level numbers mean from the perspective of an individual building?

For example, a typical Finnish multifamily house using district heating has a carbon footprint of 14.4 kilograms per square meter over its 50-year life cycle. Of the CO_2 emissions, 5.88 kilograms (40.9%) are embodied, 7.84 are generated during use, and 0.67 after use. The embodied carbon figure represents the sum of material production, logistics, and construction emissions until the handover.

If the developer and designers decided to use CLT (cross-laminated timber) instead of concrete and replace district heating with geothermal energy, the numbers would change dramatically. The footprint would decrease to 9.3 kg/sqm and embodied carbon to 4 kilograms.

50-Year Carbon Footprint Of A Finnish Multifamily House

Source: Rakennusteollisuus RT & Vesitaito: Rakennusten hiilijalanjälkitarkastelut, 2020



This example shows how project decisions have a considerable impact on the environmental burden of buildings.

Considering the various average numbers, we must remember that every project is unique, and several parameters affect the outcome. Luckily, we now have technologies and tools to evaluate and compare various scenarios and verify the results.

Customer requirements

An industry's environmental commitments, behavior, and attitudes are driven by the customers. The real estate and construction industries have a wide variety of customers with varying levels of environmental awareness.

Only a few years ago, "green building" was an exception; now, every new building project tries to achieve some level of greenness.

Knowing your customers' sustainability-related values, goals, and requirements is critical. Let's look at the trends among the major client groups.

Commercial clients increasingly adopt green building practices due to energy savings, improved public image, and potential regulatory requirements. They might pursue certification systems like LEED, WELL, or BREEAM to demonstrate their commitment to sustainability. They also focus on implementing energy-efficient systems, renewable energy sources, and sustainable materials.

Residential developers consider environmental sustainability in their construction projects, ranging from regulatory requirements and potential cost savings to growing demand for green homes. Private **residential clients** seek sustainably designed homes, such as appliances, solar panels, and non-toxic and sustainable building materials.

Governments often lead the way in sustainable construction due to policy commitments towards climate change. They may mandate the use of sustainable practices for public buildings and infrastructures and seek to exceed the minimum requirements of environmental regulations. They may also set an example by integrating renewable energy, water and waste management systems, and nature-based solutions into their projects.

Sustainability is becoming increasingly important in the **hospitality sector,** with many hotels and restaurants aiming to reduce their environmental footprint. Clients may request energy and water-efficient designs, waste reduction measures, local and sustainable materials integration, and more. In addition, some resorts are working to protect and enhance the local ecosystems where they operate.

Educational institutions often seek to incorporate sustainability into their campuses to reflect their commitment to environmental education and stewardship. This may involve energy-efficient buildings, renewable energy installations, green roofs, outdoor classrooms, and more.

Sustainable design in **healthcare** can provide both environmental benefits and improve patient outcomes.

Healthcare clients may seek buildings that minimize energy use, improve indoor air quality, use non-toxic materials, and provide access to natural light and views. In addition, some healthcare facilities are also working to reduce waste and improve their water efficiency.

Though traditionally less focused on sustainability, **industrial clients** increasingly recognize the cost savings and regulatory advantages of green building practices. They might focus on energy efficiency, waste reduction, water management, and sustainable materials. Some also consider circular economy principles in order to rethink how they design and operate their facilities.

Investors and developers

Many forward-looking investors and developers have also committed to sustainability. They openly pledge their ambitious goals.

Those who commit to zero-carbon construction look for AEC firms that can fulfill the client's pledge. If your company is among them, you can gain a competitive advantage and a lead in the inevitable future.

One pledge of a real estate developer

Let Nrep, a sustainability-oriented developer, serve as an example of client requirements that eventually translate into requirements for their AEC suppliers (Nrep, 2023). Nrep states the following:

By the end of 2023

- They are reducing upfront greenhouse gas emissions (GHG) by up to 30% from 2020 levels on their new developments.
- They are reducing at least 50% of operational carbon emissions from 2020 levels. The pledge covers the total energy consumption in standing real estate assets.
- All new developments will hold a leading sustainability certification label
- 100% CO_2 documentation will be in place

By the end of 2025

- The development of three ‘earth shot‘ innovation projects will be completed, piloting of decarbonization solutions to reduce carbon footprint as much as possible — They are searching for solutions to reduce both operational and embodied carbon.

From 2028 forward

- Net zero portfolio, including both operational and embodied carbon

Certifications

There are several universal and national “green building” certifications. Building developers and owners pursue environmental certifications for a variety of reasons.

Some of the most prominent include

- LEED (Leadership in Energy and Environmental Design)
- BREEAM (Building Research Establishment Environmental Assessment Method)
- DGNB (Germany)
- HQE (France)
- Miljöbyggnad (Sweden)
- Green Globes (USA and Canada)
- RTS and Swan Mark (Finland)

Achieving a LEED or BREEAM certification provides a clear, recognized way to demonstrate a company’s commitment to sustainability. Environmental credentials can help a property stand out in the real estate market.

Many potential tenants or buyers are willing to pay a premium for green buildings due to the associated cost savings, healthier living conditions, and the satisfaction of living or working in a sustainable environment.

Although certifications are voluntary, future-proofing the asset against potential future legislation related to climate change or building efficiency can be another motivation.

Pre-design decisions

The construction industry is project-centered. Clients typically place projects out to tender, and designers and contractors submit their proposals. Even in cases where the client hand-picks the project partners, they have already made many choices affecting the project's environmental impact.

Pyry Haahtela, COO at Haahtela TVD, claims that 80% of decisions impacting a project's carbon footprint happen before the design starts (AEC Business, 2023). He bases his argument on the simulations of hundreds of construction projects.

Since most of the construction's carbon footprint comes from building materials, the size, form, and material choices determine much of the emissions. According to Haahtela, designers and contractors can still use low-carbon concrete, for example, to affect emissions within the 20% leeway they have.

From the building life cycle point of view, the choice of the building's energy source has a substantial environmental bearing. **Mika Kovanen**, Leading Advisor at Ramboll, says that the increased intelligence of facilities and the use of renewable energy gradually decrease the energy-related CO_2 emissions of buildings. This phenomenon, in turn, further increases the portion of the embodied emissions of MEP systems.

> "The increased intelligence of facilities and the use of renewable energy gradually decrease the energy-related CO_2 emissions of buildings"
>
> Mika Kovanen – Leading Advisor at Ramboll

ESG

A few AEC companies and many more prominent clients share their sustainability goals by using the ESG framework.

ESG stands for Environmental, Social, and Governance. It's a set of financial and investment criteria to evaluate a company's sustainability and ethical impact. These criteria allow investors to consider non-financial factors when making investment decisions alongside traditional financial metrics.

The **environment** criterion refers to how a company's operations impact the natural environment. It might include the company's energy use, waste management, greenhouse gas emissions, deforestation, water stewardship, and its strategies to mitigate climate change impact or adapt to its effects.

The EU's new CSRD, Corporate Sustainability Reporting Directive, establishes rules for ESG reporting (*The European Commission, 2023*). If two of these conditions are true, companies must give out an annual ESG report: they have over 250 employees, a turnover of more than EUR 40 million, or a net property of over EUR 20 million. The report must follow the EU-wide classification, the Taxonomy.

ESG criteria are increasingly crucial to investors, who recognize that companies with strong ESG performance may be better positioned for long-term success and may pose a lower financial risk. It also reflects a growing interest in ethical and sustainable investing, where the goal is to generate a financial return and contribute to a positive societal impact.

Regulation

Regulation has proven to be a powerful change accelerator in the construction sector. Regarding environmental issues, there are regulations on the global, EU, and national levels.

Climate Regulation

Global regulation

The Paris Agreement represents a critical international commitment to combating climate change. One hundred and ninety-six parties have agreed to this legally binding agreement, effective November 4, 2016 (United Nations, 2023).

The agreement aims to keep the rise in average global temperatures below 2.0°C when compared to pre-industrial levels and limit this increase even further to 1.5°C. This emphasis on the 1.5°C limit has become even more crucial recently.

Achieving the 1.5°C limit will require drastic measures, including the peaking of greenhouse gas emissions before 2025 at the latest and achieving a 43% reduction by 2030. This means there's a specific carbon budget we can spend before surpassing the target.

Paris Agreement's impacts on EU construction

The EU has been at the forefront of implementing the Paris Agreement, which means that construction companies can expect more stringent regulations around energy efficiency, emissions, and sustainable materials. Here's what to expect:

- **Transition to Net-Zero Emissions:** This will require a significant shift in how buildings are designed, constructed, and operated.
- **Demand for Green Buildings:** As awareness of climate change grows, so does the need for green buildings.
- **Innovation and New Opportunities:** The agreement's ambitious goals may spur innovation in the construction industry. This could lead to the development of new sustainable materials, construction techniques, and digital tools. It also opens up new business opportunities for companies specializing in green buildings or retrofitting existing buildings.

- **Risk Management:** The impacts of climate change, such as increasingly frequent and severe weather events, can pose risks to construction projects. The construction sector must consider these risks more seriously, which could affect everything from the site selection to construction methods and materials.

- **Circular Economy Principles:** The EU construction sector must fully embrace circular economy principles. This can involve reducing construction waste, using materials more efficiently, recycling and reusing materials, and designing buildings for deconstruction.

- **Paris Proof construction:** Institutions, like the Dutch Green Building Council, have set targets for embodied carbon footprint per square meters for buildings (Dutch Green Building Council, 2020). The targets spread the available carbon budget for 1.5 degrees of warming over several years.

- **Skills and Training:** The shift towards more sustainable construction will require new skills and knowledge. Construction companies must invest in training to ensure that their workforce can meet the unique demands of the green building sector.

EU Regulation

The European Green Deal aims to make Europe the first climate-neutral economy and society by 2050 (The European Commission, 2019). As an intermediate goal, the EU is committed to reducing its net greenhouse gas emissions by at least 55 percent by 2030, compared to 1990.

The climate targets for 2030 and 2050 are included in the Regulation on the European Climate Law adopted in 2021. In the future, the Regulation will also be amended to have an EU climate target for 2040.

To increase material efficiency and reduce climate impact, the EU is launching a comprehensive new strategy for a sustainable built environment based on lessons learned. This strategy will ensure coherence across relevant policy areas such as climate, energy and resource efficiency, construction and demolition waste management, accessibility, digitalization, and skills. It will promote circularity principles throughout the lifecycle of buildings by:

- Addressing the sustainability of construction products in line with the Construction Product Regulations revisions, including potential recycled content requirements for certain construction products,
- Promoting the durability and adaptability of built assets in line with the circular economy principles for building design,
- Developing digital logbooks for buildings,
- Using level(s) to integrate life cycle assessment in public procurement and the EU sustainable finance framework, as well as to explore potential carbon reduction targets and carbon storage,

- Considering a revision of material recovery targets set in EU legislation for construction and demolition waste,
- Promoting initiatives to reduce soil sealing, rehabilitate abandoned or contaminated brownfields, and increase the safe, sustainable, and circular use of excavated soils.

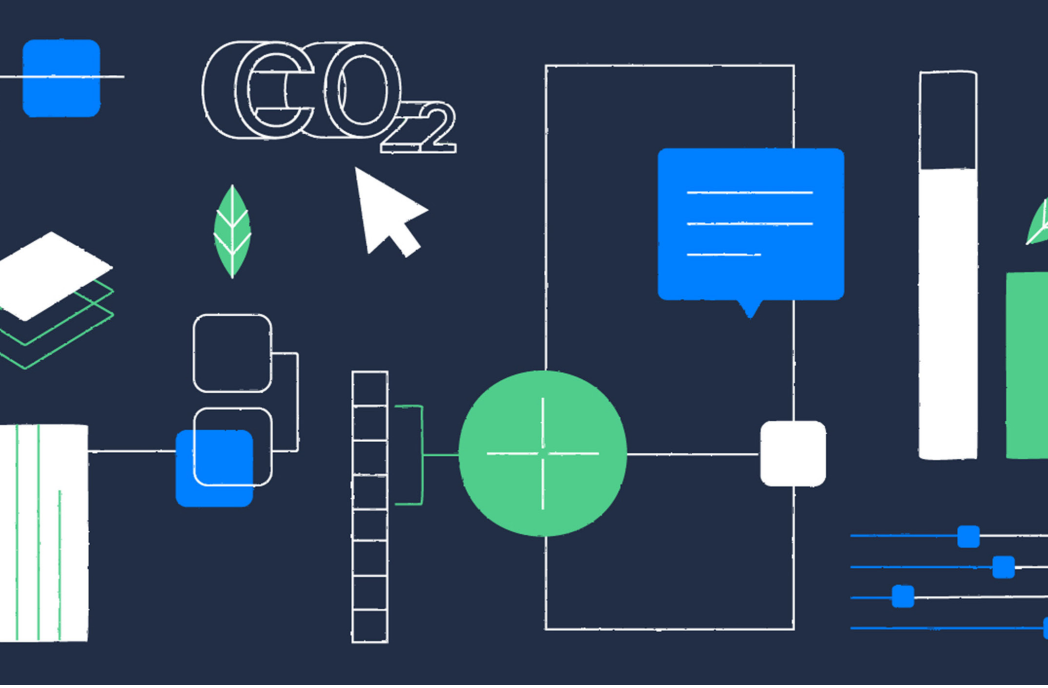
Furthermore, the Green Deal's 'renovation wave' initiative can significantly improve energy efficiency in the EU. It will implement the initiative in line with circular economy principles, notably the optimized lifecycle performance and longer life expectancy of built assets. As part of revising the recovery targets for construction and demolition waste, we will pay special attention to insulation materials, which generate a growing waste stream.

National regulation

Only a small number of countries have national regulations for construction sustainability. The following table includes European countries with voluntary certification and present or soon upcoming regulations (One Click LCA, 2022).

National regulations

COUNTRY	VOLUNTARY CERTIFICATION	METHODOLOGY FOR PUBLIC BUILDINGS	REGULATIONS
DENMARK	DGNB	Den frivillige bære-dygtighedsk lasse - methodology.	Building regulation to enter into force by 2023.
FINLAND	RTS label Zero carbon methodology (in development)	Voluntary guidelines for assessing public buildings.	Building regulation to enter into force by 2024.
FRANCE	Bâtiments Bas Carbone (BBCA). Haute Qualité Environnementale (HQE). Bâtiment à Énergie Positive & Réduction Carbone (E+C-). The regional variants of Effinergie, Quartiers et bâtiments durables.	E+C-	RE2020
NETHERLANDS	BREEAM NL GPR Gebouw	-	MPG and BENG
NORWAY	BREEAM NOR FutureBuilt Powerhouse	Simplified NS 3720:2018 Statsbygg requirements	TEK17
SWEDEN	Miljöbyggnad NollCO$_2$ BREEAM SE	Klimatdeklaration av byggnad	Law (2021:787) on climate
UK	BREEAM UK Home Quality Mark Whole life carbon for the built environment (RICS) PAS 2050	-	London Plan (London only) Part Z (proposed)



CHAPTER 2

How BIM enables carbon emission management

The following chapter focus on how building information modeling is essential in managing the embodied carbon of our projects.

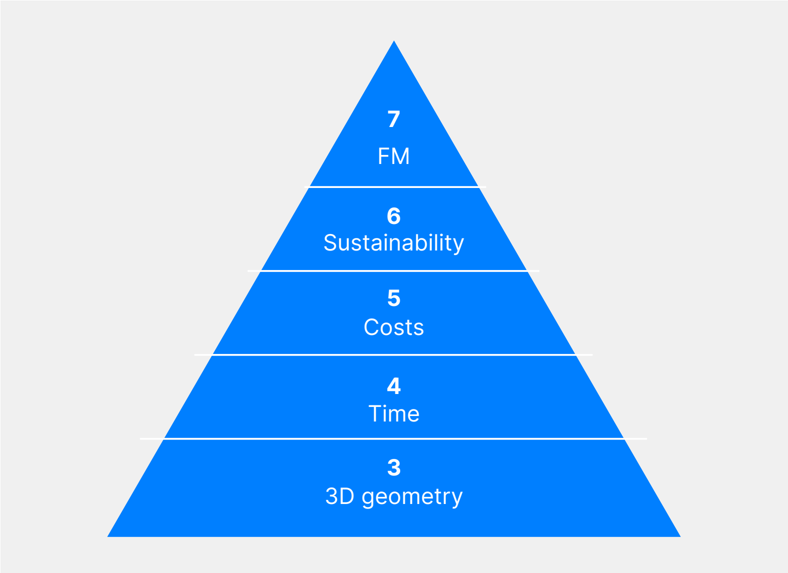
The construction industry can implement multiple strategies to reduce its carbon emissions. Whatever the plan is, information and data are at the core of the transformation to net zero. We need data to calculate how our design and procurement choices impact emissions. Building Information modeling is a perfect process for creating and managing that data and information.

BIM is not just 3D modeling

Many construction professionals only have a limited view of BIM. Some refer to it as 3D modeling, while others consider it to be a specific modeling software, like Revit, Archicad, or Tekla Structures. However, the concept of BIM is much more profound. It transforms the traditional siloed building design approach into a fully integrated and collaborative process that uses shared information models.

BIM extends beyond simple 3D geometric representation, capturing spatial relationships, light analysis, geographic information, and the quantities and properties of building components. It can include 4D simulations (adding time as a factor) and 5D (adding cost), providing a comprehensive view of the project lifecycle, from concept to commissioning and through the operational stage. This information is leveraged not only for more accurate visualization and performance analysis, cost estimation, and construction planning.

BIM Levels



The dimensions of BIM are often described as follows:

- 3D BIM contains the three-dimensional data (height, length, and depth) of the structure,
- 4D BIM has time data (duration, scheduling, etc.),
- 5D BIM adds information concerning costs,
- 6D BIM includes sustainability data (e.g., in terms of energy efficiency),
- 7D BIM also includes facility management information, in addition to all the data of the previous dimensions.

Ideally, the BIM dimensions are cumulative so that 6D BIM would incorporate all the features of the lower dimension. However, including sustainability data without, for example, cost data is possible. It all depends on who's creating and using the data in the process.

BIM maturity

The concept of BIM appeared in the 1970s, and the first software tools developed for modeling buildings emerged in the late 1970s and early 1980s. BIM has only become commonplace in most large AEC companies in the EU and USA.

Companies that apply BIM do so in a variety of ways. For some, BIM is a technology to increase their productivity in creating drawings and visualizations. The most advanced companies understand BIM as an integrated process extending across organizations and interplaying with multiple information management systems and data sources.

Maturity levels are a popular way to describe the "milestones" for measuring the BIM adoption in a project, organization, or the construction industry within a specific region.

The UK Government initially defined BIM maturity levels to describe the increasing sophistication of BIM capabilities, from essential 2D CAD (Level 0) to complete lifecycle management of the built environment (Level 3). Effective management of carbon footprint data starts at maturity level 2.

BIM Maturity levels

BIM maturity levels are typically divided into four, from 0 to 3:

Level 0

At this level, CAD produces traditional 2D drawings with no collaboration between stakeholders. Any data exchange happens manually via printouts or digital files, and there is no coordination between disciplines or professionals involved in the project.

Level 1

This level involves a mixture of 3D CAD for concept work and 2D for drafting statutory approval documentation and production information. Data is shared electronically but may not be in a standard file format. This level could also involve standard data structures for facilities management, but with different parties working separately instead of collaborating within a single integrated system.

Level 2

All project and asset information, documentation, and data are electronic, collaborative, model-based approaches. Each party contributes and maintains its information in a shared project environment. Common data environment (CDE), standardized structures, and formats are common at this stage. The UK Government's mandate for BIM adoption on public sector projects requires compliance with BIM Level 2.

Level 3

This is the ultimate goal for BIM, often referred to as integrated BIM (iBIM). It involves full collaboration between all disciplines using federated models with linked data sources in a cloud-based environment. All parties can access and modify models in real time, and the data is managed in a fully integrated way. The models comply with interoperability standards (IFC, IFD, IDM).

It’s important to note that they are not strictly hierarchical - an organization can operate at different levels on different projects or parts of the same project.

BIM mandates

The public sector is a significant client and driver of BIM adoption. Governments have understood the importance of BIM from a lifecycle perspective. They have established so-called BIM mandates that oblige construction firms to deliver construction documentation as building information models.

The UK Government has required BIM Level 2 in all public sector projects since April 2016. Even earlier, since 2007, BIM has been mandatory for all public sector projects in Denmark, including buildings and infrastructure. Other Nordic countries have followed suit, as has the Netherlands and Singapore, to mention a few.

There has been discussion about whether the mandates have advanced BIM adoption in the respective countries. For example, some UK practitioners concede that in many projects, BIM is not used collaboratively, as it should, but rather as a delivery mechanism for the final documentation.

Life-cycle management of BIM data

You can divide the lifecycle of BIM data into four stages: creation during the design phase, utilization for QTOs and construction, maintenance during the construction, operations, and maintenance stages, and archive or disposal.

VDC and BIM coordination

BIM originated from the need of designers to work efficiently and collaborate smarter than traditional document-based processes allowed. Soon, clients and building owners discovered the potential of digital models to serve maintenance and operations. Most building contractors, however, have not been able to get value from BIM until quite recently.

Virtual Design and Construction, VDC, has emerged as an alternative to a traditional construction process. It entails digital workflows, such as BIM, early collaboration, BIM coordination, and real-time project tracking. AEC firms have VDC managers, BIM managers, and BIM coordinators.

A BIM coordinator is critical in managing and coordinating BIM technology and processes on a construction project. They serve as the vital point of contact for BIM-related issues among various project stakeholders.

BIM coordinators will be vital in managing a construction project's embodied carbon data. They can check the model data quality, enrich the models with emission data, and create carbon emission takeoffs and reports.

BIM Coordinator’s tasks in carbon footprint management

A BIM Coordinator’s role is to ensure that BIM is used efficiently and effectively, serving as a bridge between technical requirements and the project team to ensure successful project outcomes. A coordinator’s capabilities can include the following:

BIM Implementation: They work on implementing BIM technology according to project needs and requirements. This includes developing and managing the project’s BIM execution plan, including guidelines for enabling carbon calculations.

Model Coordination: BIM Coordinators are responsible for coordinating different discipline models (architectural, structural, MEP, etc.), checking for any clashes or inconsistencies, and facilitating the resolution of these issues. This typically involves the use of specialized software, such as Solibri.

Data Management: They manage and maintain the BIM-related data, ensuring that the model and its associated data are up-to-date and accessible to all relevant parties.

Quality Control: They review models to ensure compliance with BIM standards, protocols, and the project’s BIM execution plan. They pay special attention to ensuring that the metadata and model construction comply with the carbon information takeoff requirements.

Training and Support: BIM Coordinators provide technical support and training to team members, helping them to understand and use BIM tools required for carbon calculations.

Collaboration: They facilitate collaboration between different stakeholders (architects, engineers, contractors, clients, etc.), ensuring a clear and consistent flow of BIM information between them.

Integration: They are responsible for integrating BIM with related technologies and processes that use the models' embodied carbon data.

A model's life cycle

A building information model starts its life quite early in the construction process. After some initial sketches, architects start creating models of the physical structures. They emphasize architectural expression and dimensions, with less emphasis on the data describing the properties of facilities and spaces.

During the early stages of a project, structural and MEP designers often use the architect's designs as 2D drawings to make schematic designs.

Once the architect's model is complete enough for building permissions and contractor bidding, structural and MEP designers start working on their models. This is the stage at which the models could incorporate properties that link to embodied carbon data in external databases. We'll look at how to enrich the model in a later chapter of this book.

As the models are separate and at various stages of maturity, BIM coordinators combine them into so-called federated models to ensure their compatibility. They can also facilitate data management over the project life cycle.

The building information models of designers potentially contain all the necessary information to automatically create quantity takeoffs, specifications, and floor area calculations. Unfortunately, design software, design firms, and individual teams may have proprietary ways to code the information for the models' objects. That makes it difficult or impossible to automate the use of design data across applications and organizations. In other words, the information is not "machine-readable" and requires human interpretation.

As a result of the inconsistencies in data representation and the way the models are built, many contractors have decided to recreate the models for planning and cost estimation purposes.

Another information gap occurs during construction. General and trade contractors might make decisions that diverge from the initial design. This can include opting for different products than originally specified or implementing installations that do not align with the BIM model. You can inspect and analyze the possible discrepancies between as-designed and actual automatically with advanced construction management software, such as Imerso (Imerso, 2023).

Often, the information from the redlining documents is not updated in the original design models. Consequently, the client or owner may receive drawings and other handover documents that differ from the designers' BIM models.

Digital twins

Digital twins are virtual replicas of physical buildings and their operations. Owners can use them for modeling, analysis, and optimization, representing a powerful tool for achieving carbon neutrality. By mirroring a building's materials, systems, and operations in a virtual environment, digital twins can enable more precise energy modeling and forecasting. They can also facilitate the design and implementation of energy-efficient solutions.

Digital twins can, for example, simulate how design decisions or operational changes might affect a building's energy consumption or greenhouse gas emissions, enabling stakeholders to select the most environmentally friendly options. Additionally, they can assist in monitoring and optimizing a building's real-time energy usage, contributing to carbon neutrality goals.

Leveraging digital twins for carbon neutrality demands significant project and construction industry commitments. The BIM models and other digital material that the project hands over to the owner must accurately reflect the as-built reality. The information for digital twins must follow standards and the client's specifications and be comprehensive and error-free.

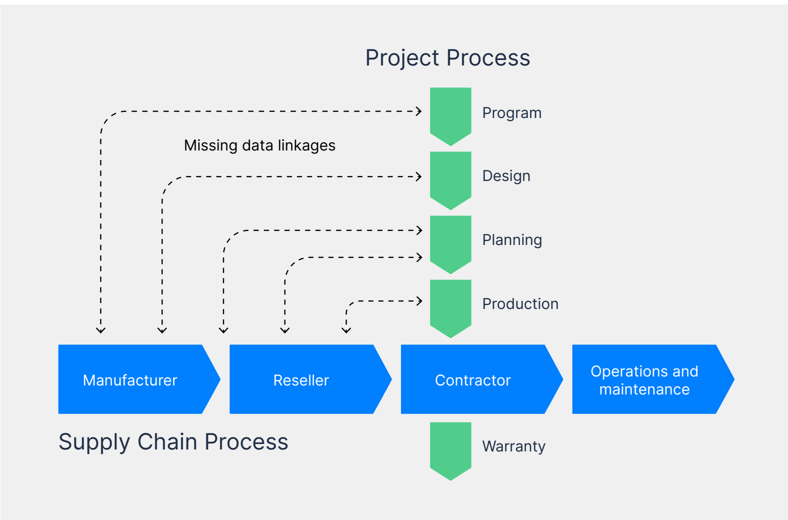
Digital twins require the input and coordination of numerous stakeholders, from architects and engineers to contractors and facilities managers. Additionally, achieving carbon neutrality with digital twins necessitates strong partnerships with technology providers and a commitment to continuous learning and innovation.

BIM in the project value chain

Ideally, every participant in the construction supply chain can access and use BIM models and their linked environmental data. There are no technical impediments to doing so, but how we present BIM data in non-standard ways makes data-driven collaboration difficult.

Construction Product Data Processes

Source: Building 2030



Product data management with identifiers

The construction sector has yet to achieve the same product data management (PDM) level as manufacturing and retail companies. Other industries use standardized identifiers whose visual presentation is the familiar bar code. The 50-year-old invention contains a standardized product number essential to the operation of the whole value chain: the retail store, the distribution center, the transportation company, the warehouse, the vendor, and the producer.

Standardized product identifiers – The GS1 numbers

The construction sector does not have to reinvent the wheel. A Finnish Building 2030 research project suggests using universal GS1 numbers in addition to or as a replacement for proprietary product identifiers (Aalto University,2023).

GS1 is an international non-profit that provides unique identifiers for manufacturers' products.

Here are examples of valuable IDs:

- GTIN (Global Trade Item Number) identifies a raw material, product, or package at the trade name level. For example, a can of paint, a kitchen cabinet, or a prefabricated wall panel can get a unique GTIN code.

- If you want to differentiate individual instances of the same product, use SGTIN (Serialized Global Trade Item Number.) For example, it is possible to identify precisely the same partition element on different floors with an SGTIN.

- If you deliver pallets or shipping containers to a construction site and want to track them, use an SSCC (Serial Shipping Container Code).

The research report points out that the required GS1 standards and tools already exist, but the implementation requires commitment from the whole industry.

Make-to-stock products already have GTIN codes. The next step is to extend the use into the Manufacture-to-Order and Design-to-Order products, like prefabricated building parts. Adding the codes to existing software should be easy.

Environmental Product Declarations

Standardized identifiers allow us consumers to find information about the ingredients of products, make price comparisons, and get food delivered to our door. Likewise, AEC firms can use the IDs to find additional information on the environmental impact of products from their Environmental Product Declarations, EPDs.

Industry-wide EPDs are standardized, independently verified documents that provide transparent and comparable information about a product's or material's environmental impact over its entire life cycle.

An international standard, ISO 21930:2017, provides the principles, specifications, and requirements to develop an EPD for construction products and services, construction elements, and integrated technical systems used in any type of construction work.

You can include standardized product identifiers in the BIM models' object datasets. They are helpful in the design, bills of materials, procurement, installation, handover, and building operation. The IDs are keys to linked data residing in in-house or public databases and you can read them with scanners or mobile devices and send the data to the cloud.

Using standardized product identifiers offers many benefits, for example:

- Performing emission and embodied carbon calculations are more straightforward with actual product data.
- Everyone involved can systematically track the status of orders and deliveries throughout the project.
- It is possible to automate design, procurement, and logistics data workflows.
- You can spot missing or incorrect product deliveries early, not during installation.
- Installation instructions and other relevant data are easy to manage and find.
- The as-built data accumulates throughout the building process.

Industrialized construction

Property developers and contractors are trying to improve construction efficiency and speed up investment projects by applying industrialized methods. They include lean construction and prefabrication, volumetric modularization, and robotized production – the so-called Modern Methods of Construction (MMC.)

Off-site construction is, in general, less wasteful than on-site construction. As much as 30% of the total weight of building materials delivered to a typical construction site can end up as landfill waste. In contrast, offsite production creates dramatically less waste (Prof.Dr. Mohamed Osmani, 2019).

With lean construction, MMC also improves on-site worker productivity and potentially shortens lead times. Efficiency translates into energy savings, leading to reduced embodied carbon emissions.

BIM is a perfect process to support industrialized construction, but it places even more emphasis on systematic data management.

> As much as 30% of the total weight of building materials delivered to a typical construction site can end up as landfill waste.
>
> (Prof.Dr. Mohamed Osmani, 2019)

Sources of environmental data

You need trustworthy sources to incorporate embodied carbon data in BIM models. The following are some examples.

Environmental Product Declarations (EPDs)

Manufacturers often offer EPDs and they are increasingly available online. You can import data from EPDs into carbon calculation applications to provide a more accurate estimate of the embodied carbon in a project.

Databases

There are several databases and tools that compile information on the embodied carbon of different materials.

These include:

- **The Inventory of Carbon and Energy (ICE)**: This free database provides information on the embodied energy and carbon of other materials (Circular Ecology, 2023).
- **EC3** (Embodied Carbon in Construction Calculator): The free tool from the Carbon Leadership Forum allows users to find and compare embodied carbon data for different materials and products (Carbon Leadership Forum, 2023).
- The **CO_2data.fi** service offers unbiased data on the climate impacts of construction products and services used in Finland. The Finnish Environmental Center SYKE is

responsible for the service, and it is open to everyone and free of charge (Finnish Environmental Insitute, 2023).

- **Boverket**, the National Board of Housing, Building, and Planning, provides an open database for a climate declaration for new buildings. In cases where a developer wants to use generic climate data in a climate declaration, the data must be retrieved from there (Boverket, 2023).
- **Dutch Environmental Database** (NMD) is required to be used in the Netherlands to calculate the environmental performance of buildings, and MPG for applying for planning permissions (Dutch Environmental Database, 2023).

Material Manufacturers

Many manufacturers provide data on the embodied carbon of their products, particularly those that have committed to sustainability. Check out the availability of their EPDs.

It's worth noting that the availability and accuracy of embodied carbon data can vary significantly between different sources, and the data is continually being updated as manufacturing processes improve and become more efficient. As a result, it's essential to use the most recent and accurate data available and to understand the assumptions and methodologies that are used to calculate the embodied carbon figures.

CHAPTER 3

How to implement BIM-based emissions management

The following chapter offers practical advice on the methods and tools for implementing carbon management with BIM.

You don't have to be a Life Cycle Assessment expert to integrate embodied carbon information into your design and management processes. Various software tools allow you to explore alternative design solutions proactively and agilely from the early design stages onward. However, the quality of models becomes ever more critical.

Technologies and tools

Until recently, incorporating carbon emission data into the design and construction process has required tailored solutions. As the demand for embodied carbon calculations has increased, there are now commercially available solutions to do the math at various stages of a construction project.

Specialized Lifecycle Assessment Software

Life Cycle Assessment (LCA) is a methodology for assessing environmental impacts associated with all the life cycle stages of a commercial product, process, or service. When applied to building projects, LCA considers material production, construction, operation, and end-of-life.

Various software solutions are available that support Life Cycle Assessment (LCA) for building projects. Remember that they often require information on material quantities and energy use that can come from BIM models. Therefore, it's beneficial when the LCA software can integrate directly with popular BIM software, such as Revit or ArchiCAD.

Life Cycle Assessment Software

Selection of popular LCA software products:

One Click LCA One Click LCA is a life cycle assessment and life cycle costing tool for buildings and construction. It uses detailed Environmental Project Declarations as the data source and integrates with popular BIM and CAD software. One Click LCA is designed for sustainability experts and non-LCA experts alike (One Click LCA, 2023).

GaBi Developed by thinkstep, GaBi is a comprehensive and sophisticated LCA software that has been widely used by industries worldwide for over 20 years. GaBi offers a range of modules for performing various types of LCAs, including a module specific to buildings (Sphera, 2023).

Athena Impact Estimator for Buildings Specifically tailored for the building industry, the Athena Impact Estimator for Buildings is an LCA tool for assessing whole buildings and building assemblies (Athena Sustainable Material Institute, 2023).

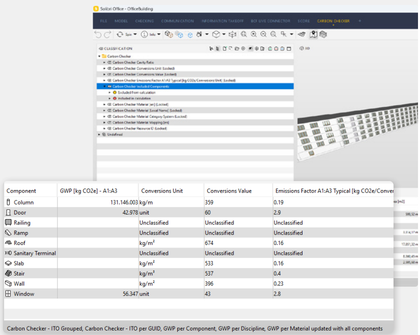
Tally® Tally is a plugin for Revit, a popular BIM software, allowing LCA to be incorporated directly into the design process. Tally provides life cycle inventory data for materials, which can be used to calculate a building's carbon footprint (Autodesk App Store, 2023).

eTool This is a user-friendly and comprehensive software for LCA. It is also fully integrated with BIM (Cerlos, 2023).

CALCULATE YOUR CARBON FOOTPRINT

Solibri Office now comes equipped with carbon checking capabilities.

Learn more



Solibri Carbon Checker

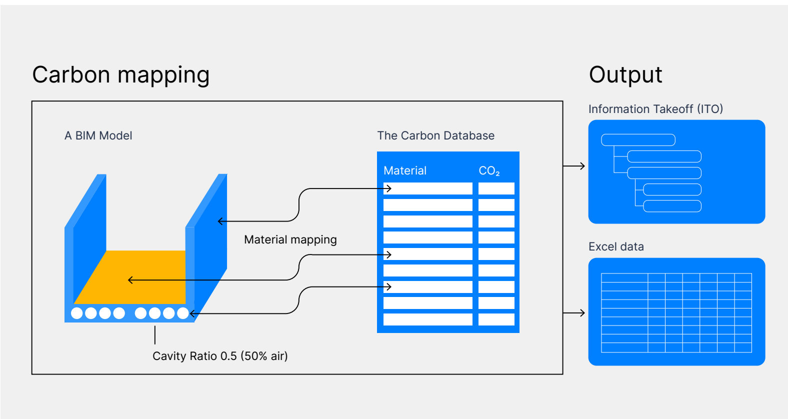
Solibri has launched Carbon Checker, an extension to its model-checking software Solibri Office. BIM managers, coordinators, and, indeed, even LCA analysts can define and calculate a project's carbon footprint without deep knowledge of embodied carbon calculations. Carbon Checker also empowers planning permission authorities to investigate the carbon footprint of proposed projects.

Carbon Checker currently uses two alternative climate databases with emission factors for various materials and processes: the Finnish SYKE's and the Swedish Boverket's. The initial version focuses on architectural and structural models of both new and refurbishment projects. It uses IFC files as a starting point.

With Carbon Checker, AEC firms can carry out a planning permission level carbon calculation considerably faster than previously and avoid hiring a consultant to carry out the math. According to **David Jirout**, the developer behind Carbon Checker, one can now model a carbon footprint three to ten times faster than with contemporary mainstream work methods. Basically, if you have a well-structured model in Solibri Office, and a BIM coordinator who knows the model already, it can take just an extra couple of hours to calculate the carbon footprint of individual BIM objects with Carbon Checker. Thus, Solibri aims to deliver cost effective carbon calculations for any construction project of any size in a democratized way.

Carbon Checker is not intended to be a fully-fledged LCA tool. Instead, it fits perfectly into the early design phases and building planning permission purposes. It allows, for example, a study of the consequences of swapping various materials during the design phase. This is beneficial before locking the design to particular solutions and material choices.

Solibri Carbon Checker



How to use Solibri's Carbon Checker

- You load IFC models of the design as a starting point. Open the model in Solibri Office and launch the Carbon Checker extension.
- First, you select one of the four roles, the carbon database, and the respective language version. Currently, the tool includes the SYKE and Boverket databases. The former is available in Finnish and English, the latter in Swedish and English. Once you've selected the role, the tool loads in the respective building material descriptions in your language of choice.
- If the project is an extension of an existing structure, you define which parts of the project exist so that we can exclude them from the carbon footprint calculation.
- The next step is to map the building objects with the respective descriptions in the carbon database. The operation is straightforward if the model's metadata matches the materials used in the design. The process requires more manual tweaking and additional interviews with the designers regarding geometries and material descriptions, if the model has known data quality issues.
- While you perform the material mapping, you can define the Cavity Ratio of the objects. A precast concrete slab, for example, can be a 50% cavity, so the ratio is 0.5. A solid object's ratio is 1.
- Once you've mapped the materials, Solibri's Information Takeoff (ITO) itemizes the quantities and CO_2 emissions of the individual components, component types, materials, and technical disciplines as such. You can also export the data to Excel for further analysis.

BIM quality assurance

BIM quality ensures conformance to specifications. The specifications can be industry-wide and client and project-specific. Another dimension is the intended use of the model. BIM quality presents the correct information correctly and at the right stage.

Why BIM quality matters

Construction projects are complex mainly because they involve many participants and overlapping and often conflicting processes and interests. Building information modeling is no exception. Designers, quantity surveyors, contractors, owners, and authorities share models that depend on each other. Any errors and discrepancies in one model can cause costly rework, delays, and poor decisions.

Embodied carbon calculations require design models that present the building objects correctly. Duplicates of the same object, overlapping objects, models that don't follow building logic, missing or incorrect metadata make the carbon calculation process faulty. When geometrical inconsistencies meet with poor material descriptions in one design, the final carbon footprint can be 10 or 100 times greater, or lower than it would have in reality. Hence, the quality of the design and the experience of the BIM coordinator matters a great deal.

The Carbon Checker user must also pay attention whether IFC files contain grouped objects, so called Assemblies, or just individual BIM objects. We developed Carbon Checker to unpack Assemblies' individual BIM objects and ignore the group as such to prevent duplicated climate calculation entries. However, other types of grouped objects may occur, hence attention must be paid to nuance any grouped formations to its individual part.

David Jirout claims that at least 15% of unique material descriptions in the model are typically erroneous. Poor material descriptions will not only lead to faulty climate calculations but also impact the project economy. If the material mapping is correct, adding the embodied carbon in Solibri Office takes a few hours. In contrast, a poorly constructed model requires several workdays to achieve the same result as the BIM coordinator will have to conduct detective work, and manually correct material mapping afterwards.

For the abovementioned reasons, BIM quality management is elemental to a successful embedded carbon management.

How-to

Quality should be "business as usual" in the BIM workflows. To ensure BIM quality throughout the project, consider the following steps:

- **Establish clear and specific BIM requirements** from the project's outset. Define how the project team should build the models to use them effectively for embedded carbon calculations.

- **Use industry-recognized BIM standards** and protocols. Standards ensure consistency and compatibility among different project stakeholders.
- **Regularly review and audit** the BIM models to identify and rectify any inconsistencies or errors.
- **Perform systematic clash detection** to identify and resolve conflicts between various building elements.
- **Use a Common Data Environment** that enables secure storage, version control, and efficient data sharing among the team members.
- **Foster a collaborative and communicative** environment among project stakeholders. Effective communication helps to address issues promptly and promotes a shared understanding of the BIM requirements.

Quality management becomes easier when you systematize it and follow it rigorously. The use of shortcuts to speed up modeling is tempting but may have harmful consequences later.

A visually correct model might have geometrically accurate representations but lacks the intelligence for embedded carbon analysis, scheduling, or quantity takeoffs. “Machine readability” becomes critical as we move on to more automated data processing.

Implementation

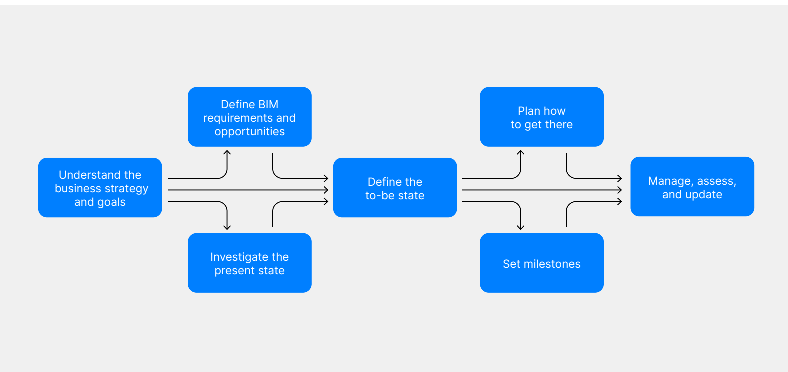
By now, it is evident that every company involved in construction must start thinking about sustainability strategically. Whatever the strategy and its goals are, they impact how the company uses BIM. Consequently, those responsible for BIM management and development of the company must ensure that the BIM supports reaching the goals in every project.

Strategy

It is advisable to lay out a strategy for BIM in general and how it enables the company to reach its sustainability goals.

A strategy defines the choices you make to reach your goals. The options are about what you will and won't do. An approach concerning sustainability and BIM helps you to use your resources and efforts for the right things on the project level and ignore those that do not add value.

Exemplary strategy process



Understand the business strategy and goals.

A company's BIM strategy starts with defining clear goals and objectives. These, of course, should be tightly aligned with your company's business strategy. If your company has set clear ESG goals, those will guide your BIM strategy. For example, if you aim at a specific reduction in embedded carbon emissions of their projects, BIM should make reaching and verifying these possible.

Define BIM opportunities and requirements.

Once you have identified the overall sustainability goals for your company's projects, you should explore BIM's information, data management, and communication opportunities. Look at various stages of the project lifecycle, whilst remembering that the early decisions impact the outcome most.

With opportunities come requirements regarding the level of detail, object data, and how you build the models. Collaboration and how and when you do it is also an important consideration.

Investigate the present state.

When you know what's possible and what's required, you should investigate how you're performing today. Are your current practices already sufficient enough to incorporate a carbon footprint aspect? Do you have the necessary skills and knowledge to manage and report carbon emissions reliably? Are the tools in place to do this?

Define the to-be state.

Define the level of service you want to reach concerning carbon footprint management. Do you limit it to building permission-level reporting, for example, or go all in and perform detailed LCA assessments for the building owner?

Plan how to get there.

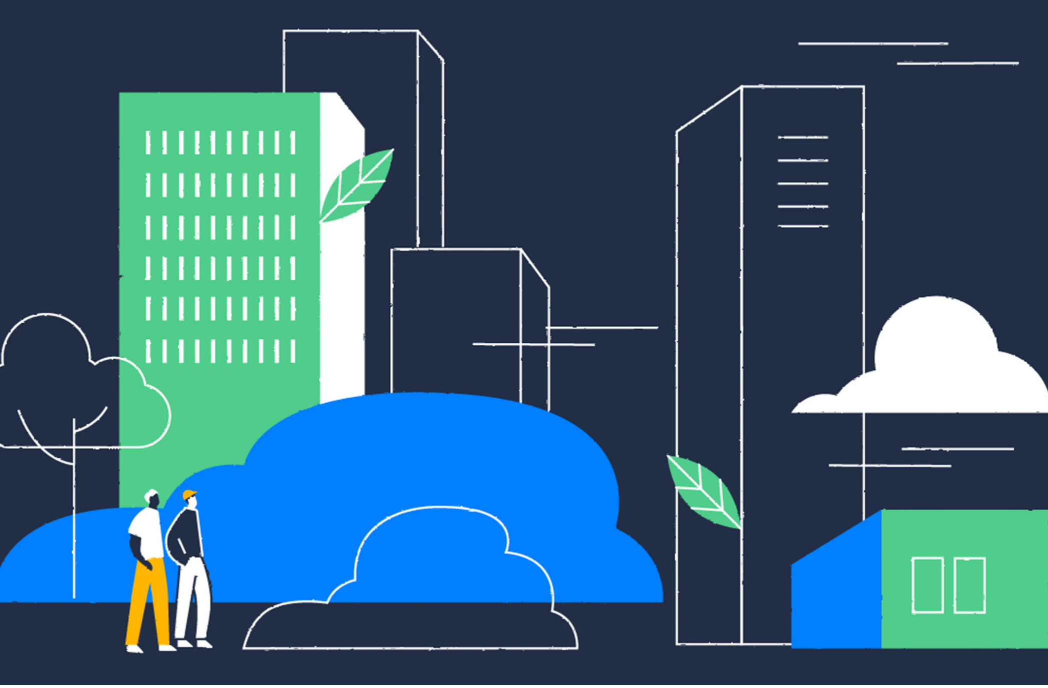
When knowing your goals and the present state, you can perform a gap analysis and determine what you need to do. The actions could include process changes, training, software investments, reporting routines, etc.

Set milestones.

It is good practice to set a timetable for your plan. Set specific milestones and determine who is responsible for reaching those. One tactic is to choose a project or two to develop and test the new practices first to learn how they work and whether they need to be adjusted.

Manage, assess, and update.

A strategy is not carved in stone. In a rapidly changing business environment, strategies must adapt. However, don't change them at the first setback. The construction industry is project-focused, and keeping an eye on the horizon is difficult.



CHAPTER 4

Future trends and opportunities

The following chapter outlines opportunities and trends from which your company can benefit.

For many companies, the sustainability journey has only started. The first milestone is understanding the concepts and implementing them in workflows. The tools for getting started are there, and more are coming. Once you've established the initial level of carbon management, you can prepare for future opportunities.

The state of construction decarbonization

Regardless of all the goodwill and public policies, the construction sector is globally far behind its targets.

The UN's 2022 Global Status Report for Buildings and Construction states that raw resource use is predicted to double by 2060 – with construction materials, such as concrete and steel, already significant contributors to greenhouse gas emissions (United Nations, 2022).

To reach the 2050 target of a zero-carbon building stock, we need to accelerate our efforts considerably.

Circularity

We live in a linear economy. 93% of the materials we use end up in landfills or are not reused. This is not sustainable even in the short term. We must adopt circularity to maintain our current level of well-being and live within our planetary boundaries.

Circularity includes three principles: eliminating waste and pollution, circulating products and materials (at their highest value), and regenerating nature.

Eliminating waste also entails an efficient use of resources. For example, the utilization rate of a car is around 4%. Alternative ways of mobility will, therefore, be a crucial circularity solution.

Kalle Saarimaa, CEO of Tana Oy and a circularity expert, claims that if our only sustainability goal would be carbon neutrality, we could reach it within the linear economy. However, more is needed to ensure biodiversity and cope with material scarcity.

For example, the reuse of materials in the automotive industry is straightforward. However, it is difficult and expensive to source materials from a construction demolition site because the material is so heterogeneous, and there is, typically, no record of its composition, Saarimaa says.

Companies must radically change their practices and business models to reach circularity. There are already some regulatory initiatives within the EU, for example, the right to repair electronic devices. Circularity regulation for the construction industry is in preparation.

AEC companies can consider circularity in their building material choices and production of buildings with net zero emissions. They must also ensure a digital and long-lasting record of building components and their materials.

Business opportunities

New regulations, increased client requirements, and sustainability-driven strategies present threats and opportunities for AEC companies.

Companies unwilling to adapt to the new reality will experience tapering business prospects. AEC firms that use sustainability as a marketing gimmick without a steadfast commitment will be seen as greenwashers, thus damaging their reputation.

On the other hand, firms that are ahead of the curve will have a competitive advantage. The following are ideas on how using BIM to manage the' carbon footprint of buildings opens up new opportunities for innovation in processes, offerings, deliveries, and finance.

Process Innovation

Architects, engineers, and constructors can streamline their design and construction processes with BIM and advanced data management. The linking of carbon footprint data with a models' objects allows them to assess and optimize the environmental impact without always resorting to LCA specialists.

AI technology creates many business opportunities for AEC firms capable of designing and developing machine learning solutions. For instance, predictive models can help to design buildings better suited to their environment, reducing the need for artificial heating, cooling, and lighting. You can also use machine learning to estimate and optimize the carbon footprint of a building, from the design and construction stages to its use and eventual deconstruction.

The construction process can improve facilities management and maintenance processes. By understanding the carbon footprint of different building components, property managers can make more informed decisions about when to repair, replace, or upgrade elements of a building to maintain its efficiency and minimize its environmental impact.

Offering Innovation

A BIM platform that includes carbon footprint data could offer a new level of service to architects, engineers, and construction companies. This tool could enable them to design and build more environmentally friendly buildings, thus offering a competitive advantage in the growing market for green construction.

A BIM platform could be integrated with other systems, like lifecycle assessment tools or materials sourcing databases, to create a more comprehensive offering covering different green building aspects.

With BIM, companies can enhance their customer service by providing more detailed and accurate information about the environmental impact of different design choices. This helps customers to make informed decisions and feel more engaged in design and construction.

Delivery Innovation

Using BIM with carbon footprint data can significantly improve the customer experience. For example, customers can visualize and understand the environmental impact of their projects. This kind of transparency can lead to increased customer trust and loyalty.

Furthermore, by incorporating carbon footprint data into their BIM processes, companies can enhance their brand as innovators and leaders in sustainable construction.

Finance Innovation

A company can use a BIM platform with embodied carbon data to create a new business model, such as a subscription service for accessing a platform or consulting services to help clients optimize the environmental performance of their projects.

By providing valuable data about the carbon footprint of building materials, such a BIM platform could create a new value network among suppliers, manufacturers, architects, engineers, and construction companies. This can lead to collaborations to develop and promote more sustainable building practices and materials.

There's a great amount of untapped business potential in the circular economy. Circularity should lower operating and capital costs if it can be scaled. So far, efforts to reuse building materials profitably have been mostly unsuccessful. With BIM and consistent material data, online “material banks” could eventually become feasible.

Conclusions and next steps

It’s now essential for every construction industry business to adopt sustainable practices. The most effective method is to weave sustainability into the company’s strategic planning and daily operations.

It is time to start implementing building information modeling collaboratively, ensuring the models’ quality for embodied carbon management, and enriching models with the latest environmental data.

Every individual working on a project should understand how their choices impact the sustainability of the end product, the building. They should also have the skills and tools to assess, improve, and verify a design’s carbon emissions.

Remember, the integration of sustainability into every facet of your operations isn’t just beneficial for the planet - it’s a crucial step in positioning your business as a forward-thinking leader in the construction industry.

Let’s embark on this journey of sustainability together!

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Mika Kovanen, Leading Advisor at Ramboll

Ville Kyytsönen, CEO at Solibri

Kalle Saarimaa, CEO of Tana Oy

David Welts, Product Manager at Solibri

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