Nordic Innovation

BIM for Building LCA
Enhancing Nordic Sustainable Construction through Digitalisation

Contents

This publication is also available online in a web-accessible version at: https://pub.norden.org/us2024-439

Preface

This report is a part of the Nordic Sustainable Construction programme initiated by the Nordic Ministers of Construction and Housing and funded by Nordic Innovation. The programme contributes to the Nordic Vision 2030 by supporting the Nordics in becoming the leading region in sustainable and competitive construction and housing with minimised environmental and climate impact.

The programme supports the green transition of the Nordic construction sector by creating and sharing new knowledge, initiating debates in the sector, creating networks, workshops and best practice cases, and facilitating Nordic harmonisation of regulation for buildings' climate impact.

The programme runs from 2021-2024 and consists of the following focus areas:

- WP1 – Nordic Harmonisation of Life Cycle Assessment
- WP2 – Circular Business Models and Procurement
- WP3 – Sustainable Construction Materials and Architecture
- WP4 – Emission-free Construction Sites
- WP5 – Programme Secretariat and Capacity-building Activities for Increased Reuse of Construction Materials

An important part of the programme is to facilitate the digitalisation of building LCA and climate declarations within the Nordic countries. In this context, this "BIM4LCA" project report has been developed. The report is one of the deliverables of task 3 in Work Package 1, led by the Finnish Ministry of Environment.

The BIM4LCA work has been carried out by VTT Technical Research Centre of Finland, Granlund, Gravicon and Insinööritoimisto Kallinen, and the Nordic partners: Sberesearch, Rangi Maja OÜ, Bengt Dahlgren Stockholm AB, Gravicon DK and Asplan Viak AS.

Authors:
Rita Lavikka, Mikko Kouhia, Martin Excell, Tomi Henttinen, Markku Kiviniemi, Tero Järvinen, Minna Salonsaari, Anna-Riitta Kallinen, Katja Maununaho and Tiina Vainio-Kaila

Other contributors:
Tarja Häkkinen, Charlotte Nyholm, Jan Karlshoej, Oddbjørn Dahlstrøm Andvik, Alexander Borg, Iselin Idunn Østvedt, Anni Oviir, Charlotta Malmén, Maximilian Von Bahr and Tytti Bruce-Hyrkäs

Nordic Sustainable Construction

For more information on Nordic Sustainable Construction, visit our website at https://nordicsustainable-construction.com/

Glossary

BIM	Building information modelling (BIM) is a process of creating and managing digital representations of a building's physical and functional characteristics. This process is supported by various tools and technologies, integrating structured, multi-disciplinary data to produce a digital representation of an asset throughout its lifecycle, from planning and design to construction and operations. This definition follows the ISO 19650-1:2018 Organization and digitisation of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling— Part 1:Concepts and principles., 2018.
BIM-based quantity take-off	BIM-based quantity take-off refers to the use of BIM technology for the detailed measurement of structures and materials needed to complete a construction project.
BIM models	BIM models are native building and infrastructure design software files, such as ArchiCAD, Revit, Tekla Structures, and MagiCAD. These files digitally represent the building and its assets. Usually, these native files are converted to a vendor-neutral format (see the definition of IFC) to be shared between design disciplines to facilitate design, construction and operation processes for informed decision-making about a building or other built assets.
Building LCA	Building Life Cycle Assessment (LCA) is a method used to evaluate the environmental impacts associated with all stages of a building's life cycle. The method involves four steps: goal and scope definition, inventory analysis, impact assessment, and interpretation. The European standard EN 15978:2011 codifies LCA for buildings and defines the life cycle stages.
Component	A component represents minor items included in, added to, or connected to or connecting elements. Components are generally not of interest to the overall structure of the building. However, these small parts may have vital and load-carrying functions within the construction. These items do not provide any actual space boundaries. This definition follows EN ISO 16739-1:2024.
Element	A built element comprises all the parts, permanent or temporary, that are the primary building parts of a built asset. Elements are physical objects, although in some cases, a void, such as a hole in a structure, is also considered an element. Elements can be prefabricated or built on-site. This definition follows EN ISO 16739-1:2024.
HVAC	Heating, Ventilation, and Air Conditioning system which is used to control the temperature, humidity, and air purity in an enclosed space.
IFC	Industry Foundation Classes (IFC) defines a standardised digital description (data model) of the built environment, including buildings and infrastructures. BuildingSMART International developed it as an open, international standard (ISO 16739-1:2018) that is vendor-neutral and can be used across various hardware devices, software platforms, and interfaces for many different use cases. IFC is used to exchange information between design disciplines.

Summary and recommendations

Introduction

Building information modelling (BIM) can help low-carbon building design by supporting the comparison of alternative design choices in the initial phases of design by different design disciplines and thus finding optimal solutions. Also, the growing regulation of various Nordic countries regarding the low-carbon nature of construction projects sets requirements for evaluating the carbon footprint. Denmark, Finland, Norway and Sweden require it during the as-built phase. Estonia is planning to require it during the building permit phase, and Iceland plans to require it twice during the building project.

BIM has become more or less mainstream in professional building projects. Life cycle analysis of buildings is largely conducted based on the used building materials and their quantities. This BIM-related information is, in some ways, already described in the models. However, the models are currently not utilised in building life cycle analysis (LCA) to the extent they might be. The data required by the LCA analyst might be missing from the model or recorded in non-standard ways; properties may be absent, and some features may be modelled multiple times. This increases time and effort, as practitioners may need to input data manually or make assumptions. Unfortunately, the discussion between BIM modellers and LCA analysts is often lacking. BIM-related information is generally not usable for carbon footprint assessment without common standard practices and requirements for information to be included in BIM models, such as naming, presented parameters, and building parts to which components are related.

This BIM4LCA project, as part of the Nordic Sustainable Construction programme, tackled these challenges. The BIM4LCA work started in May 2023 by analysing the current enablers and hindrances for BIM-based building LCA in the Nordic countries and Estonia. The results were communicated in a report explaining the building LCA and BIM practices and the constraints and enablers for harmonising building LCA in the Nordics.[1] The report supported the creation of a common understanding for all the Nordic stakeholders and further work on the project.

The following work focused on developing a BIM-based building carbon footprint calculation process where BIM provides adequate information on quantities for a list of materials/products, which is then linked with emission data. The BIM4LCA project aimed to reveal the information needs and minimum requirements for

1. Report: The Operating Environment of Building LCA and BIM in the Nordics and Estonia, published 18.12.2023, available from https://nordicsustainableconstruction.com/Media/638379082362009468/The%20Operating%20Environment%20of%20Building%20LCA%20and%20BIM%20in%20the%20Nordics%20and%20Estonia.pdf.

architectural, structural, electrical, and HVAC models and their IFCs to ensure the information can be used in the normative (required by legislation) carbon footprint assessment. Many countries have BIM guidelines and requirements to support modelling in general. Still, they are rarely nationally mandatory or support BIM modelling specifically for building carbon footprint calculation.

This current report mainly focuses on the normative building LCA required by the Nordic countries' legislation, but it needs to be noted that building LCA is a broader concept than normative LCA. At their best, building projects perform BIM-based building LCA in several project phases – conceptual design, detailed design, construction, and as-built – to ensure reaching sustainability goals. Currently, it is often the job of an LCA expert to do the work manually, perhaps taking some quantities from the BIM. The LCA is mainly done once or twice, and it may not have that big an impact on reducing emissions. In the future, there will be tools that will allow more automatic building LCA and suggest changes in the project to reduce emissions.

Results of the BIM4LCA project

This BIM4LCA report provides a generic description of the BIM to LCA process, which can support calculating and reporting normative LCA in building construction projects. The project developed generic guidelines for reliable BIM-based material inventory (bill of materials), specifications for information needed for modelled building components, data transfer from BIM tools to LCA tools, and iterative design and analysis workflow between BIM and LCA tools. The guidelines target the architects, structural engineers, heating, ventilation, and air conditioning (HVAC) and electrical designers who create the BIM models and the LCA analysts who extract information from the models. The starting point for the guidelines has been that they require as small changes as possible to the current BIM modellers' workflow. Locations for data in the models are recommended so the LCA analyst will receive material quantity information from the model, as designed by the architects and other designers, with reliable outcomes. Also, the level of detail in different stages of construction projects is recognised, and best practices for amending that information are recommended.

The BIM4LCA project produced two examples of buildings and their BIM models, which can be used by practitioners architects, structural engineers, HVAC and electrical designers and LCA analysts to learn how to do the modelling to support BIM-based building LCA in practice. The buildings are designed according to the Finnish Construction Act and building codes. The design principles have emphasised the life-cycle properties of buildings, e.g. in terms of multi-purpose usability, adaptability and access to natural light. The report provides links to the native architectural, structural, HVAC and electrical BIM models and their Industry Foundation Classes (IFCs) files, including their BIM specification documents and related material and product information. These files[2] are provided for free with a Creative Commons license.

The project also created seven educational videos that support practitioners in learning BIM-based building LCA. The videos explain how BIM model authors should do the modelling to support the LCA specialists in BIM-based quantity take-off and mapping of the result to the LCA calculation software (see more specifically Appendix F: Educational videos on BIM-based building LCA). The videos are on the YouTube channel of the Nordic Sustainable Construction programme.[3]

The BIM4LCA project suggests BIM data requirements and best practices for modelling and data processing that can enhance the usability and accuracy of BIM data for LCA purposes. The project also recommends that Nordic authorities set BIM requirements for BIM modellers if a climate declaration is required and support information harmonisation in the construction sector. The project proposes a future vision of automated BIM-based LCA that can provide instant feedback and optimal solutions for low-carbon building design.

The results have been co-created by a consortium of VTT Technical Research Centre of Finland, Granlund, Gravicon and Insinööritoimisto Kallinen, and the Nordic partners: Sberesearch, Rangi Maja OÜ, Bengt Dahlgren Stockholm AB, Gravicon DK and Asplan Viak AS. The draft results have been communicated to the advisory board of the Nordic Sustainable Construction programme, and their comments and requests for changes have been considered. The draft BIM-based building LCA process was communicated to a broader public audience in a "BIM-Based Building LCA" webinar[4] organised on the 12th of December 2023, and the oral and written comments from the audience have been considered when finalising this report. The BIM4LCA working group has also participated and presented results in internal meetings with the sister tasks of the Nordic Sustainable Construction programme.

Set BIM requirements

The BIM4LCA project raises action recommendations to support country-specific BIM-based building LCA processes. It is advisable to set BIM requirements for the BIM model authors if a climate declaration is required during the building permit or as-built phases. This project suggests BIM data requirements (See section Instructions for BIM-based material inventory), which can be used as guidelines. These requirements are part of the increased information harmonisation that has taken place in the real estate and construction sector since early 2000. Information harmonisation can significantly impact the sector's productivity and support creating a more sustainable built environment. However, information harmonisation comes with certain burdens: the designers need to learn to model in a more detailed

2. https://www.nordicsustainableconstruction.com/knowledge/2024/august/bim4lca-files
3. NordicSustainableConstruction YouTube channel, available from https://www.youtube.com/playlist?list=PLKuMoWj9yd7Ww3rne-uU3iq-LM2IypfE9&jct=zFxiyDdah8WJ_MAxaWlYEA
4. Recording and Presentation from Webinar "BIM-Based Building LCA", published 14.12.2023, available from https://nordicsustainableconstruction.com/knowledge/2023/december/webinar-on-bim-based-lca.

and structured way. This entails a learning curve, which will at first take resources. However, stakeholders agree that information standardisation is the right path.

Currently, the level of detail in BIM models in the Nordics is governed by national regulations and established modelling practices, such as required components in the models, classification of components and requirements for model data. The Nordic countries use different classification systems, and the countries' normative building LCA regulations use local classifications for definitions and reporting requirements. From the LCA perspective, the classification should help recognise model content for the LCA reporting: the ability to separate all elements that must be reported separately.

Integrate classification systems for effective BIM and LCA alignment

The basic feature of classification systems is to group information from a particular perspective or for a specific purpose. Thus, an activity is always built into them, such as purchasing, installation, or maintenance. The prEN 15978 standard provides a table showing the grouping of building elements according to the needs of the LCA calculation. It can be considered as a classification system for BIM models used in LCA. Although the classification of building elements presented in prEN 15978 has some minor shortcomings, it proved to be very useful in the BIM4LCA project. It has the advantage of being quite coarse but, at the same time, sufficiently accurate; the coarseness allows the different national classification systems to be mapped to prEN 15978 (see Appendix B), and the accuracy enables the elements in the IFC models to be identified accordingly (see Appendix A). One of the key recommendations of this project is that the classification of building elements in prEN 15978 should be considered as a starting point for developing LCA reporting requirements.

BIM represents design results (currently also in the as-built phase, which should represent the as-built data), a source for several information needs in the building construction, use, and maintenance phases. BIM should include data required to produce needed information in these downstream operations. The designers are not capable of producing all the needed information. Still, the role of the designers is to produce the core data for further processing by other value-chain stakeholders.

This BIM4LCA report suggests that BIM should contain identifiers for element types in all design models. However, it does not suggest a harmonised way of naming/identifying the different materials/sub-elements included in the element types. The report proposes that the elements' details be attached to the LCA calculation phase to ensure correct emission data will be used.

Develop a machine-readable data structure to integrate BIM and LCA processes

The next development phase would be to define a machine-readable data structure to express the contents of component types (materials/layers) as they are currently presented in PDF documents. This data would be outside the BIM, and this suggestion should be tested to determine how it will support LCA calculation as needed. In the longer term, with further development and testing, detailed materials would be linked to BIM for more automated processing of BIM data, including LCA.

A big question about BIM-based design is often how much extra work it creates for designers. This project investigated the minimum level of BIM models required to achieve significant benefits supporting LCA calculations. The finding is that modelling does not increase the amount of information produced. In any case, designers must produce similar information for permitting, procurement, construction, and maintenance for every project. However, if the timing for producing the data needed for the LCA calculations is different from the timing of other processes or if the information content to be produced differs from the other information needs of the project, the additional work involved in producing the data will be significant.

Synchronise BIM and LCA information for improved accuracy and efficiency

The accuracy and timing of the information produced for the LCA calculation should be synchronised with other project information processes. The BIM4LCA project identified the content of the information required for procuring construction products and aligned the information to be produced from the BIM models for LCA. In this way, the same information serves two different processes, which increases the motivation to produce needed LCA and other information and, thus, the quality of the information.

Equip designers with BIM skills and harmonise information

Another question related to BIM-based design is what kind of new skills it requires and what capabilities the different parties involved need to adopt the required skills. There are certainly major national differences in this respect. The BIM4LCA project found that in Finland, designers have been using BIM-based design software for a long time and have a reasonable basic understanding of how to use it. Getting the geometry of the models right did not pose significant problems beyond the usual design issues. The challenge, however, was the consistent information on the elements in the models. Uniform information specifications have only been developed nationally in recent years, but designers do not yet have experience using them. There are also still gaps in the definitions. The information content in the models should be highly harmonised to enable automated and reliable data generation using BIM models. This requires both specification work and national efforts to implement the specifications. Again, motivation and information quality can be improved by drawing up specifications so that harmonised information content serves as many processes as possible, such as LCA calculation, permitting, procurement and construction.

We hope this report will pave the way towards more automatic BIM-based building LCA calculation and significantly better building data management in construction, leading to efficiency gains and better living environments. This report has pictured steps towards a future where BIM-based building LCA could take place automatically (see Figure 2). Since the quantity information required in LCA is identical to the quantity information in cost accounting, the principles described in this document also serve cost accounting and thus improve the quality of the information content of the BIM models more broadly.

The structure of the report

The structure of the rest of the report is as follows:

- Section 1 introduces a process of using Building Information Modelling (BIM) for building Life Cycle Assessment (LCA). It discusses the challenges for employing BIM models in LCA calculations, emphasizing the need for accurate quantity take-off and data specification. It also outlines steps towards automating BIM-based LCA and the key principles for calculating embodied emissions using BIM. Additionally, it addresses the organization of data for quality assurance and the scope of Nordic climate declarations in the context of building LCA.
- Section 2 presents the LCA requirements and data availability in different building project phases.
- Section 3 provides instructions for BIM-based material inventory.
- Section 4 discusses supplementing BIM data from external sources.
- Section 5 guides the transferring of data from BIM tools to LCA tools
- Section 6 guides the iterative design and analysis workflow between BIM and LCA tools.
- Section 7 provides an example for information take-off for LCA calculations
- Section 8 details the design principles of the example buildings, a residential and an office building, which were developed. The models of these buildings

can be used to demonstrate how BIM models support BIM-based building Life Cycle Assessment (LCA). The section presents the multidisciplinary design team involved and explains the availability of BIM models under a Creative Commons license. The section also discusses the design process, the information content in models for different project phases, and the use of IFC for quantity data in LCA calculations.

The contents of the appendices are as follows:

- Appendix A provides a comparison of an LCA standard (prEN 15978) to IFC 4.3.
- Appendix B provides a comparison between several classification systems.
- Appendix C lists the BIM models and their authors
- Appendix D provides example BIM specification documents of the architectural, structural, HVAC, and electrical BIM models
- Appendix E provides links to educational videos supporting practitioners in learning BIM-based building LCA
- Appendix F provides instructions for BIM-based material inventory in native Nordic languages and in Estonian.

1. BIM-based building LCA process

A building information model (BIM) typically contains geometrical and alphanumerical information on the employed building products. During a construction project, different design fields produce BIM models: depending on the design stage, there may be an architectural model, a structural model, and an HVAC and electrical model. All these models contain quantity information that can be employed in building life cycle assessment (LCA) to assess embodied emissions. Figure 1 depicts different stages of data flow required to convert BIM data to usable LCA results.

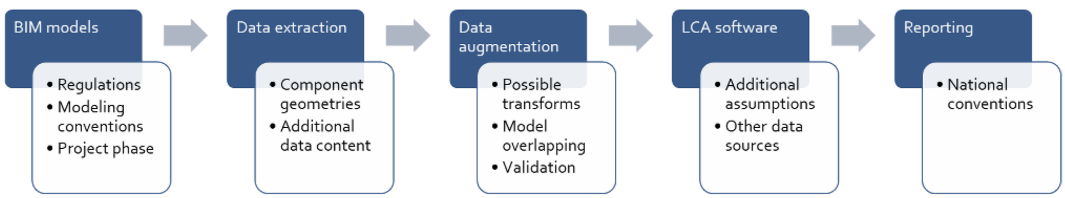


Figure 1. The phases for using BIM for building LCA

The BIM contents were not designed originally with LCA in mind; thus, there are many issues regarding data usability in the current state of modelling. These are related to, for example, reliability in quantity take-off, data specification in property sets, object labelling and model coordination. This work establishes guidelines for how BIM models can be used more in LCA calculations. This is done to support existing BIM modelling conventions and specify minimum requirements for additional information from an LCA point of view. Minimum additional information content in the models and other documentation conventions that support data retrieval from supplementing sources are specified. Best practices are established on how the BIM information can be amended and how overlapping between BIM models is handled.

Figure 2 establishes the steps required to transform the status towards automated BIM-based LCA. As more steps are taken, increasing demands arise on data quality, availability, and the amount of modelling work, among other things. This proposed process aims to take the first step in enabling reliable material take-offs for LCA purposes and establishing conventions on data processing. Further automation is left for the future. The first and second steps are likely to be reached rather quickly. However, to reach the full automation step may take several years due to required integrations with authority systems in countries.

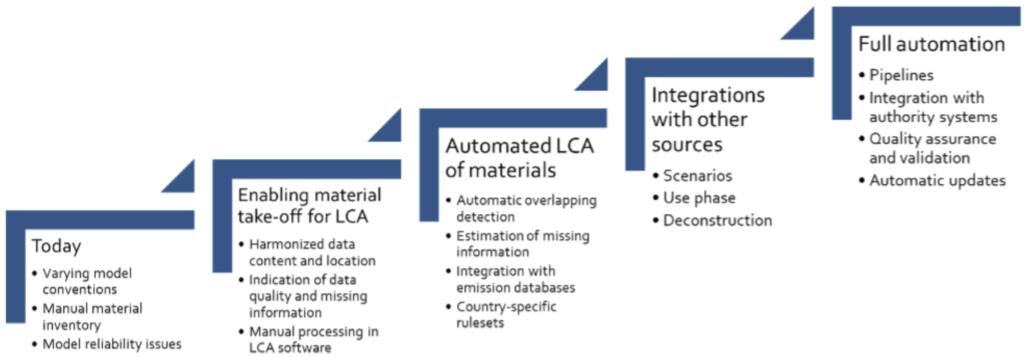


Figure 2. Steps towards automated building LCA

1.1. Key principles for BIM-based embodied emissions calculation

BIM-based embodied emissions calculation as part of a building life cycle assessment (LCA) requires that the type data (products and materials), quantities (dimensions) and function in the building (e.g. external wall, intermediate floor) are correctly modelled in the building information model (BIM). Defined entities and properties should be specified in the BIM specification document so that the background information for the model is available.

One of the basic features of a three-dimensional, BIM-based design model is that it produces quantity data with a high degree of accuracy. The degree of accuracy of the data that can be read from the model depends on the precision of the modelling and the modelling approach. However, the coverage of the models is more important. For example, if the model is missing 10% of the walls, the accuracy of modelling a single wall is no longer relevant. The extent of the elements in the model should correspond as closely as possible to the object to be built.

However, it is not worthwhile or possible to model everything. This depends on the technology used, the design phase's information content, and the modelling resources. For example, it can be very time-consuming to include all equipment in a model compared to listing them in a spreadsheet. In this case, the benefits achieved are not in balance with the time and cost involved. On the other hand, not all equipment and materials are known precisely, especially in the early stages of a project, so it is not even possible to model them. To make reliable use of the quantitative information from the models, it is necessary to know what has been modelled on them and, on the other hand, what information needs to be sought elsewhere.

The IFC standard data structure would allow material and product information to be included within the IFC model. However, there are two problems with this. The technical problem is that the most popular software tools used for BIM-based design do not support storing the type-based design data, i.e. the planned products and materials, in the design models. Some of the data would, therefore, be outside the model in any case.

The second, more significant problem relates to the process. During the construction phase, the designer is still responsible for updating the BIM model, but the contractors manage the type data for as-built products and materials. These parties often do not have a contractual relationship to take responsibility for updating the type data in the design model. To ensure the integrity of the data, it is therefore advisable to hold the contractor responsible for data management. The key between the element in the design model and the material and product catalogue maintained by the contractor is the element type identifier.

To link type information maintained in non-model records to elements in design models, type records must be in a machine-readable format. The simplest way to store type data is to use spreadsheet software. However, any spreadsheet format is not machine-readable; it must be standardised. In this project, a spreadsheet in Excel format was developed. It was programmatically converted into a structured XML format and then back to the original Excel spreadsheet format (roundtrip). This proof-of-concept implementation was intended to ensure that a simple spreadsheet, which does not require any special software investments by designers or contractors, can maintain machine-readable data linked to design model elements. However, as mentioned above, the format of a spreadsheet must be very formal and its content should be able to be automatically converted into a structured data model and vice versa.

Figure 3 illustrates the principles of typing elements in architectural design BIM models. Each element shall be defined with the correct IFC class, predefined type, and required properties in the design model. This information can be used to filter the IFC model by element group, making it easier to organise and check the information that can be read from the models.

Each building and product element type in the IFC model is assigned a project-specific type identifier (e.g., US-1). These type identifiers allow the elements to be linked to external material and product data maintained in a machine-readable format, e.g., in the spreadsheet described above.

Three-dimensional IFC elements, corresponding to real building and product elements, can be used to generate the quantity data for each element. Depending on the elements, the quantities can be read from the model as lengths, areas, volumes, or numbers of elements.

The quantity data of the IFC model are transferred to the LCA calculation software. However, it should be noted that the IFC model contains quantitative data only for the elements to be implemented. Waste materials, formwork, supports and other temporary structures must be considered separately. In addition, the LCA software shall contain quantitative estimates for elements not included in the design model.

The project-specific type identifiers in the IFC model can be used in the LCA calculation software to link the breakdown structure and product data for each element.

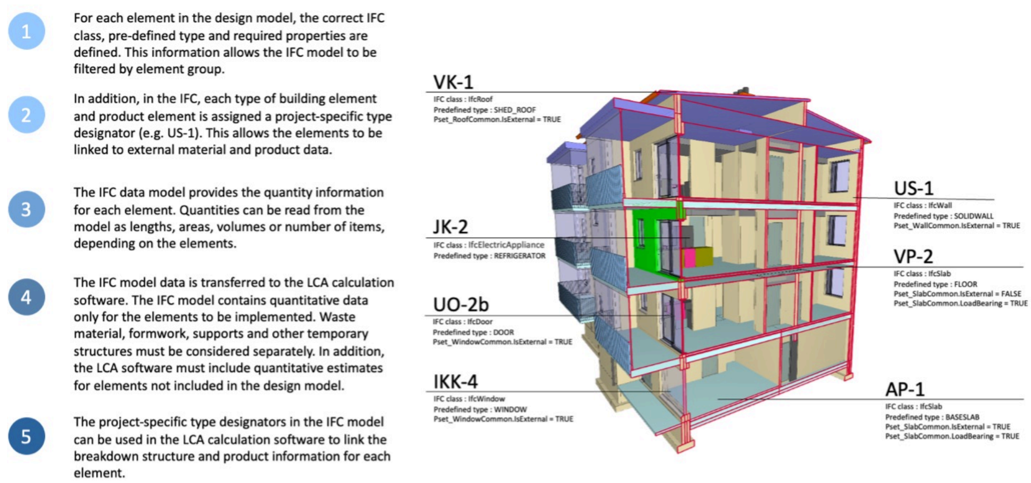


Figure 3. Use of the IFC model to calculate the carbon footprint of a building

1.2. Scope of Nordic climate declarations

Regardless of the differences in assessment methods (e.g., building parts to be included) between the Nordic countries, the basic requirements and principles for modelling are the same. Table 1 displays a comparison of scopes included in assessment methods in Nordic countries.

The national assessment methods regulate system boundaries and the level of detail in reporting on building life cycle assessments. The scope of the assessment methods varies between countries. This BIM to LCA process description intends to enable better data flow from the models to the LCA calculation, regardless of the data content and handling of the actual LCA calculation. Table 1 displays the scope of the assessment methods for reporting and calculation. The national building part labelling is required to be provided as information in a suitable information field. Reporting with the national building part labelling enables, e.g., the assessment of the impacts of using different materials in building parts.

Table 1. Coverage of national assessment methods.

Included building parts		Denmark BRsB	Estonia Proposed draft method for climate declaration (2021)	Finland Climate declaration	Iceland Climate declaration proposal (under development)	Norway TEK17	Sweden Climate declaration (2022)	Sweden Limit values 2025 Climate declaration 2027 (Boverket's proposal)	Europe LEVEL(s)
Site preparation		-	-	Soil stabilisation and site reinforcement elements	-	-	-	Reported from 2027	?
Substructure	Foundations	x	x	x	x	x	x	x	x
	Piling	x	x	x	x	x	-	Reported from 2027	?
	Basement walls	x	x	x	x	x	x	x	x
	Ground floor structure	x	x	x	x	x	x	x	x
Super-structure (external elements)	The frame (columns and beams)	x	x	x	x	x	x	x	x
	External walls, facade	x	x	x	x	x	x	x	x
	External doors, windows	x	x	x	x	x	x	x	x
	Balconies	x	x	x	x	-	x	x	x
	Roof structures	x	x	x	x	x	x	x	x

Super-structure (internal elements)	Internal walls, load- and non-load bearing	x	x	x	x	x	x	x	x
	Floor slabs	x	x	x	x	x	x	x	x
	Internal doors	x	x	x	x	x	x	x	x
	Stairs and ramps	x	x	x	x	-	x	x	x
Internal finishes	Wall and ceiling interior finishes and coverings	x	x	x	x	x	-	x	x
	Flooring materials	x	x	x	x	x	-	x	x
	Suspended ceilings	x	x	x	x	x	x	x	x
Building services	Lifts and escalators	x	x	x	x	-	-	**only for building types in Group 1**	x
	Electricity system	-	x	-	x	-	-	**only for building types in Group 1**	x
	HVAC systems	x	x	x	x	-	-	**only for building types in Group 1**	x
	Renewable energy systems	x	x	x	x	-	**Only building integrated solar panels**	**All panels in 2025**	x
	Water system	x	x	x	x	-	-	**only for building types in Group 1**	x

	Sewage system	x	x	x	x	-	-	x	x
	Other systems (e.g., firefighting)	-	x	x	x	-	-	only for building types in Group 1	x
External works		**Only if included in the area definition**	-	only external structures in the yard	-	-	-	-	x
Furnishing	Fixed furniture	-	-	x	-	-	-	only for building types in Group 1	x
	User furniture	-	-	-	-	-	-	-	-
Floor area	Heated net floor area	-	x	x	-	-	-	-	-
	Gross floor area	-	-	-	x	x	x	x	x
	Reference area, heated gross floor area	x	-	-	-	-	-	-	-

Limit value scope
Climate declaration scope
Proposed limit value scope
Proposed climate declaration scope

Source: Nordic Sustainable Construction, 2024

1.3. Organisation of data

Quality assurance can be divided into the validation of the usability of information in the BIM and the validation of the assessment results. The quality assurance follows the requirements for calculation and reporting. The BIM is prepared in line with the BIM requirements, and the information is precise, correct, and informative. Defined entities and properties are disclosed in the BIM specification document for easy access to information regarding the model. The availability of information supports the quality assurance and validation of correctness and analysis of uncertainties in LCA, which impacts assessments made during an early phase of the project.

It should be noted that the classification of building elements varies at the national level. What all classification systems have in common is that they tend to group building elements into logical categories. However, these logical categories can differ depending on the intended use.

One misconception is that the IFC standard (ISO 16739-1) is a classification system. However, this is not the case. IFC is a system of classes, not a classification system. This is not a semantic difference; it is a fundamental difference. A classification system typically describes a category of a building component in one dimension. A component defined by the IFC can implement the requirements of several different categories and classification systems simultaneously, depending on the attributes of the IFC entity. On the other hand, an IFC component is not independently associated with any particular category of the classification system. A classification system expresses a need that can be met by an IFC component.

Although classification systems are inherently perspective-dependent, they share significant similarities. This project aims to exploit these similarities and transform their needs into IFC standard specifications, producing a generic specification that can be adopted by any national classification system.

The system boundary for building life cycle information is set in the International Standard ISO 21930 and European Standard EN 15804/15978, which set out a common life-cycle model for building and construction works. The system boundary is common for all assessment methods, although national assessment methods differ in which life cycle stages are included in the assessment. ISO 16739-1 is the set standard for Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries.

1.4. Scope and purpose of this work

This instruction describes the process of extracting quantity data from building information modelling (BIM) to calculate and report emissions of materials in life cycle assessment (LCA). The aim is to suggest improvements in BIM models, to better support, optimise and unify life cycle assessments across the Nordic countries, and to unify and streamline the LCA calculation process itself. The work focuses on the method that enables the calculation of embodied emissions; the operational emissions are not extracted from the BIM models and are thus not in the report's scope. The LCA calculations may be based on the enhanced information take-offs as described in this document; the actual calculations themselves will be performed according to the national guidelines and are not within the scope of this work.

1.5. Possible pathways from BIM to LCA

There are two major pathways for calculating the life cycle effects of building components from BIM models. Domain-specific carbon calculation plugins provide one pathway. These plugins have been developed for various design software, such as Tekla Structures, Autodesk Revit and ArchiCAD. These tools are useful as they can give planners or designers instant feedback about GHG emissions, for example, when comparing alternative design solutions. The other pathway leads to a complete LCA for an entire building, which requires data beyond what is available in any single design software. Therefore, quantity take-off from BIM and import to an LCA tool is preferable for required normative calculations. This document focuses on the latter pathway.

2. LCA requirements and data availability in different project phases

All Nordic countries have either effective or planned legislation concerning mandatory carbon footprint calculations for certain building types. Limit values are also implemented or planned to be implemented in all countries. Voluntary carbon footprint calculations are made for various reasons, such as requirements from environmental certification schemes like LEED, BREEAM or DGNB or corporate or municipal strategies and roadmaps for sustainability. Depending on the purpose, LCA calculations can be performed at different stages in the design and construction process. The procedure for calculation remains the same throughout different stages, but the available BIM models and the included data differ.

In this document, the LCA required by legislation is referred to as normative LCA. It is useful to note that although legislation specifies a point at which the normative calculation must be done, this will likely not be the first time the calculation is made. Especially where limit values are in place, a preliminary calculation must be done early in the project to ensure compliance with the legislated limit when the time comes. This has been taken into account in the instructions of this document. In this way, LCA calculations resemble cost estimates: to stay within budget, regular check-ins are needed to ensure the project stays on target.

There are some national differences as to when the normative LCA is calculated (Figure 4). In Finland, Sweden, Norway, and Denmark, the carbon footprint calculation is based on as-built information and is submitted before the building inspection clears the building for use. In Estonia, the draft legislation requires normative LCA calculations to be reported along with the building permit. However, the stage for Estonian normative LCA is pending.

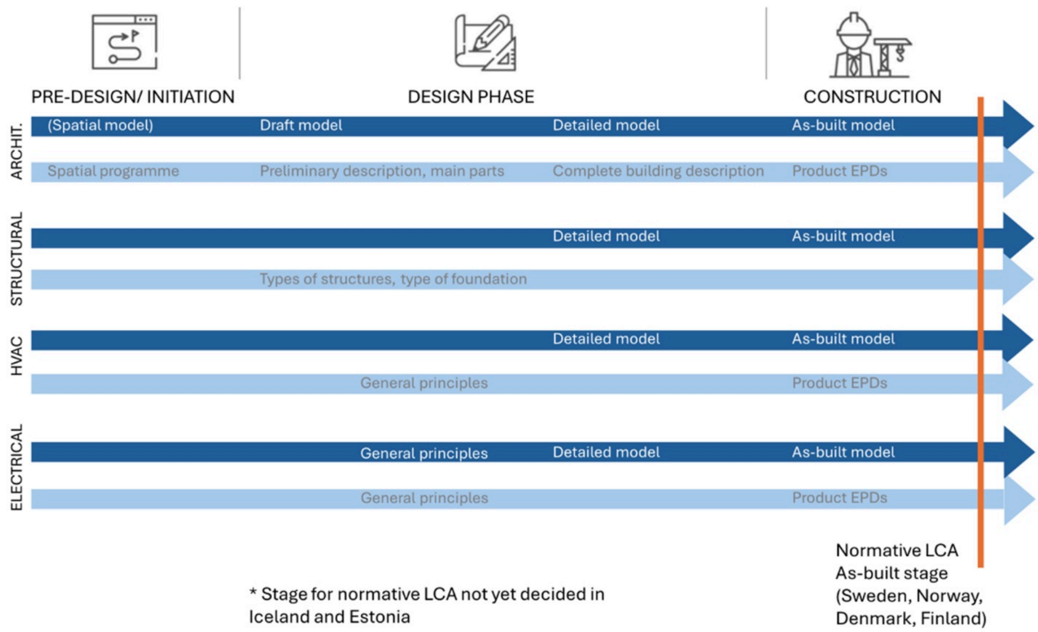


Figure 4. Stages of design and construction vs. normative LCA calculation in various Nordic countries

This difference in timing means that the data available from designers to be used in the normative LCA differs. The earlier the calculation is required in the construction process, the sparser and more inaccurate the information available is hence, more assumptions are required from the LCA specialist. At the building permit phase, only the architectural BIM model is typically available, with other disciplines either providing some data in other formats (structural engineering) or providing little or no data (HVAC engineering, electrical engineering). At the building permit stage, specific building products are mostly not yet defined; thus, product and material data are mainly based on generic data from national databases. Information regarding interior finishings and materials is typically also not available. Once the building is completed, the situation is different. All design disciplines have completed their BIM models, all materials are specified in some document (though not necessarily in BIM format), and all used products are known. However, not all chosen products have environmental product declarations (EPDs) available, which results in using generic data from national databases. The documentation conventions on installed products might still vary.

This BIM4LCA project has produced requirements for BIM-related information for normative LCA. The requirements include information that should be available during the building permit and as-built phases. The source of information in each phase has been identified as part of the work.

3. Instructions for BIM-based material inventory

This description focuses mainly on assessing carbon hand and footprint during the life cycle of a new construction project, not projects focused on renovating the existing building stock, as only one Nordic country, Norway, includes major renovations in its LCA-related legislation for the time being. It is important to note that due to the nature of LCA calculations of renovation projects, the requirements for BIM differ slightly in these types of projects. The following instructions have been translated into Nordic languages and Estonian (Appendix E: Instructions for BIM-based material inventory in native Nordic languages).

BIM modelling should follow the EN ISO 19650 standard series principles for building information modelling. Countries may have more specific national standards or guidelines based on this standard (e.g., "RAVA3Pro" in Finland, "Tillämpningsanvisningar BIM" being developed in Sweden, "SIMBA" for public buildings in Norway and DS/EN ISO 19650 and Molio's guidelines in Denmark). A European standard, CEN/TC 442, is also being developed. The EN ISO 19650 standard series includes conventions such as project information requirements and managing and storing model data.

3.1 General requirements for BIM

The information required for LCA is like the information needed for cost calculations. Building elements must be modelled so that the quantities are generated correctly in the design model and consequently exported correctly into the IFC model. For BIM to be most useful in LCA calculation, the general requirements for BIM modelling are:

- **High-quality modelling** - According to national best practices
- **Precise -** The model's contents are accurate, and the elements are modelled to be exported correctly into the IFC model.
- **Descriptive and informative** – The model's contents consider the needs of the end-users of the BIM.
    - A description file is provided along with the BIM model specifying which information fields contain relevant data and for what purposes the model is intended. Software may generate unintended

information, which may not be accurate, and thus, it is relevant to specify which fields are intended to be used.

- **Correct naming and categorising** - According to national standards or best practices (or project-specific naming, in which case the naming conventions must remain the same throughout the entire project)
    - All building elements are given descriptive type names, also used in other documents. For example, all wall elements with the same structure have the same wall type identifier defined in the BIM, which is also found in the structural plans. This enables the retrieval of information from sources outside of the BIM models.
    - When the manufacturer and product names of installed products are known (mostly in the case of as-built models), these are disclosed in the BIM to support the mapping of product-specific environmental product declarations (EPD). Alternatively, a mapping of product type names in the model to the installed products is provided externally.
    - If installed products are not specified, materials are named in a harmonised way throughout the models, utilising established classifications where possible. The materials are either recorded in the model or referenced externally with the type name in the BIM model.

3.2. BIM specification documents

The contents and modelling principles of the BIMs are documented and described in according to national best practices. The BIM specification format employed is based on a Finnish BIM specification convention.

The specification documents should disclose, for example, which information fields are generated in the information model. This is important, as software may generate information (additional fields automatically) that may not be accurate.

The specification document is also used as a tool for communicating information about the completeness of the model by indicating, for example, any assumptions made by the designer or any yet unmodelled elements. This is relevant, particularly for modelling done in the earlier stages of the design process. Information added as a draft (structure type, material, etc.) and subject to change should also be clearly indicated in the BIM specification document.

3.3. Required data in the BIM model for information take-off

Quantities and properties within BIM models are extracted through information take-off features in BIM or IFC software. Below are listed data that are required, at minimum, to perform LCA. The quantity take-off units are further discussed later in the section "Managing the overlap between BIM models".

LCA software may currently support direct IFC input, and these features may be employed in such cases. It is, however, worth noting that the programs' handling of preferred units may differ from the ones presented in this document. Here, we present how to extract information from the models and then import them into the LCA software. This way, if manual verification or conversion of quantities is required, they can be performed before importing the quantities to the LCA program. Manual selection of the structures may also be necessary if the building classification required by the normative LCA is not readily available in the BIM model or the modelled content differs from the LCA system boundary.

High-quality, precise, descriptive, and informative data in the information take-off increases the efficiency and accuracy of the process both during the export from IFC software and the import of information to LCA software. The most important requirements are listed in the following:

Building element

Building element classification is done according to the national best practices. The building element type is used to categorise emissions according to the building element. Categorisation according to the building element is crucial for the LCA assessment, as it enables component-level assessment.

Component type (class)

Crucial for the import of data to LCA software. Component types are, e.g. slab, column or beam.

Displays by which tool in the modelling software the component has been generated and enables a level of quality assurance that information is correct in the model.

Type (Reference)

Built element type according to national best practice and depending on what has been agreed on in the project. The reference is descriptive information about the element, which corresponds with naming in other design documents. For example, the built element type of a ground floor slab.

Quantity information

- **Volume -** Crucial for building elements for which the preferred unit is volume (m3)
- **Area -** Crucial for building elements for which the preferred unit is area (m2).
- **Linear meter -** Crucial for building elements for which the preferred unit is length (m).
- **Number of pieces -** Crucial for building elements for which the preferred unit is the number of units (unit).

Material

Material information is used to describe the material used in the structure. Displays the material used in the component, e.g., wood, concrete, or steel. Additional information related to the material, such as the strength class of concrete, may be disclosed in sources for supplementary data. Displays the thickness of material layers in structure (when available).

Total thickness

The total thickness of a structure is crucial, especially for components of the structural frame.

3.4. Managing the overlap between BIM models

Architectural and structural BIM models are the main sources of information for life cycle assessments. Information on building parts not available in any BIM model (e.g., internal finishes and number of elevators) must be supplemented from other design documents. The availability of information depends on the stage of the modelling. LCAs often require estimating material and amounts in project phases where designs are not yet available or quantity take-off from the model cannot be performed. This is especially typical for early-phase assessments. Draft information may be added to the BIM to support the early phase LCA. However, such information should be clearly labelled as a draft to inform the LCA specialist that the information is subject to change. It is recommended that information on the maturity level is disclosed in the BIM description document or in a part of the model where it can be easily identified by the life cycle assessor.

Based on the EN 15978 standard, Table 2 describes the recommended BIM model to be used as a material and quantity information source in building permit and as-built phases. Furthermore, the table shows with which units of measurement the relevant building elements are catalogued for LCA calculation from the BIM models. The table also shows if the information is based on a generic design-based estimate. This is often necessary, especially at the building permit stage, because accurate information on the building element is not yet available. If the preferred unit for the structure is area, length, volume or other information other than the number of units, then these measures are supplemented with additional information about the building part, such as the materials in the structure. Table 2 also presents the building parts which typically require assumptions.

The range of building elements included in each national assessment method varies, and thus, not all categories presented are necessarily included in the national assessment method for all countries. The BIM model is recommended to include the building element classification according to the national best practices.

Table 2. The breakdown structure and phasing of the components in BIM models

Arch BIM = architectural BIM; Arch design = architectural design; no of units = number of units; QTO = quantity take-off; *Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method.

prEN 15978*			QTO	Lifecycle stage	
Building parts	**Building elements and processes**		**QTO**	**Building permit**	**As-Built**
Pre-construction works	Facilitating works	Temporary/Enabling works			
		Specialist groundworks			
	Work on the existing building	Demolition and alterations			
Substructure	Foundations		m^3	Structural estimate	Structural BIM
	Piles		m	Structural estimate	Structural BIM
	Basement walls		m^2	Arch BIM	Structural BIM
	Retaining walls		m^2	Arch BIM	Structural BIM
	Waterproofing		m^2	Arch BIM	Arch BIM
	Ground floor construction		m^2	Arch BIM	Arch BIM
Superstructure	Frame	Columns	kg (steel structure), m^3 (concrete, wood)	Arch BIM	Structural BIM
		Beams	kg (steel structure), m^3 (concrete, wood)	Arch BIM	Structural BIM
		Shear walls	kg (steel structure), m^3 (concrete, wood)	Arch BIM	Structural BIM
	Upper floors		m^2 (net area)	Arch BIM	Arch BIM
	Balconies		square meters, meters	Arch BIM	Structural BIM

	Roof	Roof structure	m^2	Arch BIM	Arch BIM
		Weatherproofing	m^2	Arch BIM	Arch BIM
	Stairs and ramps		m^3	Arch BIM	Arch BIM
Fabric	External envelope	External walls	m^2 (net area)	Arch BIM	Arch BIM
		Windows	No. of units	Arch BIM	Arch BIM
		External doors	No. of units	Arch BIM	Arch BIM
		Shading devices	No. of units	Arch BIM	Arch BIM
	Internal walls	Internal walls – load bearing	m^2 (net area)	Arch BIM	Structural BIM
		Internal walls – non-loadbearing	m^2 (net area)	Arch BIM	Arch BIM
		Internal doors	No. of units	Arch BIM	Arch BIM
Finishes	External finishes	Cladding	m^2	Estimate, based on arch design	Arch BIM
		Coatings	m^2	Estimate, based on arch design	Arch BIM
	Internal finishes	Wall finishes	m^2	Estimate, based on arch design	Arch BIM, based on room geometry
		Raised floors	m^2	Estimate, based on arch design	Arch BIM, based on room geometry
		Floor finishes	m^2	Estimate, based on arch design	Arch BIM, based on room geometry
		Ceiling finishes	m^2	Estimate, based on arch design	Arch BIM, based on room geometry

Building services	Water systems	Hot water distribution	m (pipes, insulations), No. of units	Estimate, based on arch design	MEP BIM
		Cold water distribution	m (pipes, insulations), No. of units	Estimate, based on arch design	MEP BIM
		Water treatment systems	m (pipes, insulations), No. of units	Estimate, based on arch design	MEP BIM
		Rainwater systems	m (pipes, insulations), No. of units	Estimate, based on arch design	MEP BIM
	Sewage systems		m (pipes, insulations), No. of units	Estimate, based on arch design	MEP BIM
	Lighting	Internal lighting	No. of units	Estimate, based on arch design	MEP BIM
		External lighting	No. of units	Estimate, based on arch design	MEP BIM
	Electricity generation and distribution		m (wires), No. of units	Estimate, based on arch design	MEP BIM
	Renewable generation systems		No. of units	Estimate, based on arch design	MEP BIM
	Heating systems		No. of units	Estimate, based on arch design	MEP BIM
	Cooling systems		No. of units	Estimate, based on arch design	MEP BIM
	Ventilation systems		m (ducts, insulations) No. of units	Estimate, based on arch design	MEP BIM
	Conveying systems		No. of units	Estimate, based on arch design	MEP BIM
	Telecoms and data systems		No. of units	Estimate, based on arch design	MEP BIM

	Fire protection systems		m (pipes), No. of units	Estimate, based on arch design	MEP BIM
	Communication and security installations		m (wires), No. of units	Estimate, based on arch design	MEP BIM
Additional categories not specified in prEN 15978					
Accessories	Furniture systems	Built-in furniture	No. of units	Estimate, based on room types	Arch BIM
		Movable furniture	No. of units	Estimate, based on room types	Estimate, based on room types
		Appliances	No. of units	Arch BIM	Arch BIM
		Sanitary fittings	No. of units	Arch BIM	MEP BIM
	Transportation systems	Elevators	No. of units	Estimate, based on room types	Arch BIM
		Escalators	No. of units	Estimate, based on room types	Arch BIM
		Mowing walkways	No. of units	Estimate, based on room types	Arch BIM
		Craneways, lifting gear and other transport elements	No. of units	Estimate, based on room types	Arch BIM
	Safety systems	Railings	m	Arch BIM	Arch BIM
		Handrails	m	Arch BIM	Arch BIM
Areas	Gross floor area		m^2	Arch BIM	Arch BIM
	Net room area		m^2	Arch BIM	Arch BIM

Appendix A: prEN 15978 comparison to IFC 4.3 (ISO 16739-1:2024) shows how the EN 15978 building component categories are expressed according to EN ISO 16739-1, the IFC standard. IFC, Industry Foundation Classes, is not a classification system. In contrast, in a BIM model according to the IFC standard, the identification of building elements requires a class, a class subtype and often also property attributes. Under the IFC standard, these are called IFC entity class, PredifinedType and property (grouped into property sets). For example, to identify a building component group 'exterior walls' in the IFC model according to EN 15978, all components belonging to it must have the class IfcWall, the PredefinedType SOLIDWALL and the IsExternal property of the Pset_WallCommon group set to TRUE.

Building elements and components that may be included or excluded in the BIM (such as parking garages, often included in BIM but not necessarily included in LCA) are agreed upon separately in the project, and included or excluded elements are documented in the building information model description. The inclusion or exclusion of building elements may vary depending on the local best practice and building area specification used. The inclusion of building parts relevant to the defined assessment method is ensured through quality assurance of the calculation.

4. Supplementing BIM data from external sources

4.1. Sources for supplementary data

BIM data is typically supplemented using external sources when BIM information is unavailable. Typical sources for supplementing information are:

- Structural design documents with information on e.g.:
    - Design of steel rebars e.g., 8-150 rebar net.
    - Material details, e.g., Ready-mix concrete C30/37.
- Architectural design documents with information on e.g.:
    - Surface/room descriptions
        - Surface materials
    - Paved and green areas and site constructions according to ground plan/site layout.
    - Brick and mortar mass, calculated separately depending on the size and type of bricks.
    - Mass of steel profiles in internal walls
    - Box units (Assessment is challenging due to lack of available EPDs for box units)
    - The number of elevators and escalators, building height does not currently impact the quantity of equipment (e.g. a 3-floor and a 10-floor elevator produce the same calculation outcome)
- Building services design documents (when not included in the nationally predefined values):
    - Masses of the building service components
    - Large-size technical equipment, such as hospital equipment, is supplemented from other design documents.

Building services are included in the Finnish assessment methodology; Sweden and Norway leave out all technical equipment, and Denmark leaves most plumbing-related parts out from the calculations.

- Energy reports and design documents, depending on the building's heating/cooling source (geothermal) and electricity source (e.g., solar panels).

- Area of solar panels
- Design specification of geothermal systems such as:
    - Length of geothermal probes
    - Effect of heat pumps

The area used in life cycle assessment varies by country and assessment method. Finland and Estonia use the heated net area from energy reports. Sweden and Norway use the gross floor area from building descriptions. Denmark uses the reference area for embodied emissions and the heated gross floor area for operational emissions. The used area should be included in the BIM model.

4.2. Material assumptions

When calculations require making assumptions about materials, the employed assumptions should be documented. Assumptions should be based on the best available knowledge and expertise, such as benchmark data or generic manufacturer estimates. LCA tools provide usable generic material assumptions that may be used in calculations when detailed information is unavailable.

4.3. LCA documentation

LCA reporting is done according to the national LCA reporting requirements or another applicable standard. The reporting requirement also applies to disclosing employed source data, scope, assumptions, and environmental product declarations (EPDs). The main assumptions should also be documented and provided transparently to the client with the LCA results.

It is recommended that the LCA expert keeps track of the employed data sources and supplements information in a manner that enables straightforward calculation revision. For example, if LCA calculations are first performed in an early design stage and the models are updated, the analyst can revise the sources of previous data and compare differences.

5. Guidance for transferring data from BIM tools to LCA tools

The BIM4LCA project developed guidance for transferring data from BIM tools to LCA tools. The possible pathways for BIM data to LCA have been described in previous chapters. This guidance focuses on the phase from data extraction from IFC to open format. The process of transferring data from BIM tools consists of the steps presented below.

In the BIM tool, select and sort the data required for the LCA. The information to be extracted from IFC has been described in previous chapters; however, the quantity information and identifiable information, such as building element and component type, shall be included in the information take-off (ITO). ITO features are part of BIM tools, enabling information take-off from the BIM model.

In the ITO, data is extracted from the BIM model to be used in other tools, such as LCA tools. This data is typically enriched with data from external sources, as described in previous chapters, and may require an intermediate stage in a spreadsheet editor. Information enrichment is an important part of the data transfer process from BIM to LCA. The data is extracted from the BIM in an open format, which enables the processing of the data and necessary modifications to easily import the data to the wanted LCA tool. When importing data to LCA tools, the LCA expert should ensure that all information from the ITO is imported correctly to the LCA tool to ensure the assessment's quality.

When information has been extracted from the BIM to open format, the LCA expert must supplement the data with information from other sources. Typical sources for supplementing information, as described in a previous chapter, are architectural and structural design documents, and building services design documents. Other typical sources are energy reports and design documents featuring information such as the building's energy consumption and energy sources. Integration with emission databases happens in the chosen LCA tool. It is recommended that quality assurance of information is done for data imported to LCA tools.

Six-step checklist for transferring data from BIM tools to LCA tools:

1. Identify the data required: Select and sort data that is required for the LCA
2. Export data from the BIM tool: Generate an information take-off (ITO)
3. Supplement the data with information from external sources, such as design documents.
4. Import data into the chosen LCA tool
5. Verify data accuracy: Perform quality assurance
6. Perform LCA analysis using the imported data.

6. Guidance for iterative design and analysis workflow between BIM and LCA tools

LCA calculations for climate declarations can be utilised for decision-making during design by providing insights into the environmental impact of different design options. The availability of data depends on the project phase. As described in previous chapters, the information matures as the design proceeds. Also, the recommended source of information changes for specified building parts depending on the design phase.

At an early stage in the design, the LCA expert may need to supplement more information and make assumptions based on expertise and best available knowledge than at a later stage in the project. To ensure the robustness of a life cycle assessment, any significant data gaps may be covered with conservative assumptions for building elements. However, any assumptions made must be declared in the report. The assumptions must be based on average or generic data and be justified based on the expertise of the LCA assessor. A declaration of assumptions enables iteration of the life cycle assessment when design data becomes available. Typical situations where data gaps may exist are during the early design phase; however, once the design process advances, the assumptions will be replaced with design data.

Incremental design changes occur during the design process, which may impact and require reassessing the LCA. Incremental changes may be made directly in LCA tools. Incremental changes may also be identified from BIM. Two BIM models can be compared using, for example, BIM software, and differences in, e.g., geometry and properties can be identified. The building information model description document also enables a comparison of models and the identification of changes and differences in the models. The LCA expert is responsible for documenting the used information and assumptions made in the LCA. Documentation of any changes made to the LCA is especially important for the iterations of the LCA. Well-documented steps ease the iterations of the LCA at later phases of the project.

7. Example for information take-off for LCA calculations

The LCA calculations required for the normative LCA declarations are calculated in LCA software according to the national guidelines. Information extraction features in the LCA software may be employed, but the information may be extracted for each building part separately and then transferred to the LCA software after supplementing the information with, for example, properties in other documents.

This example considers the external wall of the concrete office building. Other building parts are handled in a similar way, with specifications, such as recommended quantity units, detailed in previous chapters. Previous chapters describe the coverage of national assessment methods and building elements to include in each assessment method.

In Figure 5, building element US-1 is selected for the ITO. The unit for the building element is the net area in square meters. The ITO is reported to a spreadsheet report. The material information for the building element can be found in the BIM. However, the information is supplemented by structural design documents on the thickness of different materials in the built element type and from the architectural design documents on the internal and external finishes. The quantity of each material is based on the net area of the built element. After supplementing the needed data to the spreadsheet editor, the information is imported to the chosen LCA tool for the assessment. In the LCA tool, BIM data is combined with other information, such as energy information, to create a holistic LCA.

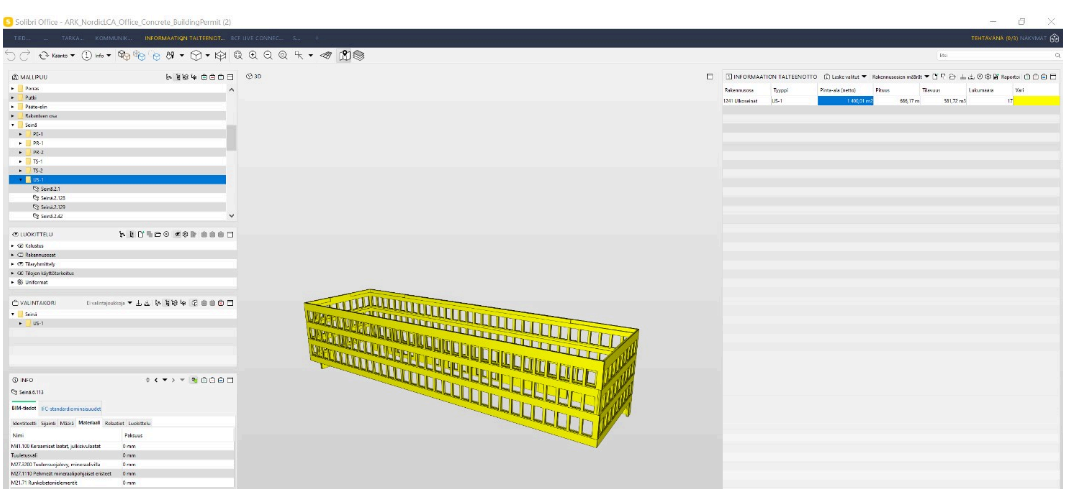


Figure 5. The external wall (Type: US-1) of the concrete office building in Solibri.

8. BIM models supporting the BIM-based building LCA

8.1. Example buildings' design principles

To investigate and demonstrate how modelling supports BIM-based building LCA, the project developed two example buildings and their sites: a residential building (Figure 6) and an office building (Figure 7). Both buildings are designed with a wooden and a concrete structure. The buildings are designed according to the Finnish Construction Act and building codes. The design principles emphasise the life-cycle properties of buildings, e.g., multi-purpose usability, adaptability, and access to natural light. Both buildings are modelled as wooden and concrete structures. The structural material versions of both buildings start from identical room layouts. The differences caused by the materials of the structures are therefore reflected in small differences in the floor areas and volumes of the buildings.

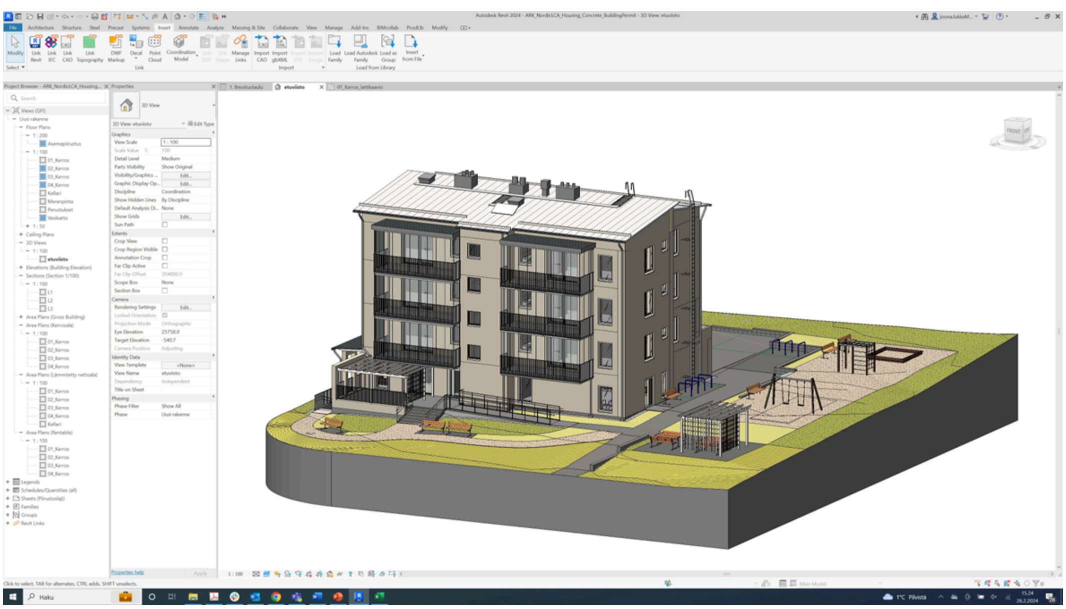


Figure 6. A concrete residential building in Revit.

The residential building is designed to provide housing for residents who may need care services but want to live with or close to their families. The building consists of half of the apartments designed for service housing for families and half of the regular family apartments. The building is narrow in width, and all apartments have windows opening on three sides, allowing good natural light and flexible furnishing.

On the ground floor, there is a shared space. Next to the shared space, there is a sheltered outdoor terrace with a pleasant microclimate.

On the basement floor, there is a rentable space that supports services and possibilities for social functions for the residents. The shading structures of the facades are made of recycled materials. Accessible parking spaces are located on the ground floor, with direct access to lifts and apartments. Other parking spaces are in the external car shelter.

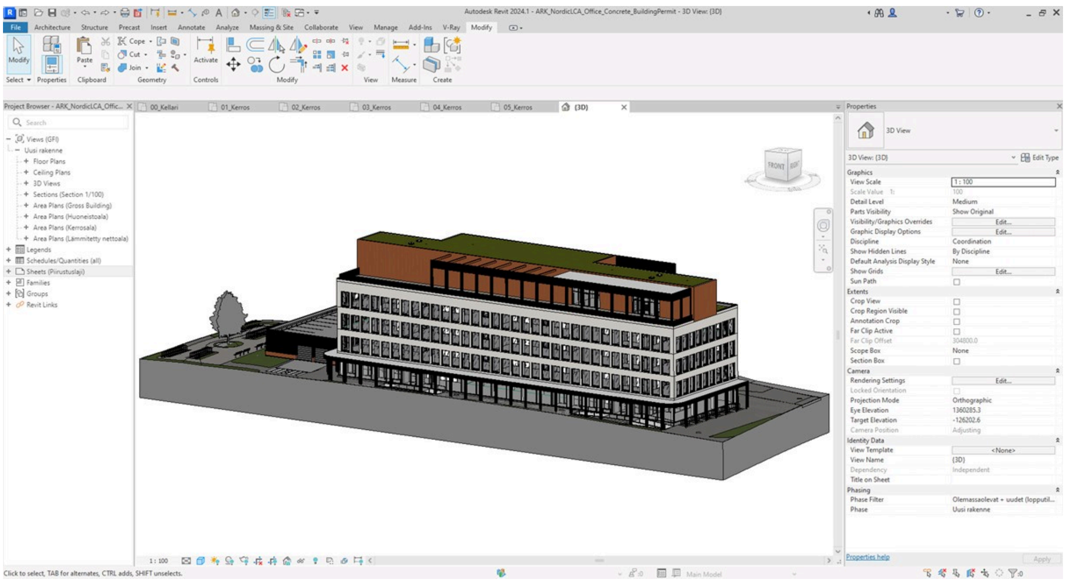


Figure 7. A concrete office building in Revit.

The office building is designed to provide flexible office space and recreational and exercise facilities for the company's employees. MEP and electrical solutions have also been implemented in a way that allows for flexible combining and sharing of spaces. On the ground floor, there is a restaurant, a cabinet space for meetings and a space for an office hub that serves the building but also other teleworking people in the neighbourhood. The three floors with office space can be divided for 1-4 different users. The building's narrow width provides good natural light to all working spaces. To reduce the heat loads from the sun, a shading system has been designed for the south-west façade.

There is a gym in the garage and a sauna and roof terrace on the top floor. In a post-COVID work culture, the service facilities respond to the need to attract employees back to the office. In the future, if the need for office space in the area decreases, the service spaces will create opportunities to convert the building to other uses (e.g. hotel) during its life cycle. To allow for future flexible use of the site, car parking has also been provided on two levels in a separate building attached to the main building.

8.2. Several design disciplines

Both buildings and their versions consist of several native models and their IFCs: architectural, structural, electrical and heating, ventilation and air conditioning (HVAC) systems. Wood-framed buildings also include sprinkler systems. The design team was led by architects from Huvila Oy. Gravicon was responsible for the structural design, and Granlund was responsible for the HVAC, sprinkler, and electrical design. VTT managed the overall design process, ensuring all design disciplines followed the design schedule and commonly agreed design principles and produced BIM specification documents.

In all design phases of the project, the disciplines carried out the design work solely by modelling. As a result, several model versions were produced (Table 3). All the models are available on the Nordic Sustainable Construction website[5]. They are free for anyone to use under the Creative Commons license (CC BY-SA 4.0).[6] Figure 8 shows the folder structure of the models. For example, under ARCH (architecture), ArchiCAD files are to be found under the ARCHICAD folder, Revit files under the REVIT folder, IFC files under the IFC folder and BIM specification documents under the SPECIFICATIONS folder. Electrical models are under the HCAC folder and MAGICAD-FOR-REVIT folder.

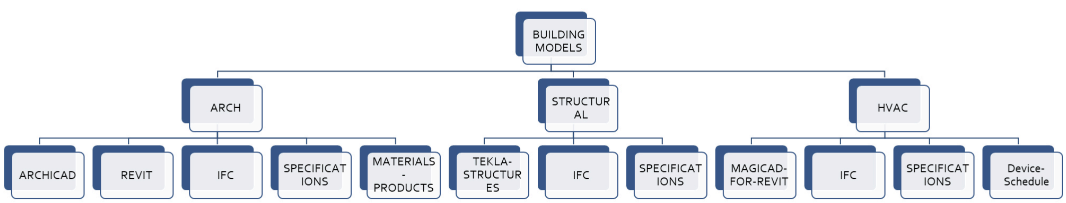


Figure 8. The folder structure of models on the Nordic Sustainable Construction website.[7]

A list of the people who have created the BIM models for this BIM4LCA project can be found in the Appendix C: BIM model authors and BIM file names. The appendix includes the names of the BIM files.

5. https://www.nordicsustainableconstruction.com/knowledge/2024/august/bim4lca-files
6. Creative Commons license (CC BY-SA 4.0), available from https://creativecommons.org/licenses/by-sa/4.0/deed.en
7. https://www.nordicsustainableconstruction.com/knowledge/2024/august/bim4lca-files

Table 3. BIM models and IFCs produced in the project

Design model	Wooden		Concrete		Site models	IFC files
Architectural building permit models	**Residential** building in Revit	**Office** building in Revit	**Residential** building in Revit	**Office** building in Revit and ArchiCAD	Residential and office building sites for Wooden and Concrete versions in Revit, Office building site in Archicad	As many as the native models = 10 IFC files
Architectural as-built models	**Residential** building in Revit and ArchiCAD	**Office** building in Revit	**Residential** building in Revit	**Office** building in Revit	Residential building site in Archicad	= 2 IFC files
Structural models	**Residential** building in Tekla Structures	**Office** building in Tekla Structures	**Residential** building in Tekla Structures	**Office** building in Tekla Structures		= 4 IFC files
HVAC models (Wood frame also includes sprinkler - systems)	**Residential** building in MagiCAD for Revit	**Office** building in MagiCAD for Revit	**Residential** building in MagiCAD for Revit	**Office** building in MagiCAD for Revit		= 4 IFC files
Electrical models	**Residential** building in MagiCAD for Revit	**Office** building in MagiCAD for Revit	**Residential** building in MagiCAD for Revit	**Office** building in MagiCAD for Revit		= 4 IFC files

8.3. Two frame material options

Two different frame material options were produced for each building: concrete and timber frame (Table 4). The aim was to keep the buildings' functionality unchanged regardless of the frame material. The material influenced, among other things, the distance between the floors of both buildings. This approach was used to simulate the impact of the frame material options on the LCA.

The buildings' frame structure is based on prefabricated production. The spaces and built components are organised in the models according to the Finnish interoperability specifications. The Finnish definitions are published on the National Interoperability platform, which provides tools for defining interoperable data content.[8] The Digital and Population Data Services Agency maintains it. The definitions reflect national conventions on dividing building components, and they may impose some rules on LCA in national contexts.

Table 4. Description of the building types.

Residential building (wooden and concrete structure)	Office building (wooden and concrete structure)
· Ground floor with service spaces + 3 floors with apartments (half designed for service housing for families, half regular family apartments: window orientation in each to 3 directions) · A basement with storage spaces · A garage · One stairwell with an elevator · Apartment-specific ventilation system · Wooden structure version: Load-bearing wood frame structure walls with wood panel facades · Concrete structure version: Load-bearing concrete walls with brickwork facades	· Ground floor with restaurant /other public functions + 3 floors with flexibly dividable office space (narrow building width for minimising dark room spaces) · A basement with a bomb shelter, employee facilities and storage space · A garage · Two stairwells with elevators · A top floor with a semipublic reservable sauna, roof terrace and ventilation engine room · Wooden structure version: Wooden column and beam structure, wood panel facades · Concrete structure version: Concrete column and beam structure, siding panel facades

8.4. Building design process

Although the buildings developed in the project are not intended to be built, the project closely simulates the actual design process. The design process started with the architectural design. After the first design versions were completed, the rest of the design team started to develop their own designs with a technical review of the architectural design. This review produced many changes. These changes aimed to rationalise the technical solutions and make the buildings as realistic as possible. At the same time, however, the ambition was to maintain the original architectural objectives.

8. Interoperability platform, available from https://dvv.fi/en/interoperability-platform, accessed 29.5.2024.

Once the main principles of the structural solutions and building services had been worked out, the design work moved on to the technical design phase. The team held weekly design meetings to solve small and large design problems in the same way as in real projects. During the whole process, the team also shared the developing versions of their models with each other.

While the technical designers were working on their own designs, the architects were finalising the designs corresponding to the information content of the building permit phase. Once the building permits phase models were ready, the architects started to collect material and product data for the as-built output. This was a deviation from a typical project where final data regarding materials and products is usually provided by the contractors.

8.5. Information content in the two phases of the project

The produced models cover both the building permit phase and the as-built phase. These stages define the information content of the models. Models in this context refer to the set of BIM models and their accompanying material and product descriptions in tabular form. Their interrelationship is explained in the chapter 'Key principles'. HVAC models represent both phases, following the current industry practice. More information on Finnish HVAC standardisation can be found in the external folder HVAC - 0_MEP_standardization_2024.docx.

The models at the building permit stage provide generic material information, which, in practice, are the requirements for product and material selection for the project. The as-built phase models provide more detailed information on selected products and materials. However, it is difficult or impossible to incorporate as-built information directly into IFC models because the contractor responsible for product and material procurement often cannot access the design models. Therefore, the product and material information are recorded in external spreadsheets (in this project, they are in Excel sheets in the folder "MATERIALS-PRODUCTS" of the Nordic Sustainable Construction website[9]).

Technically, material data could be included in an IFC model, but different software have slightly different ways of assigning materials to components, and the information is not consistent between components, even in models created with the same software. Another reason for separating material and product data into a separate file is in the process. In the construction phase, at the latest, responsibility for products and materials is transferred to contractors (of which there are several in different domains), while responsibility for the model's geometry remains with the designer.

9. https://www.nordicsustainableconstruction.com/knowledge/2024/august/bim4lca-files

By splitting the data into different records, the production of data does not create additional work for the parties involved. It is essential that in both BIM models and external records, building components have consistent type identifiers that can be used to link model components and external product and material data. The external record should be in a machine-readable format. This project developed a standard Excel spreadsheet to meet this requirement, which is adopted for all models produced in the project. Nevertheless, it would be more feasible for the data to be in an international standard format. However, no such international standard was yet implemented at the time of this project.

Geometrically, the models of the building permit and as-built phases are very close to each other. The architectural model for the as-built phase typically has some building services enclosures added, and possibly the dimensions of some walls or other structures have been updated. However, major changes are not even possible for residential homes for sale after sales activity has started. Further, the as-built phase models do not require any additions to precast element groups that were not included at the building permit stage.

8.6. Modelling standards

The main standards guiding the modelling have been EN 15978 (Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method) and EN ISO 16739-1 (Industry Foundation Classes or IFC for short). At the time of the project design and modelling work, an unpublished review version of EN 15978 was available. The version of EN ISO 16739-1 published in 2018 was mainly used, but also the version published in the first half of 2024, where applicable.

The data structure of the models is mainly governed by EN ISO 16739-1, i.e. the IFC standard. IFC has established itself globally as an open, software-independent data structure for model-based data exchange. The National Archives of Finland has adopted the IFC data structure in STEP format as an official archiving format. It will, therefore, be the data format that the building authorities will accept for BIM models under the updated Building Act from the beginning of 2026.

In Finland, IFC has been used in construction projects for two decades. However, the industry has not been able to harmonise the data content of IFC models, and there have been large variations between projects and design offices. This has complicated the automated extraction of data from the models. The machine readability requirements of the revised Building Act have mandated the standardisation of data content so that models can be used widely and in a standardised way, for example, in LCA calculations.

All BIM models in the project have been developed according to the principles published in 2012 in the Finnish Common BIM Requirements (COBIM2012). These requirements are based on the IFC standard. The breakdown structure of the models follows the system categories of EN 15978. Where necessary (e.g. furniture, railings and room areas), this standard approach has been supplemented by the requirements under the new Finnish Building Act as defined, for example, in the national RAVA3pro project. The EN 15978 categories correspond well to the IFC classes and the Finnish Talo2000 classification, so its use did not lead to any particular changes in the modelling. However, particular attention was paid to the type labelling of the elements in the model.

The national codes are recorded in the IFC models and may be employed through the material inventory lists in LCA software as per existing conventions. Although the example models are based on the Finnish code definition, the same data processing principles can be applied using different international classification and coding systems.

IFC 4.0.2.1 (ISO 16739-1:2018) does not provide sufficient coverage for identifying MEP product components using IFC standard entities and enumerations. For this reason, the identification of product components was implemented using national MEP product nomenclatures (see the folder HVAC - 0_MEP_standardization_2024.docx). The data structure, i.e., the feature sets and properties, had to be defined on a product-by-product basis. Each product-based property set, property, and property value were defined separately for each object, even if it represented type data.

The content of all models, including the standards and classification systems used, is documented in model-specific BIM specification documents following COBIM2012 requirements. The various disciplines' example BIM specification documents are listed in Appendix D: Example BIM specification documents.

8.7. Classification systems

The modelling requirements proposed in this report are independent of a particular classification. The classification system used has no technical impact on transferring element data to the LCA software. Still, it facilitates the grouping of quantity data from the IFC model according to the needs of the LCA calculation. Therefore, the classification system should provide an equivalent for the EN 15978 categories.

The BIM4LCA project developed together with a parallel project (Task 2"Data for LCA") a comparison table comparing the consistency of prEN 15978 and ISO 16739-1:2024 (IFC 4.3) in terms of design model data content (see Appendix A: prEN 15978 comparison to IFC 4.3 (ISO 16739-1:2024)). The BIM4LCA project also included a comparison between prEN 15978, IEC 81346-12 classification, the Swedish CoClass classification, the Talo2000 classification and the interoperability code sets and ICMS classification system (See Appendix B: Comparison between prEn 15978, ISO

81346-12, CoClass, Talo2000 and ICMS). The first version of the comparison was published in the final report of Task2 "Data for LCA" project.[10] Appendix A and Appendix B contain a slightly refined version of the same comparison.

The comparisons (Appendix A and Appendix B) show that a comprehensive mapping between the different classification systems, the IFC and the national code systems, is possible. From a BIM modelling context, EN 15978 contains, with a few exceptions, an adequate breakdown of the content of design models. When modelling for LCA purposes, the BIM4LCA project recommends that EN 15978 is the common starting point for the elemental breakdown structure of models for LCA calculation.

8.8. Models as proprietary formats of the design software

The BIM4LCA project produced a large number of models using different design software. These models can be used to develop and disseminate the project results to the various stakeholders. As a result of the project, all models are shared, both in the open file format (IFC4) according to ISO 16739-1:2018 and in the proprietary formats of the software used to create them (Finnish versions of Revit, MagiCAD for Revit, ArchiCAD, Tekla Structures). There may be some limitations in the software's proprietary models due to the way the software embeds various libraries or utilities that cannot be distributed with the models. Further use may, therefore, require the missing libraries to be re-linked. The IFC models do not have similar shortcomings.

A suitable software is needed to open the models. There are several freeware tools available for examining IFC models. However, commercial software may be needed for more extensive use of the models, such as reporting quantity data. Opening and viewing proprietary format files always requires commercial software licences with the same or newer version of the software and, in many cases, a correct language pack (in this case, Finnish). This means that IFC models are accessible to a wider range of end-users.

Proprietary format models can be useful for data producers, mainly designers, as they can explore solutions for generating data content from models available in proprietary formats in the design software. On the other hand, data users can utilise IFC models as a reference to ensure the correctness of data content in real construction projects. Models in both formats can also be used for presentations and training. The BIM models created in this project are expected to be widely used

10. See the report here: Nordic view on data needs and scenario settings for full life cycle building environmental assessment available: https://www.nordicsustainableconstruction.com/Media/638542191749462744/Nordic%20view%20on%20data%20needs%20and%20scenario%20settings%20for%20full%20life%20cycle%20building%20environmental%20assessment.pdf, accessed 25.6.2024

because BIM models of similar quality, well-created and "correctly" designed for real buildings are unavailable.

From the point of view of LCA calculation, the most important document related to the models is the external spreadsheet (i.e., the Excel sheets in the folder “MATERIALS-PRODUCTS” of the Nordic Sustainable Construction website), which records the properties of the element types in the model, such as material layers and product information. The project also published a BIM specification document for each IFC model. This document captures the key aspects of the model, such as the elevation of floors, the coordinate system, the classifications used, and related external documents.

For further use of the models, it should be noted that they have been developed primarily according to the principles of the BIM4LCA project and have been used to verify the principles of this project. The models are certainly not flawless in all respects; it would be very time-consuming to produce them completely error-free, which was not possible within the timeframe of this project. Furthermore, the plans have not been thoroughly examined from a technical point of view, nor, for example, have the structural solutions been calculated or otherwise structurally dimensioned in detail. However, as part of the project's final outputs, the models will also be published in the proprietary formats of the design software. They can be refined in future development projects to meet additional needs.

8.9. Use of IFC for quantity data

Although the BIM4LCA project has produced proprietary BIM models, the primary intention in building LCA is to use the IFC versions of the models. The necessary quantity data can be read from them using a variety of software, some of which are even free. Furthermore, the data contained in the models is used in the same way regardless of the software used to create the model.

Each model is accompanied by a spreadsheet that accommodates the properties of the element types in the model, such as material and product information. This spreadsheet is used in parallel with the IFC model. The quantity data of building elements by type is captured from the model, and the material and product data for each type are read from the spreadsheet. The data is then aggregated in the LCA software. The material and product data in the IFC models are not intended to be used in the LCA calculation.

The primary way to generate the quantity data from the models is to read it from the geometry of the components in the model. This ensures that the data format (volume, area, length, number of pieces) and level of detail match the data usage requirements. Exceptions are HVAC and electrical models, where the quantity data is stored in standard properties in the design software (see BIM specifications for HVAC and electrical models for more information). The architectural models also include QTO properties attached to each element, which contains the quantity data generated by the proprietary software. If these are used, it should be noted that the author of the model is not responsible for the quality of the data as they are automatically generated by the software.

To summarise, the process of using quantity data and product and material data in LCA calculations is as follows: The designer creates a model according to the design and ensures that the geometry of the models is correct and that all model elements have a type identifier. The designer exports the model in IFC format. At the building permit stage, the designer creates an external record in which the material and product information for each element type is entered to the level of accuracy known at that time. During the construction phase, the responsibility for updating the data in the external record is transferred to the contractors. The LCA expert generates the quantity data from the IFC model and combines it with the material and product data in the external record in the LCA calculation software using the type identifiers. The emission data for materials and products can be linked either in the external record or LCA software.

Appendix

Appendix A: prEN 15978 comparison to IFC 4.3 (ISO 16739-1:2024)

*Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method.

prEN 15978*			IFC 4.3 (ISO 16739-1:2024)		
Building parts	**Building elements and processes**		**IFC Entity**	**IFC PredefinedType**	**IFC Properties**
Pre-construction works	Facilitating works	Temporary/Enabling works	IfcTask 2)	STARTUP	
		Specialist groundworks	IfcTask 2)	CONSTRUCTION	
	Work on existing building	Demolition and alterations	IfcTask 2) IfcTask 2)	DEMOLITION ADJUSTMENT	
Sub-structure	Foundations		IfcFooting	FOOTING_BEAM, PAD_FOOTING, PILE_CAP, STRIP_FOOTING	
	Piles		IfcPile	BORED, COHESION, DRIVEN, FRICTION, JETGROUTING, SUPPORT	
	Basement walls		IfcWall	SOLIDWALL	
	Retaining walls		IfcWall	RETAININGWALL	
	Waterproofing		IfcCovering	MEMBRANE	
	Ground floor construction		IfcSlab	BASESLAB	Pset_SlabCommon.-LoadBearing = TRUE
Super-structure	Frame	Columns	IfcColumn	COLUMN	Pset_ColumnCommon.-LoadBearing = TRUE
		Beams	IfcBeam	BEAM	Pset_BeamCommon.-LoadBearing = TRUE
		Shear walls	IfcWall	SHEAR	Pset_WallCommon.-LoadBearing = TRUE
	Upper floors		IfcSlab IfcBeam	FLOOR HOLLOWCORE	Pset_SlabCommon.-LoadBearing = TRUE Pset_BeamCommon.-LoadBearing = TRUE

	Balconies		IfcElementAssembly - IfcSlab - IfcWall - IfcRailing - IfcRailing - IfcCurtainWall	FLOOR PARAPET GUARDRAIL HANDRAIL	
	Roof	Roof structure	IfcRoof	* Shape of the roof * = userdefined type	
		Weatherproofing	IfcCovering	ROOFING	
	Stairs and ramps		IfcStair IfcRamp IfcSlab	LANDING	
Fabric	External envelope	External walls	IfcWall	SOLIDWALL	Pset_SlabCommon.IsExternal = TRUE
		Windows	IfcWindow	WINDOW, LIGHTDOME, SKYLIGHT	Pset_WindowCommon.-IsExternal = TRUE
		External doors	IfcDoor	DOOR, TRAPDOOR	Pset_DoorCommon.-IsExternal = TRUE
		Shading devices	IfcShadingDevice	SHUTTER	Pset_ShadingDevice-Common.IsExternal = TRUE
	Internal walls	Internal walls – load bearing	IfcWall	PARTITIONING, SHEAR	Pset_WallCommon.-IsExternal = FALSE Pset_WallCommon.-LoadBearing = TRUE
		Internal walls – non-loadbearing	IfcWall	PARTITIONING, SHEAR	Pset_WallCommon.IsExternal = FALSE Pset_WallCommon.-LoadBearing = FALSE
		Internal doors	IfcDoor	DOOR	Pset_DoorCommon.-IsExternal = FALSE
Finishes	External finishes	Cladding	IfcCovering	CLADDING	Pset_CoveringCommon.-IsExternal = TRUE
		Coatings	IfcCovering	COPING	Pset_CoveringCommon.-IsExternal = TRUE
	Internal finishes	Wall finishes	IfcSpace	SPACE	Pset_SpaceCovering-Requirements.WallCovering
		Raised floors	IfcSpace	SPACE	Pset_SpaceCovering-Requirements.ConcealedFloor
		Floor finishes	IfcSpace	SPACE	Pset_SpaceCovering-Requirements.FloorCovering

		Ceiling finishes	IfcSpace	SPACE	Pset_SpaceCovering-Requirements.Ceiling-Covering Pset_SpaceCovering-Requirements.ConcealedCeilin
Building services	Water systems	Hot water distribution	IfcDistributionSystem	DOMESTICHOTWATER	
		Cold water distribution	IfcDistributionSystem	DOMESTICCOLDWATER	
		Water treatment systems	IfcDistributionSystem	WASTEWATER	
		Rainwater systems	IfcDistributionSystem	RAINWATER	
	Sewage systems		IfcDistributionSystem	SEWAGE	
	Lighting	Internal lighting	IfcElectricalCircuit	LIGHTING	
		External lighting	IfcElectricalCircuit	LIGHTING	
	Electricity generation and distribution		IfcDistributionSystem	POWERGENERATION	
	Renewable generation systems		IfcDistributionSystem	POWERGENERATION	
	Heating systems		IfcDistributionSystem	HEATING	
	Cooling systems		IfcDistributionSystem	AIRCONDITIONING	
	Ventilation systems		IfcDistributionSystem	VENTILATION	
	Conveying systems		IfcDistributionSystem	CONVEYING	
	Telecoms and data systems		IfcDistributionSystem	FIXEDTRANSMISSION-NETWORK	
	Fire protection systems		IfcDistributionSystem	FIREPROTECTION	
	Communication and security installations		IfcDistributionSystem	SECURITY	
Additional categories Not specified in prEN 15978					
Accessories	Furniture systems	Built-in furniture	IfcFurniture	IfcFurnitureTypeEnum	Pset_FurnitureType-Common.IsBuiltIn=TRUE
		Movable furniture	IfcSpace	SPACE	Pset_SpaceOccupancy-Requirements.OccupancyType
		Appliances	IfcElectricAppliance	IfcElectricApplianceTypeEnum	
		Sanitary fittings	IfcSanitaryTerminal	IfcSanitaryTerminalTypeEnum	
	Transportation systems	Elevators	IfcTransportElement	ELEVATOR	
		Escalators	IfcTransportElement	ESCALATOR	
		Mowing walkways	IfcTransportElement	MOVINGWALKWAY	
		Craneways, lifting gear and other transport elements	IfcTransportElement	CRANEWAY, HAULINGGEAR, LIFTINGGEAR	

	Safety systems	Railings	IfcRailing	BALUSTRADE, GUARDRAIL	
		Handrails	IfcRailing	HANDRAIL	
Areas	Gross floor area		IfcSpace	GFA	
	Net room area		IfcSpace	SPACE	Pset_SpaceOccupancyRequire

Appendix B: Comparison between prEn 15978, ISO 81346-12, CoClass, Talo2000 and ICMS

* Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method.
**(Building) LVI2010 (HVAC) S2010 (Electrical)
***3rd edition, November 2021

prEN 15978*			IEC/ISO 81346-12		CoClass		Talo2000**		ICMS***	
Building parts	Building elements and processes		Code	Description	Code	Description	Code	Description	Code	Description
Pre-construction works	Facilitating works	Temporary/-Enabling works	-	-			NA	NA	2.01.	Demolition, site preparation and formation
		Specialist groundworks	-	-			NA	NA	2.01.	Demolition, site preparation and formation
	Work to existing building	Demolition and alterations	-	-			NA	NA	2.01.	Demolition, site preparation and formation
Sub-structure	Foundations		A	Ground system	A20	Foundation	121 1121	Foundations Piles	2.02.	Sub-structure
	Piles		B	Wall system	B31	Cellar wall system	121 1121	Foundations Piles	2.02.	Sub-structure
	Basement walls		B	Wall system	B32	Retaining wall system	1212	Enclosure walls	2.02.	Sub-structure
	Retaining walls		FSG	Protective seal	FSG10	Water-proofing	1153	Retaining walls	2.02.	Sub-structure
	Waterproofing		C	Slab system	C10	Bottom slab system	12124	Thermal insulation	2.02.	Sub-structure

<table>
<tr><td></td><td>Ground floor construction</td><td></td><td>ULD</td><td>Column</td><td>ULD</td><td>Column</td><td>122</td><td>Ground floors</td><td>2.02.</td><td>Sub-structure</td></tr>
<tr><td>Super-structure</td><td>Frame</td><td>Columns</td><td>ULE</td><td>Beam</td><td>ULE</td><td>Beam</td><td>1233</td><td>Columns</td><td>2.03.</td><td>Structure</td></tr>
<tr><td></td><td></td><td>Beams</td><td>BD</td><td>Wall structure</td><td>BD</td><td>Wall structure</td><td>1234</td><td>Beams</td><td>2.03.</td><td>Structure</td></tr>
<tr><td></td><td></td><td>Shear walls</td><td>C</td><td>Slab system</td><td>C20</td><td>Mid slab system</td><td>1232</td><td>Bearing walls</td><td>2.03.</td><td>Structure</td></tr>
<tr><td></td><td>Upper floors</td><td></td><td>C</td><td>Slab system</td><td>C41</td><td>Balcony slab system</td><td>1235</td><td>Intermediate floors</td><td>2.03.</td><td>Structure</td></tr>
<tr><td></td><td>Balconies</td><td></td><td>D</td><td>Roof system</td><td>D</td><td>Roof system</td><td>1251</td><td>Balconies</td><td>2.03.</td><td>Structure</td></tr>
<tr><td></td><td>Roof</td><td>Roof structure</td><td>FSG
RQA</td><td>Protective seal
Insulation</td><td>FSG10
RQA</td><td>Water proofing
Insulation</td><td>1261</td><td>Roof substructures</td><td>2.03.</td><td>Structure</td></tr>
<tr><td></td><td></td><td>Weather-proofing</td><td>AF
AG</td><td>Stair construction
Ramp construction</td><td>AF
AG</td><td>Stair construction
Ramp construction</td><td>1263</td><td>Roofings</td><td>2.03.</td><td>Structure</td></tr>
<tr><td></td><td>Stairs and ramps</td><td></td><td>B</td><td>Wall system</td><td>B10</td><td>Exterior wall system</td><td>1237</td><td>Structural frame stairs</td><td>2.03.</td><td>Structure</td></tr>
<tr><td>Fabric</td><td>External envelope</td><td>External walls</td><td>QQA</td><td>Window</td><td>QQA</td><td>Window</td><td>1241</td><td>External walls</td><td>2.04.</td><td>Architectural works | non-structural works</td></tr>
<tr><td></td><td></td><td>Windows</td><td>QQC</td><td>Door</td><td>QQC</td><td>Door</td><td>1242</td><td>Windows</td><td>2.04.</td><td>Architectural works | non-structural works</td></tr>
<tr><td></td><td></td><td>External doors</td><td>RQD</td><td>Screen</td><td>RQD</td><td>Screen</td><td>1243</td><td>External doors</td><td>2.04.</td><td>Architectural works | non-structural works</td></tr>
<tr><td></td><td></td><td>Shading devices</td><td>B</td><td>Wall system</td><td>B20</td><td>Interior wall system</td><td>1244</td><td>Facade attachments</td><td>2.04.</td><td>Architectural works | non-structural works</td></tr>
<tr><td></td><td>Internal walls</td><td>Internal walls – load bearing</td><td>B</td><td>Wall system</td><td>B20</td><td>Interior wall system</td><td>1232</td><td>Bearing walls</td><td>2.03.</td><td>Structure</td></tr>
<tr><td></td><td></td><td>Internal walls – non-loadbearing</td><td>QQC</td><td>Door</td><td>QQC</td><td>Door</td><td>1311</td><td>Partitions</td><td>2.04.</td><td>Architectural works | non-structural works</td></tr>
</table>

		Internal doors	NCB	Wall covering	NCB	Wall covering	1315	Internal doors	2.04.	Architectural works | non-structural works
Finishes	External finishes	Cladding	FSZ	Coating	FSZ	Coating	12414	Sheating	2.04.	Architectural works | non-structural works
		Coatings	FSZ	Coating	FSZ	Coating	12414	Sheating	2.04.	Architectural works | non-structural works
	Internal finishes	Wall finishes	AQ	Floor construction	AQ	Floor construction	13261	Wall finishing	2.04.	Architectural works | non-structural works
		Raised floors	NCC	Flooring	NCC	Flooring	1321	Floor surface elements	2.04.	Architectural works | non-structural works
		Floor finishes	NCE	Roofing	NCE	Roofing	1322	Floorings	2.04.	Architectural works | non-structural works
		Ceiling finishes	F	Water and fluid system	F22	Tap hot water system	1324	Ceiling finishings	2.04.	Architectural works | non-structural works
	Water systems	Hot water distribut	F	Water and fluid system	F21	Tap cold water system	212	Water and sewerage systems	2.05.	Services and equipment
		Cold water distribut	KC	Cleaning system	KC	Cleaning system	212	Water and sewerage systems	2.05.	Services and equipment
		Water treatment systems	G	Drainage and waste system	G24	Roof water runoff system	212	Water and sewerage systems	2.05.	Services and equipment
		Rainwater systems	G	Drainage and waste system	G11	Wastewater system	2124	Regional sections for water and sewerage systems	2.06.	Surface and underground drainage

Building services	Sewage systems		Q	Lighting system	Q11	General lighting system for building space	212	Water and sewerage systems	2.05.	Services and equipment
	Lighting	Internal lighting	Q	Lighting system	Q12	General lighting system for outdoors space	S251	Internal lighting system	2.05.	Services and equipment
		External lighting	K	Electrical system	K	Electrical system	S252	External lighting system	2.05.	Services and equipment
	Electricity generation and distribution		K.HG	Electrical system > Electrical power supply system	K.HG31	Electrical system > Solar electric supply system	S212	Electricity generation systems	2.05.	Services and equipment
	Renewable generation systems		H	Cooling and heating system	H20	Heating system	S212	Electricity generation systems	2.05.	Services and equipment
	Heating systems		H	Cooling and heating system	H10	Cooling system	211	Heating systems	2.05.	Services and equipment
	Cooling systems		J	Ventilation system	J	Ventilation system	214	Cooling systems	2.05.	Services and equipment
	Ventilation systems		N	Transportation system	N	Transportation system	213	Ventilation systems	2.05.	Services and equipment
	Conveying systems		M	Information and communication system	M	Information and communication system	S222	Main distribution system	2.05.	Services and equipment
	Telecoms and data systems		P.PA	Security and safety system > Fire protection system	P10	Fire safety system	T1	Communication and information network systems	2.05.	Services and equipment
	Fire protection systems		M	Information and communication system	P30	Personal safety system	T6	Fire safety systems	2.05.	Services and equipment
	Communication and security installations		a) ISO 81346-12:2019, Table A.1 b) ISO 81346-12:2019, Table A.2 c) EN IEC 81346-2:2019, Table 2				T5	Security systems	2.05.	Services and equipment

Additional categories Not specified in prEN 15978										
Accessories	Furniture systems	Built-in furniture	S.RB	Arrangement system > Furniture system	S.RB	Arrangement system > Furniture system	1331	Standard fittings		
		Movable furniture	S.RB	Arrangement system > Furniture system	S.RB	Arrangement system > Furniture system	1331	Standard fittings		
		Appliances	S.RC	Arrangement system > Equipment system	S.RC	Arrangement system > Equipment system	1334	Standard appliances		
		Sanitary fittings	XK?	Collecting interfacing object	XK?	Collecting interfacing object	21	Plumbing		
	Transportation systems	Elevators	N.JM	Transportation system > Passenger transportation system	N.JM	Transportation system > Passenger transportation system	2511	Lifts		
		Escalators	N.JM	Transportation system > Passenger transportation system	N.JM	Transportation system > Passenger transportation system	2512	Escalators and conveyors		
		Mowing walkways	N.JM	Transportation system > Passenger transportation system	N.JM	Transportation system > Passenger transportation system	2512	Escalators and conveyors		
		Craneways, lifting gear and other transport elements	N.JN	Transportation system > Goods transportation system	N.JN	Transportation system > Goods transportation system	2513	Other transportation equipment		
	Safety systems	Railings	FQD	Protective rail	FQD	Protective rail	1314	Balustrades and railings		
		Handrails	FQC	Protective rod	FQC	Protective rod	13143	Handrails		
Areas	Gross floor area		-	-	-	-	N/A	N/A		
	Net room area		-	-	-	-	N/A	N/A		

na=Not Available; N/A=Not applicable

Appendix C: BIM model authors and BIM file names

Several designers and engineers have taken part in BIM modelling. The following tables (Table 5, Table 6 and Table 7) list the BIM model authors and related BIM and IFC files. The native BIM files can be opened using their specific commercial software, such as Revit, ArchiCad and Tekla Structures. IFC files can be opened with IFC-viewer or several commercial software that can import IFC files. IFC-viewer software or viewer service can be found for free on the web.

Table 5. BIM model authors of architectural designs

Design model	Wooden		Concrete	
Architectural building permit models	Residential building in Revit[11], IFC[12]	Office building in Revit[13], IFC[14]	Residential building in Revit[15], IFC[16]	Office building in Revit[17], IFC[18] & ArchiCAD[19], IFC [20]
Site models	Residential building site in Revit[21], IFC[22]	Office building site in Revit[23], IFC[24]	Residential concrete building site in Revit[25], IFC [26]	Office building site in Revit[27], IFC[28]
BIM model authors	Joona Lukka	Elli Wendelin	Joona Lukka	Elli Wendelin
Architectural as-built models	Residential building in Revit[29], IFC[30]and ArchiCAD,[31]IFC [32]	Office building in Revit[33], IFC[34]	Residential building in Revit[35], IFC[36]	Office building in Revit[37], IFC[38]
BIM model authors	Joona Lukka; Pekka Tuominen	Elli Wendelin	Joona Lukka	Joona Lukka; Pekka Tuominen

Architectural IFC files and site models by Joona Lukka, Elli Wendelin, and Pekka Tuominen.

11. ARK_NordicLCA_Housing_Timber_BuildingPermit.rvt
12. ARK_NordicLCA_Housing_Timber_BuildingPermit_Revit.ifc
13. ARK_NordicLCA_Office_Timber_BuildingPermit.rvt
14. ARK_NordicLCA_Office_Timber_BuildingPermit_Revit.ifc
15. ARK_NordicLCA_Housing_Concrete_BuildingPermit.rvt
16. ARK_NordicLCA_Housing_Concrete_BuildingPermit_Revit.ifc
17. ARK_NordicLCA_Office_Concrete_BuildingPermit.rvt
18. ARK_NordicLCA_Office_Concrete_BuildingPermit_Archicad.ifc
19. ARK_NordicLCA_Office_Concrete_BuildingPermit. pla
20. ARK_NordicLCA_Office_Concrete_BuildingPermit.ifc
21. ARK_NordicLCA_Housing_Terrain-Timber_BuildingPermit.rvt
22. ARK_NordicLCA_Housing_Terrain-Timber_BuildingPermit_Revit.ifc
23. ARK_NordicLCA_Office_Terrain_Timber_BuildingPermit.rvt
24. ARK_NordicLCA_Office_Terrain_Timber_BuildingPermit_Revit.ifc
25. ARK_NordicLCA_Housing_TerrainConcrete_BuildingPermit.rvt
26. ARK_NordicLCA_Housing_Terrain-Concrete_BuildingPermit_Revit.ifc
27. ARK_NordicLCA_Office_Terrain_Concrete_BuildingPermit.rvt
28. ARK_NordicLCA_Office_Terrain_Concrete_BuildingPermit_Revit.ifc
29. ARK_NordicLCA_Housing_Timber_As-Built.rvt
30. ARK_NordicLCA_Housing_Timber_As-Built_Archicad.ifc
31. ARK_NordicLCA_Housing_Timber_As-Built.pla
32. ARK_NordicLCA_Housing_Timber_As-Built.ifc
33. ARK_NordicLCA_Office_Timber_As-Built.rvt
34. ARK_NordicLCA_Office_Timber_As-Built_Revit.ifc
35. ARK_NordicLCA_Housing_Concrete_As-Built.rvt
36. ARK_NordicLCA_Housing_Concrete_As-Built_Revit.ifc
37. ARK_NordicLCA_Office_Concrete_As-Built.rvt
38. ARK_NordicLCA_Office_Concrete_As-Built_Revit.ifc

Table 6. BIM model authors of structural designs

Design model	Wooden		Concrete	
Structural models	Residential building in Tekla Structures[39]	Office building in Tekla Structures [40]	Residential building in Tekla Structures[41]	Office building in Tekla Structures [42]
BIM model authors	Minna Salonsaari	Minna Salonsaari	Minna Salonsaari	Minna Salonsaari

Structural IFC files by Minna Salonsaari.

39. STRUC_NordicLCA_Housing_Timber_BuildingPermit.db1; matdb.bin; profdb.bin; profitab.inp
40. STRUC_NordicLCA_Office_Timber_BuildingPermit.db1; matdb.bin; profdb.bin; profitab.inp
41. STRUC_NordicLCA_Housing_Concrete_BuildingPermit.db1; matdb.bin; profdb.bin; profitab.inp
42. STRUC_NordicLCA_Office_Concrete_BuildingPermit.db1; matdb.bin; profdb.bin; profitab.inp

Table 7. BIM model authors of HVAC and electrical designs

Design model	Wooden		Concrete	
HVAC models (Wood frame also includes sprinkler systems)	Residential building in MagiCAD for Revit[43], IFC[44]	Office building in MagiCAD for Revit[45], IFC[46]	Residential building in MagiCAD for Revit[47], IFC[48]	Office building in MagiCAD for Revit[49], IFC[50]
Electrical models	Residential building in MagiCAD for Revit[51], IFC[52]	Office building in MagiCAD for Revit[53], IFC[54]	Residential building in MagiCAD for Revit[55], IFC[56]	Office building in MagiCAD for Revit[57]
BIM model authors	HVAC design management: Johanna Härkönen Sprinkler design management: Minna Tuononen HVAC and Sprinkler BIM modelling: Johanna Härkönen Electrical design management: Henri Waaramaa Electrical BIM modelling: Sofia Öhman	HVAC design management: Niina Erkkilä Sprinkler design management: Tomi Käyhkö HVAC and Sprinkler BIM modelling: Marko Mielty Electrical design management: Stefan Biström Electrical BIM modelling: Sofia Öhman	HVAC design management: Johanna Härkönen HVAC BIM modelling: Johanna Härkönen Electrical design management: Henri Waaramaa Electrical BIM modelling: Sofia Öhman	HVAC design management: Niina Erkkilä HVAC BIM modelling: Marko Mielty Electrical design management: Stefan Biström Electrical BIM modelling: Sofia Öhman
	HVAC design management: Johanna Härkönen Sprinkler design management: Minna Tuononen HVAC and Sprinkler BIM modelling: Johanna Härkönen Electrical design management: Henri Waaramaa Electrical BIM modelling: Sofia Öhman	HVAC design management: Niina Erkkilä Sprinkler design management: Tomi Käyhkö HVAC and Sprinkler BIM modelling: Marko Mielty Electrical design management: Stefan Biström Electrical BIM modelling: Sofia Öhman	HVAC design management: Johanna Härkönen HVAC BIM modelling: Johanna Härkönen Electrical design management: Henri Waaramaa Electrical BIM modelling: Sofia Öhman	HVAC design management: Niina Erkkilä HVAC BIM modelling: Marko Mielty Electrical design management: Stefan Biström Electrical BIM modelling: Sofia Öhman

HVAC and electrical IFCs by Johanna Härkönen, Sofia Öhman, Marko Mielty and Markus Järvenpää.

43. HVAC_NordicLCA_Housing_Timber_BuildingPermit.rvt
44. HVAC_NordicLCA_Housing_Timber_BuildingPermit.ifc
45. HVAC_NordicLCA_Office_Timber_BuildingPermit.rvt
46. HVAC_NordicLCA_Office_Timber_BuildingPermit.ifc
47. HVAC_NordicLCA_Housing_Concrete_BuildingPermit.rvt
48. HVAC_NordicLCA_Housing_Concrete_BuildingPermit.ifc
49. HVAC_NordicLCA_Office_Concrete_BuildingPermit.rvt
50. HVAC_NordicLCA_Office_Concrete_BuildingPermit.ifc
51. ELE_NordicLCA_Housing_Timber_BuildingPermit.rvt
52. ELE_NordicLCA_Housing_Timber_BuildingPermit.ifc
53. ELE_NordicLCA_Office_Timber_BuildingPermit.rvt
54. ELE_NordicLCA_Office_Timber_BuildingPermit.ifc
55. ELE_NordicLCA_Housing_Concrete_BuildingPermit.rvt
56. ELE_NordicLCA_Housing_Concrete_BuildingPermit.ifc
57. ELE_NordicLCA_Office_Concrete_BuildingPermit.rvt

Appendix D: Example BIM specification documents

BIM specification documents were created for each native BIM file and are in the same folder as the BIM files. The following are examples of architectural, structural, HVAC, and electrical documents.

Architectural BIM specification document

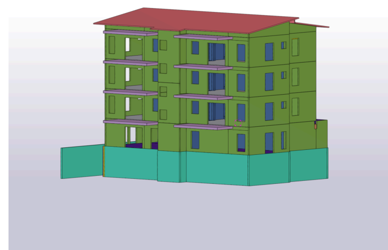
DISCIPLINE	Architecture
Illustration image	
Object	
Intended use	
Design phase	As built
Revision date	
Organisation	Arkkitehtitoimisto Huvila
BIM contact person	
Contact email address	
Contact telephone number	
Principal designer	
Project manager	Rita Lavikka
Software and versions used	Revit 2024
Separate IFC or native models related to this model	ARK_NordicLCA_Office_Timber_As-Built.rvt ARK_NordicLCA_Office_Terrain_Timber_BuildingPermit.ifc ARK_NordicLCA_Office_Terrain_Timber_BuildingPermit.rvt ARK_NordicLCA_Office_Timber_As-Built_Materials_and_Products.xlsx
Additional information and comments	

GENERAL MODELLING PRINCIPLES	
Classification systems used	Talo2000
Layer systems used	Talo2000
Naming of building elements	http://uri.suomi.fi/codelist/rakrek/raktkk_builtsystem_1_0
Unit system	Metric
Coordinate system	ETRS-GK 25 planar coordinates N2000 elevation system
Origin location (x,y,z)	X = E = I Y = N = P Z Origin 25505183.456 6706938.966 0,000 Models are not rotated in the project coordinate system; all models are placed in a true-north position.
Level names and elevations in the N2000 system	Sea level +0,000 Basement +51,700 Level_01 +55,500 Level_02 +59,700 Level_03 +63,720 Level_04 +67,740 Level_05 +72,310 Roof +78,370
IFC version	IFC4 (IFC 4.0.2.1)
Level of detail (LoD)	As built
Deviations from the LoD	
Level of information (LoI)	As built
Deviations from the LoI	
Presentation of the phasing	-

Building element and component coding	**Source of information**
http://uri.suomi.fi/codelist/rakrek/raktkk_builtsystem_1_0	Element attribute/ Name

	Propertyset	**Property**	**Used values**
Identification of the external envelope of the building	Pset_______Common	IsExternal	Elements that are part of or outside the outer envelope TRUE Elements inside the outer envelope FALSE or empty
Identification of load-bearing building elements	Pset_______Common	IsLoadBearing	Load-bearing elements TRUE Non-load-bearing elements FALSE or empty
Identification of surface materials in rooms	Pset_______Common	WallCovering CeilingCovering FloorCovering	Surface materials in text format according to the attachment: SurfaceMaterials_ARK_NordicLCA_Office_Timber_AsBuilt.xlsx

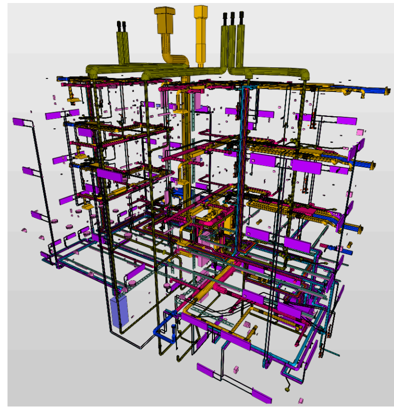
Structural BIM specification document

DISCIPLINE	Structural
Illustration image	
Object	
Intended use	
Design phase	building permit
Revision date	
Organisation	
BIM contact person	
Contact email address	
Contact telephone number	
Principal designer	
Project manager	Rita Lavikka
Software and versions used	Tekla Structures 2023
Separate models and documents related to this model	STRUC_NordicLCA_Office_Concrete_BuildingPermit.ifc
Additional information and comments	It should be noted that this model has been developed primarily according to the principles of the BIM4LCA project and have been used to verify the principles of this project. This model is certainly not flawless. Plans have not been thoroughly examined from a technical point of view, nor, for example, have the structural solutions been calculated or otherwise structurally dimensioned in detail.

GENERAL MODELLING PRINCIPLES	
Classification systems used	
Layer systems used	
Naming of building elements	
Unit system	Metric
Coordinate system	ETRS-GK25 planar coordinates N2000 elevation system
Origin location (x,y,z)	X = E = I Y = N = P Z Origin 25505171,787 6707188,716 0,000 Models are not rotated in the project coordinate system; all models are placed in a true-north position.
Level names and elevations in the N2000 system	Sea level +0,00 Foundations +47,300 Basement +49,070 Level_01 +52,000 Level_02 +54,930 Level_03 +58,030 Level_04 +61,130 Roof +64,035
IFC version	IFC4
Level of detail (LoD)	building permit
Deviations from the LoD	
Level of information (LoI)	building permit
Deviations from the LoI	
Presentation of the phasing	-

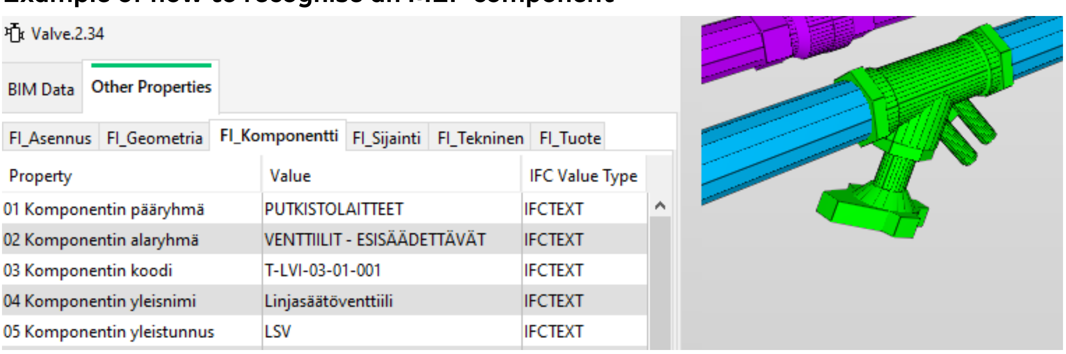
	Propertyset	Property	Used values
Identification of the external envelope of the building	Pset_______Common (part)	IsExternal	Elements that are part of ou outside the outer envelope TRUE Elements inside the outer envelope FALSE
Identification of load-bearing building elements	Pset_______Common	IsLoadBearing	Load-bearing elements TRUE Non-load-bearing elements FALSE or empty

HVAC BIM specification document

Discipline	HVAC
View of the model	
Project	**BIM4LCA**
Design phase	Detail Design
Initial date	16.6.2024
Revision date	
Revision version	
Company	Granlund Oy
BIM4LCA project leader	Rita Lavikka, VTT
Software	MagiCAD for Revit 2024
Native model	HVAC_NordicLCA_Housing_Concrete_BuildingPermit.rvt
More info on, comments...	MEP standardization guide, please see document: 0_MEP_standardization_2024.pdf

Overview of modelling principles	
Nomenclatures to be used	-
Naming product components	http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0
Naming of systems	http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0
Units	mm
Coordinate reference system	ETRS-GK 25 coordinate system N2000-height system
Origo (x,y,z)	X = E = I Y = N = P Z Origo 25505171,787 6707188,716 0,000 The project does not rotate models in the project coordinate system, all models are modelled at a real-world angle.
Floor names and floor elevations	Merenpinta +0,00 (Sea level) Perustukset +47,30 (Foundations) Kellari +49,07 (Basement) 01_Kerros +52,00 (1. Floor) 02_Kerros +54,93 (2. Floor) 03_Kerros +58,03 (3. Floor) 04_Kerros +61,13 (4. Floor) Vesikatto +64,03 (Roof)
IFC-version	IFC4
Model accuracy	Detail Design
Deviations from the level of accuracy	-
Information content	According to Rava3pro project (www.rava3pro.fi, https://search.bsdd.buildingsmart.org/uri/finnish-mep/FI-MEP/1.0
Deviations from the data content	-

Example of how to recognise an MEP component

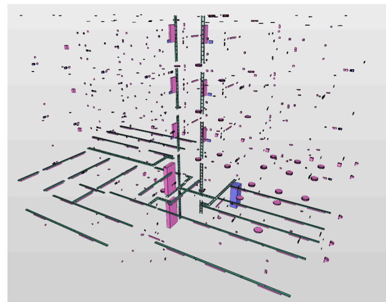


Component common names can be found from in Finnish national common code platform:
http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0

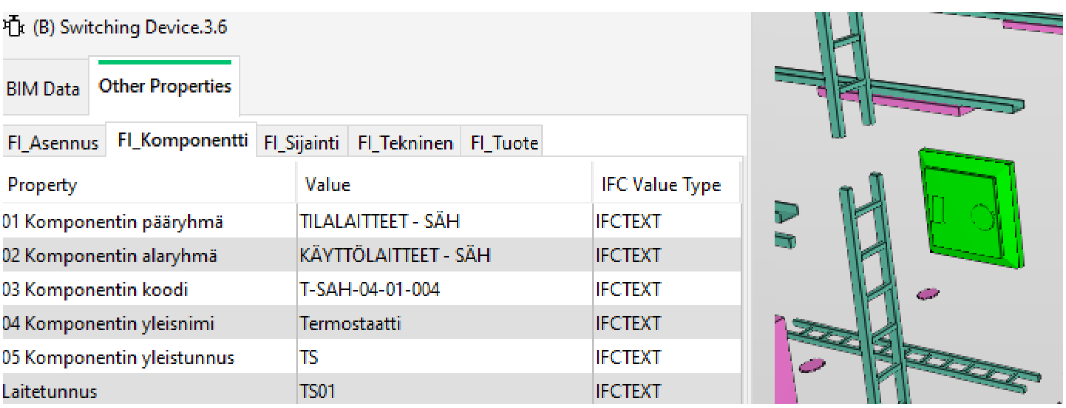
Identification of components		
Property Set	**Property**	**Values used**
FI_Komponentti	01 Komponentin pääryhmä	Level 1: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0
FI_Komponentti	01 Komponentin alaryhmä	Level 2: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0
FI_Komponentti	01 Komponentin koodi	Level 3: "Koodin arvo" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0
FI_Komponentti	01 Komponentin yleisnimi	Level 3: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0
FI_Komponentti	01 Komponentin yleistunnus	Level 3: "Lyhyt nimi" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0

Identification of systems		
Property Set	**Property**	**Values used**
FI_Järjestelmä	01 Järjestelmälaji	Level 1: http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI
FI_Järjestelmä	01 Järjestelmäluokka	Level 2: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI
FI_Järjestelmä	01 Järjestelmän koodi	Level 3: "Koodin arvo" http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI
FI_Järjestelmä	01 Järjestelmätyyppi	Level 3: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI
FI_Järjestelmä	01 Järjestelmätyypin yleistunnus	Level 3: "Lyhyt nimi" http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI

Electrical BIM specification document

DISCIPLINE	Electrical
View of the model	
Project	BIM4LCA
Design phase	Detail Design
Initial date	16.6.2024
Revision date	
Revision version	
Company	Granlund Oy
BIM4LCA project leader	Rita Lavikka, VTT
Software	MagiCAD for Revit 2024
Native model	ELE_NordicLCA_Housing_Concrete_BuildingPermit.rvt
More info on, comments…	MEP standardization guide, please see document: 0_MEP_standardization_2024.pdf

OVERVIEW OF MODELLING PRINCIPLES	
Nomenclatures to be used	-
Naming product components	http://uri.suomi.fi/codelist/rytj/SAHKO-TUOTEOSA_Versio_1_0
Naming of systems	http://uri.suomi.fi/codelist/rytj/SAHKO-JARJESTELMA_Versio_1_0
Units	mm
Coordinate reference system	ETRS-GK 25 coordinate system N2000-height system
Origo (x,y,z)	X = E = I Y = N = P Z Origo 25505171,787 6707188,716 0,000 The project does not rotate models in the project coordinate system, all models are modeled at a real-world angle.
Floor names and floor elevations	Merenpinta +0,00 Perustukset +47,30 Kellari +49,07 01_Kerros +52,00 02_Kerros +54,93 03_Kerros +58,03 04_Kerros +61,13 Vesikatto +64,03
IFC-version	IFC4
Model accuracy	Detail Design
Deviations from the level of accuracy	-
Information content	According to Rava3pro project (www.rava3pro.fi, https://search.bsdd.buildingsmart.org/uri/finnish-mep/FI-MEP/1.0
Deviations from the data content	-



Property	Value	IFC Value Type
01 Komponentin pääryhmä	TILALAITTEET - SÄH	IFCTEXT
02 Komponentin alaryhmä	KÄYTTÖLAITTEET - SÄH	IFCTEXT
03 Komponentin koodi	T-SAH-04-01-004	IFCTEXT
04 Komponentin yleisnimi	Termostaatti	IFCTEXT
05 Komponentin yleistunnus	TS	IFCTEXT
Laitetunnus	TS01	IFCTEXT

Component common names can be found from the Finnish national common code platform:
http://uri.suomi.fi/codelist/rytj/SAHKO-TUOTEOSA_Versio_1_0

Identification of components		
Property Set	**Property**	**Values used**
FI_Komponentti	01 Komponentin pääryhmä	Level 1: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0
FI_Komponentti	01 Komponentin alaryhmä	Level 2: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0
FI_Komponentti	01 Komponentin koodi	Level 3: "Koodin arvo" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0
FI_Komponentti	01 Komponentin yleisnimi	Level 3: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0
FI_Komponentti	01 Komponentin yleistunnus	Level 3: "Lyhyt nimi" http://uri.suomi.fi/codelist/rytj/LVI-TUOTEOSA_Versio_1_0

Identification of systems		
Property Set	**Property**	**Values used**
FI_Järjestelmä	01 Järjestelmälaji	Level 1: http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI
FI_Järjestelmä	01 Järjestelmäluokka	Level 2: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI
FI_Järjestelmä	01 Järjestelmän koodi	Level 3: "Koodin arvo" http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI
FI_Järjestelmä	01 Järjestelmätyyppi	Level 3: "Koodin nimi" http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI
FI_Järjestelmä	01 Järjestelmätyypin yleistunnus	Level 3: "Lyhyt nimi" http://uri.suomi.fi/codelist/rytj/LVI-JARJESTELMA_Versio_1_0/code/J-LVI

Appendix E: Instructions for BIM-based material inventory in native Nordic languages

Dansk

Instruktioner til BIM-baseret materialeopgørelse

Denne specifikation er oversat fra afsnittet "Instructions for BIM-based material inventory" i slutrapporten for dette BIM-baserede bygnings-LCA-projekt. Mere detaljerede instruktioner er beskrevet i rapporten.

BIM-modellering bør følge internationale standarder. Nationalt kan være mere specifikke nationale kravene eller retningslinjer (f.eks. »RAVA3Pro« i Finland, »Tillämpningsanvisningar BIM«, der er under udvikling i Sverige, »SIMBA« for offentlige bygninger i Norge og DS/EN ISO 19650 i Danmark).

Generelle krav til BIM

De oplysninger, der kræves til LCA, ligner de oplysninger, der er nødvendige til kalkulationer. Bygningselementer skal modelleres, så mængderne genereres korrekt i designmodellen og følgelig eksporteres korrekt til IFC-modellen. For at BIM skal være mest muligt anvendelig i LCA-beregninger, er de generelle krav til BIM-modellering:

- **Modellering af høj kvalitet** - i henhold til national bedste praksis
- **Præcis** - Modellens indhold er nøjagtigt, og elementerne er modelleret, så de kan eksporteres korrekt til IFC-modellen.
- **Beskrivende og informativ** - Modellens indhold tager højde for slutbrugernes behov.
    - Der følger en beskrivelsesfil med BIM-modellen, som angiver, hvilke informationsfelter der indeholder relevante data, og hvilke formål modellen er beregnet til. Software kan generere utilsigtede oplysninger, som måske ikke er nøjagtige, og derfor er det relevant at specificere, hvilke felter der er beregnet til at blive brugt.
- **Korrekt navngivning og kategorisering** - i henhold til nationale standarder eller bedste praksis (eller projektspecifik navngivning, i hvilket tilfælde navngivningskonventionerne skal forblive de samme gennem hele projektet)
    - Alle bygningselementer får beskrivende typenavne, som også bruges i andre dokumenter. For eksempel har alle vægelementer med samme

struktur den samme vægtypeidentifikator defineret i BIM'en, som også findes i konstruktionsplanerne. Det gør det muligt at hente oplysninger fra kilder uden for BIM-modellerne.

- Når producent- og produktnavne på installerede produkter er kendt (for det meste i tilfælde af as-built-modeller), oplyses disse i BIM'en for at understøtte kortlægningen af produktspecifikke miljøvaredeklarationer (EPD). Alternativt leveres en kortlægning af produkttypenavne i modellen til de installerede produkter eksternt.
- Hvis de installerede produkter ikke er specificeret, navngives materialerne på en harmoniseret måde i modellerne, og der anvendes etablerede klassifikationer, hvor det er muligt. Materialerne registreres enten i modellen eller refereres eksternt med typenavnet i BIM-modellen.

BIM-specifikationsdokumenter

BIM'ernes indhold og modelleringsprincipper skal dokumenteres og beskrives i bilag i henhold til national bedste praksis. Specifikationsdokumenterne skal f.eks. oplyse, hvilke informationsfelter der genereres i informationsmodellen. Dette er vigtigt, da software kan generere oplysninger (ekstra felter automatisk), som måske ikke er nøjagtige.

Specifikationsdokumentet bruges også som et værktøj til at kommunikere information om modellens fuldstændighed ved f.eks. at angive eventuelle antagelser, som designeren har gjort, eller eventuelle endnu ikke modellerede elementer. Dette er især relevant for modellering, der udføres i de tidligere faser af designprocessen. Oplysninger, der er tilføjet som et udkast (konstruktionstype, materiale osv.), og som kan ændres, skal også angives tydeligt i BIM-specifikationsdokumentet.

Nødvendige data i BIM-modellen til informationsudtræk

Mængder og egenskaber i BIM-modeller udtrækkes via informationsudtagningsfunktioner i BIM- eller IFC-software. Nedenfor er angivet de data, der som minimum kræves for at udføre LCA.

Præcise, beskrivende og informative data af høj kvalitet i informationsudtrækket øger effektiviteten og nøjagtigheden af processen både under eksport fra IFC-software og import af information til LCA-software.

De vigtigste krav er anført i det følgende:

Bygningselement

Klassificering af bygningselementer i henhold til national bedste praksis. Bygningselementtypen bruges til at kategorisere emissioner i henhold til bygningselementet. Kategorisering i henhold til bygningselementet er afgørende for LCA-vurderingen, da det muliggør vurdering på komponentniveau.

Komponenttype (klasse)

Afgørende for import af data til LCA-software. Komponenttyper er f.eks. plade, søjle eller bjælke.

Viser, hvilket værktøj i modelleringssoftwaren komponenten er genereret med, og muliggør et niveau af kvalitetssikring af, at oplysningerne er korrekte i modellen.

Type (reference)

Bygget elementtype i henhold til national best practice og afhængigt af, hvad der er aftalt i projektet. Referencen er beskrivende information om elementet, som svarer til navngivningen i andre designdokumenter. For eksempel den benyttede dækelementtype i stueetagen.

Oplysninger om mængde

Volumen

Afgørende for bygningselementer, hvor den foretrukne enhed er volumen (m3)

Areal

Afgørende for bygningselementer, hvor den foretrukne enhed er areal (m2).

Lineær meter

Afgørende for bygningselementer, hvor den foretrukne enhed er længde (m).

Antal stykker

Afgørende for bygningselementer, hvor den foretrukne enhed er antal enheder (unit).

Materiale

Materialeinformation, der bruges til at beskrive det anvendte materiale i konstruktionen. Viser det materiale, der er brugt i komponenten, f.eks. træ, beton eller stål. Yderligere oplysninger om materialet, f.eks. betonens styrkeklasse, kan oplyses i kilder til supplerende data.

Viser tykkelsen af materialelagene i konstruktionen (når de er tilgængelige).

Samlet tykkelse

Den samlede tykkelse af en konstruktion er afgørende, især for komponenter i den strukturelle ramme.

Eesti keel
Juhised BIM-põhise materjaliinventuuri jaoks

See spetsifikatsioon on tõlgitud käesoleva BIM-põhise hoone LCA projekti lõpparuande jaotisest "Instructions for BIM-based material inventory". Täpsemad juhised on kirjeldatud aruandes.

BIM-modelleerimisel tuleks järgida rahvusvahelised standardid. Riikidel võivad olla konkreetsemad riiklikud standardid või suunised (nt „RAVA3Pro“ Soomes, „Tillämpningsanvisningar BIM“, mida töötatakse välja Rootsis, „SIMBA“ avalike hoonete jaoks Norras ja DS/EN ISO 19650 Taanis).

BIMi üldised nõuded

LCA jaoks vajalik teave on sarnane teabega, mida on vaja kuluarvutuste tegemiseks. Ehituselemendid tuleb modelleerida nii, et kogused genereeritakse projekteerimismudelis õigesti ja eksporditakse sellest tulenevalt õigesti IFC-mudelisse. Selleks, et BIM oleks LCA arvutamisel kõige kasulikum, on BIM-modelleerimise üldised nõuded järgmised:

- **Kvaliteetne modelleerimine - vastavalt riiklikele parimatele tavadele.**
- **Täpne - mudeli sisu on täpne ja elemendid on modelleeritud nii, et neid saab õigesti eksportida IFC-mudelisse.**
- **Kirjeldav ja informatiivne - mudeli sisu arvestab BIMi lõppkasutajate vajadusi**.
    - Koos BIM-mudeliga esitatakse kirjeldusfail, milles täpsustatakse, millised andmeväljad sisaldavad asjakohaseid andmeid ja millisteks eesmärkideks mudel on mõeldud. Tarkvara võib genereerida soovimatut teavet, mis ei pruugi olla täpne, mistõttu on asjakohane täpsustada, millised väljad on mõeldud kasutamiseks.
- **Õige nimetamine ja kategoriseerimine - vastavalt riiklikele standarditele või parimatele tavadele (või projektipõhine nimetamine, mille puhul nimetamiskonventsioonid peavad jääma kogu projekti jooksul samaks).**
    - Kõigile ehituselementidele antakse kirjeldavad tüübinimetused, mida kasutatakse ka teistes dokumentides. Näiteks on kõigil sama struktuuriga seinaelementidel BIMis määratletud sama seina tüübi identifikaator, mis on ka struktuuriplaanides. See võimaldab teabe otsimist BIM-mudelitest välistest allikatest.
    - Kui paigaldatud toodete tootja ja tootenimetused on teada (enamasti as-built-mudelite puhul), avalikustatakse need BIMis, et toetada tootespetsiifiliste keskkonnadeklaratsioonide (EPD) kaardistamist. Teise võimalusena esitatakse mudelis olevate tootetüüpide nimede

kaardistamine paigaldatud toodetele väljastpoolt.

- Kui paigaldatud tooteid ei ole täpsustatud, on materjalide nimetused mudelites ühtlustatud, kasutades võimaluse korral kehtestatud klassifikatsioone. Materjalid kas registreeritakse mudelis või viidatakse väliselt BIM-mudelis tüübinimetusega.

BIM-spetsifikatsioonidokumendid

BIM-mudelite sisu ja modelleerimise põhimõtted dokumenteeritakse ja kirjeldatakse lisades vastavalt siseriiklikele parimatele tavadele. Spetsifikatsioonidokumentides tuleks näiteks avalikustada, milliseid infovälju mudelis genereeritakse. See on oluline, sest tarkvara võib genereerida teavet (täiendavaid välju automaatselt), mis ei pruugi olla täpne.

Spetsifikatsioonidokumenti kasutatakse ka mudeli täielikkust käsitleva teabe edastamise vahendina, näidates näiteks projekteerija tehtud eeldusi või veel modelleerimata elemente. See on oluline eelkõige projekteerimisprotsessi varasemates etappides toimuva modelleerimise puhul. BIM-spetsifikatsioonidokumendis tuleks selgelt märkida ka teave, mis on lisatud eelnõuna (konstruktsiooni tüüp, materjal jne) ja mida võidakse muuta.

BIM-mudelis teabe ülevõtmiseks nõutavad andmed

BIM-mudelites olevad kogused ja omadused eraldatakse BIM- või IFC-tarkvara teabe võtmise funktsioonide abil. Allpool on loetletud andmed, mida on vaja vähemalt LCA teostamiseks.

Kvaliteetsed, täpsed, kirjeldavad ja informatiivsed andmed teabe ülevõtmisel suurendavad protsessi tõhusust ja täpsust nii IFC-tarkvarast eksportimisel kui ka teabe importimisel LCA-tarkvarasse.

Kõige olulisemad nõuded on loetletud allpool:

Hooneelement

Ehituselemendi klassifikatsioon vastavalt siseriiklikele parimatele tavadele. Hooneelemendi tüüpi kasutatakse heitkoguste liigitamiseks vastavalt hooneelemendile. Ehituselemendi järgi kategoriseerimine on ökoanalüüsi hindamisel väga oluline, sest see võimaldab komponentide tasandil hindamist.

Komponendi tüüp (klass)

Oluline andmete importimisel LCA-tarkvarasse. Komponentide tüübid on näiteks plaat, post või tala.

Näitab, millise modelleerimistarkvara vahendiga on komponent loodud, ja võimaldab kvaliteedi tagamist, et teave on mudelis õige.

Tüüp (viide)

Ehitatud elemendi tüüp vastavalt siseriiklikule heale tavale ja sõltuvalt sellest, mis on projektis kokku lepitud. Viide on kirjeldav teave elemendi kohta, mis vastab nimetamisele teistes projekteerimisdokumentides. Näiteks esimese korruse plaadi ehitatud elemendi tüüp.

Teave koguse kohta

Maht Oluline ehituselementide puhul, mille eelistatud mõõtühik on ruumala (m3).

Pindala Oluline nende ehituselementide puhul, mille eelistatud ühik on pindala (m2).

Lineaarne meeter Oluline nende ehituselementide puhul, mille eelistatud ühik on pikkus (m).

Tükkide arv Oluline nende ehituselementide puhul, mille eelistatud ühik on tükkide arv (tk).

Materjal

Materjali andmed, mida kasutatakse konstruktsioonis kasutatud materjali kirjeldamiseks. Näitab elemendis kasutatud materjali, nt puit, betoon või teras. Lisateavet materjali kohta, näiteks betooni tugevusklass, võib avaldada lisaandmete allikates.

Näitab materjali kihtide paksust konstruktsioonis (kui see on kättesaadav).

Kogupaksus

Konstruktsiooni kogupaksus on oluline eelkõige konstruktsiooni raami komponentide puhul..

Suomi

Ohjeet BIM-pohjaista materiaalin inventointia varten

Tämä ohjeistus on käännetty tämän Tietomallipohjaisen rakennuksen LCA-projektin loppuraportin "Instructions for BIM-based material inventory" -osiosta. Raportissa kuvataan tarkemmat ohjeet.

BIM-mallinnuksen tulisi noudattaa rakennusten tietomallinnusta koskevia kansainlisiä standardeja. Lisäksi kansallisesti voi olla tarkempia vaatimuksia tai ohjeita (esim. "RAVA3Pro" Suomessa, Ruotsissa kehitteillä oleva "Tillämpningsanvisningar BIM", "SIMBA" julkisia rakennuksia varten Norjassa ja DS/EN ISO 19650 Tanskassa).

BIM:n yleiset vaatimukset

LCA:n edellyttämät tiedot ovat samankaltaisia kuin kustannuslaskennassa tarvittavat tiedot. Rakennuselementit on mallinnettava siten, että määrät tuotetaan oikein suunnittelumallissa ja viedään näin ollen oikein IFC-malliin. Jotta BIM olisi mahdollisimman hyödyllinen LCA-laskennassa, BIM-mallinnuksen yleiset vaatimukset ovat seuraavat:

- **Laadukas mallintaminen** - Kansallisten parhaiden käytäntöjen mukaisesti.
- **Tarkkuus** - Mallin sisältö on tarkka ja elementit on mallinnettu siten, että ne voidaan viedä oikein IFC-malliin.
- **Kuvaileva ja informatiivinen** - Mallin sisältö ottaa huomioon BIM:n loppukäyttäjien tarpeet.
    - BIM-mallin mukana toimitetaan tietomalliseloste, jossa määritetään, mitkä tietokentät sisältävät olennaisia tietoja ja mihin tarkoituksiin malli on tarkoitettu. Ohjelmisto voi tuottaa tahattomia tietoja, jotka eivät välttämättä ole tarkkoja, ja siksi on tärkeää määritellä, mitä kenttiä on tarkoitus käyttää.
- **Oikea nimeäminen ja luokittelu** - Kansallisten standardien tai parhaiden käytäntöjen mukaan (tai hankekohtainen nimeäminen, jolloin nimeämiskäytäntöjen on pysyttävä samoina koko hankkeen ajan).
    - Kaikille rakennusosille annetaan kuvaavat tyyppinimet, joita käytetään myös muissa asiakirjoissa. Esimerkiksi kaikilla rakenteeltaan samanlaisilla seinäelementeillä on BIM:ssä määritelty sama seinätyypin tunniste, joka löytyy myös rakennesuunnitelmista. Tämä mahdollistaa tietojen hakemisen BIM-mallien ulkopuolisista lähteistä.
    - Kun asennettujen tuotteiden valmistaja ja tuotenimet ovat tiedossa (useimmiten as-built-malleissa), ne ilmoitetaan BIM:ssä tuotekohtaisten ympäristötuoteselosteiden (EPD) kartoittamisen

tueksi. Vaihtoehtoisesti mallissa olevien tuotetyyppien nimien kartoitus asennettuihin tuotteisiin tehdään ulkoisesti.

- Jos asennettuja tuotteita ei ole eritelty, materiaalit nimetään yhtenäisellä tavalla kaikissa malleissa käyttäen mahdollisuuksien mukaan vakiintuneita luokituksia. Materiaalit joko kirjataan malliin tai niihin viitataan ulkoisesti BIM-mallissa olevan tyyppinimen avulla.

Tietomalliselosteet

BIM-asiakirjojen sisältö ja mallinnusperiaatteet on dokumentoitava ja kuvattava liitteissä kansallisten parhaiden käytäntöjen mukaisesti. Tietomalliselosteessa on ilmoitettava esimerkiksi, mitä tietokenttiä tietomalliin tuotetaan. Tämä on tärkeää, koska ohjelmistot saattavat tuottaa automaattisesti tietoja (lisäkenttiä), jotka eivät välttämättä ole tarkkoja.

Tietomalliselostetta käytetään myös välineenä, jolla välitetään tietoa mallin täydellisyydestä esimerkiksi ilmoittamalla suunnittelijan tekemät oletukset tai vielä mallintamattomat elementit. Tämä on tärkeää erityisesti suunnitteluprosessin aikaisemmissa vaiheissa tehtävän mallintamisen kannalta. Myös luonnoksena lisätyt tiedot (rakennetyyppi, materiaali jne.), jotka voivat muuttua, olisi ilmoitettava selvästi BIM-määrittelyasiakirjassa.

Tietomallissa vaadittavat tiedot tietojen vientiä varten

BIM-mallien sisältämät määrät ja ominaisuudet poimitaan BIM- tai IFC-ohjelmiston tiedonottotoimintojen avulla. Seuraavassa luetellaan tiedot, joita tarvitaan vähintään LCA:n suorittamiseen.

Laadukkaat, täsmälliset, kuvaavat ja informatiiviset tiedot tietojen otossa lisäävät prosessin tehokkuutta ja tarkkuutta sekä viennissä IFC-ohjelmistosta että tietojen tuonnissa LCA-ohjelmistoon.

Tärkeimmät vaatimukset luetellaan seuraavassa:

Rakennuselementti

Rakennusosien luokittelu kansallisten parhaiden käytäntöjen mukaisesti. Rakennusosan tyyppiä käytetään päästöjen luokitteluun rakennusosan mukaan. Rakennusosan mukainen luokittelu on ratkaisevan tärkeää LCA-arvioinnin kannalta, koska se mahdollistaa komponenttitason arvioinnin.

Komponentin tyyppi (luokka)

Ratkaisevaa tietojen tuonnin kannalta LCA-ohjelmistoon. Komponenttityyppejä ovat esimerkiksi laatta, pilari tai palkki.

Näyttää, millä mallinnusohjelmiston työkalulla komponentti on luotu, ja mahdollistaa laadunvarmistuksen, että tiedot ovat mallissa oikein.

Tyyppi (viite)

Rakennetun elementin tyyppi kansallisten parhaiden käytäntöjen mukaisesti ja sen mukaan, mitä hankkeessa on sovittu. Viite on elementtiä kuvaavaa tietoa, joka vastaa nimeämistä muissa suunnitteluasiakirjoissa. Esimerkiksi pohjakerroksen laatan rakennetun elementin tyyppi.

Määrää koskevat tiedot

Tilavuus Olennaista rakennusosille, joiden ensisijainen yksikkö on tilavuus (m3).

Pinta-ala Ratkaiseva rakennuselementeille, joiden ensisijainen yksikkö on pinta-ala (m2).

Lineaarinen metri Ratkaiseva rakennusosille, joiden ensisijainen yksikkö on pituus (m).

Kappalemäärä Ratkaiseva rakennusosille, joiden ensisijainen yksikkö on kappalemäärä (kpl).

Materiaali

Materiaalitiedot, joita käytetään kuvaamaan rakenteessa käytettyä materiaalia. Näyttää komponentissa käytetyn materiaalin, esim. puu, betoni tai teräs. Materiaaliin liittyvät lisätiedot, kuten betonin lujuusluokka, voidaan ilmoittaa lisätietojen lähteissä.

Näyttää rakenteessa olevien materiaalikerrosten paksuuden (jos saatavilla).

Kokonaispaksuus

Rakenteen kokonaispaksuus on ratkaisevan tärkeä erityisesti rakenteellisen rungon osien osalta.

Íslenskt

Leiðbeiningar um efnisskráningu sem byggir á BIM

Þessi forskrift er þýdd úr hlutanum „Instructions for BIM-based material inventory" í þessari lokaskýrslu um byggingar LCA verkefni sem byggir á BIM. Í skýrslunni er lýst nánari leiðbeiningum.

BIM líkanagerð ætti að vera í samræmi við alþjóðlega staðla um gerð upplýsingalíkana. Á landsvísu geta verið sértækari innlendar kröfur eða leiðbeiningar (t.d. „RAVA3Pro" í Finnlandi, „Tillämpningsanvisningar BIM" í þróun í Svíþjóð, „SIMBA" fyrir opinberar byggingar í Noregi og DS/EN ISO 19650 í Danmörku).

Almennar kröfur um BIM

Upplýsingarnar sem krafist er fyrir LCA eru eins og þær upplýsingar sem þarf til kostnaðarútreikninga. Byggingarþættir verða að vera gerðir þannig að magnið sé myndað á réttan hátt í hönnunarlíkaninu og þar af leiðandi rétt flutt út í IFC líkanið. Til þess að BIM nýtist best í LCA útreikningum eru almennar kröfur fyrir BIM líkanagerð:

- **Hágæða líkanagerð** - Samkvæmt bestu starfsvenjum í landinu
- **Nákvæmt -** Innihald líkansins er nákvæmt og þættirnir eru gerðir til að vera fluttir rétt út í IFC líkanið.
- **Lýsandi og upplýsandi** – Innihald líkansins tekur mið af þörfum notenda BIM.
    - Lýsingarskrá fylgir með BIM líkaninu sem tilgreinir hvaða upplýsingareitir innihalda viðeigandi gögn og í hvaða tilgangi líkanið er ætlað. Hugbúnaður getur myndað óviljandi upplýsingar, sem gætu ekki verið nákvæmar, og því er mikilvægt að tilgreina hvaða reiti er ætlað að nota.
- **Rétt nafngift og flokkun** - Samkvæmt innlendum stöðlum eða bestu starfsvenjum (eða verkefnissértæk nafngift, en þá verða nafnavenjur að vera þær sömu í öllu verkefninu)
    - Öllum byggingareiningum eru gefin lýsandi gerðarheiti, sem einnig eru notuð í öðrum skjölum. Til dæmis hafa allir veggþættir með sömu uppbyggingu sama vegggerðarauðkenni sem er skilgreint í BIM, sem einnig er að finna í byggingaráætlunum. Þetta gerir kleift að sækja upplýsingar frá heimildum utan BIM líkananna.
    - Þegar framleiðandi og vöruheiti uppsettra vara eru þekkt (aðallega þegar um er að ræða einskonar gerðir) eru þau birt í BIM til að styðja við kortlagningu vörusértækra umhverfisvarayfirlýsinga (EPD). Að öðrum kosti er kortlagning á vörutegundarheitum í líkaninu við uppsettar vörur veittar að utan.

- Ef uppsettar vörur eru ekki tilgreindar eru efni nefnd á samræmdan hátt í öllum gerðum og notast við viðteknar flokkanir þar sem hægt er. Efnin eru ýmist skráð í líkanið eða vísað til utanaðkomandi með tegundarheiti í BIM líkaninu.

BIM forskriftarskjöl

Innihald og líkanareglur BIM skulu skjalfest og lýst í viðaukum í samræmi við bestu starfsvenjur í hverju landi. Í forskriftarskjölunum skal til dæmis koma fram hvaða upplýsingareitir eru búnir til í upplýsingalíkaninu. Þetta er mikilvægt, þar sem hugbúnaður getur búið til upplýsingar (aukareitir sjálfkrafa) sem gætu ekki verið nákvæmar.

Forskriftarskjalið er einnig notað sem tæki til að miðla upplýsingum um heilleika líkansins með því að tilgreina, til dæmis, allar forsendur sem hönnuðurinn hefur gefið sér eða hvaða þætti sem eru enn ómótaðir. Þetta á við, sérstaklega fyrir líkanagerð sem gerð er á fyrri stigum hönnunarferlisins. Upplýsingar sem bætt er við sem drög (gerð mannvirkis, efni o.s.frv.) og geta breyst ættu einnig að koma skýrt fram í BIM forskriftarskjalinu.

Nauðsynleg gögn í BIM líkaninu fyrir flugtak upplýsinga

Magn og eiginleikar innan BIM líkana eru dregin út með upplýsingaflugsaðgerðum í BIM eða IFC hugbúnaði. Hér að neðan eru skráð gögn sem eru nauðsynleg, að lágmarki, til að framkvæma LCA.

Hágæða, nákvæm, lýsandi og upplýsandi gögn í upplýsingafluginu auka skilvirkni og nákvæmni ferlisins bæði við útflutning frá IFC hugbúnaði og innflutning upplýsinga í LCA hugbúnað.

Mikilvægustu kröfurnar eru taldar upp í eftirfarandi:

Byggingarþáttur

Flokkun byggingarhluta, samkvæmt bestu starfsvenjum í landinu. Gerð byggingarhluta er notuð til að flokka losun eftir byggingareiningu. Flokkun eftir byggingarþætti skiptir sköpum fyrir LCA mat þar sem það gerir íhlutamat kleift.

Tegund íhluta (flokkur)

Mikilvægt fyrir innflutning gagna í LCA hugbúnað. Tegundir íhluta eru t.d. hella, súlu eða bjálki. Sýnir með hvaða tóli í líkanahugbúnaðinum íhluturinn hefur verið búinn til og gerir gæðatryggingu kleift að upplýsingar séu réttar í líkaninu.

Tegund (tilvísun)

Byggð þáttagerð samkvæmt bestu starfsvenjum á landsvísu og eftir því sem samið hefur verið um í verkefninu. Tilvísunin er lýsandi upplýsingar um þáttinn, sem samsvarar nafngiftum í öðrum hönnunarskjölum. Til dæmis, innbyggða frumefnisgerð jarðhæðarplötu.

Upplýsingar um magn

Bindi

Mikilvægt fyrir byggingarhluta þar sem valin eining er rúmmál (m3)

Svæði

Mikilvægt fyrir byggingarþætti þar sem ákjósanleg eining er flatarmál (m2).

Línulegur mælir

Mikilvægt fyrir byggingarhluta þar sem æskileg eining er lengd (m).

Fjöldi stykkja

Afgerandi fyrir byggingarhluta þar sem æskileg eining er fjöldi eininga (eining).

Efni

Efnisupplýsingar notaðar til að lýsa notuðu efni í mannvirkinu. Sýnir efnið sem notað er í íhlutinn, t.d. tré, steypu eða stál. Viðbótarupplýsingar sem tengjast efninu, svo sem styrkleikaflokk steypu, kunna að vera birtar í heimildum fyrir viðbótargögn.

Sýnir þykkt efnislaga í uppbyggingu (þegar það er til staðar).

Heildarþykkt

Heildarþykkt mannvirkis skiptir sköpum sérstaklega fyrir íhluti burðargrindarinnar

Norsk
Instruksjoner for BIM-basert materialmengder

Denne spesifikasjonen er oversatt fra delen "Instructions for BIM-based material inventory" i denne sluttrapporten for BIM-baserte bygg-LCA-prosjekter. Rapporten beskriver mer detaljerte instruksjoner.

BIM-modellering bør være i samsvar med internasjonale standarder for bygningsinformasjonsmodellering. I tillegg kan det finnes mer spesifikke krav eller retningslinjer på nasjonalt nivå (f.eks. "RAVA3Pro" i Finland, "Tillämpningsanvisningar BIM" som er under utvikling i Sverige, "SIMBA" for offentlige bygninger i Norge og DS/EN ISO 19650 i Danmark).

Generelle krav til BIM

Informasjonen som kreves for LCA, er den samme informasjonen som kreves for kostnadsberegninger. Bygningselementene må modelleres slik at mengdene genereres riktig i prosjekteringsmodellen og deretter eksporteres korrekt til IFC-modellen. For at BIM skal være mest mulig nyttig i LCA-beregninger, er de generelle kravene til BIM-modellering:

- **Modellering av høy kvalitet** - i henhold til nasjonal beste praksis
- **Presis** - Modellens innhold er nøyaktig, og elementene er modellert slik at de kan eksporteres korrekt til IFC-modellen.
- **Beskrivende og informativ** - Modellens innhold tar hensyn til behovene til sluttbrukerne av BIM-en.
    - Sammen med BIM-modellen skal det følge en beskrivelsesfil som spesifiserer hvilke informasjonsfelt som inneholder relevante data, og hva modellen er ment å brukes til. Programvare kan generere utilsiktet informasjon, som kanskje ikke er nøyaktig, og det er derfor viktig å spesifisere hvilke felt som skal benyttes.
- **Korrekt navngivning og kategorisering** - i henhold til nasjonale standarder eller beste praksis (eller prosjektspesifikk navngivning, der navngivningreglene skal være de samme gjennom hele prosjektet)
    - Alle bygningselementer gis beskrivende typenavn, som også brukes i andre dokumenter. For eksempel skal alle veggelementer med samme struktur ha den samme veggtypeidentifikatoren som er definert i BIM-en, og som også finnes i konstruksjonsplanene. Dette gjør det mulig å hente informasjon fra kilder utenfor BIM-modellene.
    - Når produsent- og produktnavnene på installerte produkter er kjent (som oftest i as-built-modeller), oppgis disse i BIM-en for å gjøre det enklere å finne produktspesifikke miljødeklarasjoner (EPD). Alternativt

leveres en ekstern oversikt over produkttypenavnene til de installerte produktene i modellen.

- Hvis de installerte produktene ikke er spesifisert, navngis materialene der det er mulig, på en harmonisert måte i modellene ved hjelp av etablerte klassifikasjoner,. Materialene registreres enten i modellen eller refereres eksternt med typenavnet i BIM-modellen.

BIM-spesifikasjonsdokumenter

Innholdet og modelleringsprinsippene i BIM-ene skal dokumenteres og beskrives i vedlegg i henhold til beste praksis. Spesifikasjonsdokumentene bør for eksempel opplyse om hvilke informasjonsfelt som genereres i informasjonsmodellen. Dette er viktig ettersom programvare kan generere informasjon (ekstra felter automatisk) som kanskje ikke er nøyaktig.

Spesifikasjonsdokumentet brukes også som et verktøy for å gi informasjon om hvor fullstendig modellen er, for eksempel ved å påpeke eventuelle antakelser som designeren har gjort, eller elementer som ennå ikke er modellert. Dette er særlig relevant for modellering som gjøres i de tidligere stadiene av designprosessen. Informasjon som er lagt til som utkast (konstruksjonstype, materiale osv.) og som kan bli endret, bør også angis tydelig i BIM-spesifikasjonsdokumentet.

Nødvendige data i BIM-modellen for informasjonsuttak

Mengder og egenskaper i BIM-modeller hentes ut ved hjelp av informasjonsuttaksfunksjoner i BIM- eller IFC-programvare. Nedenfor er data som minimum kreves for å utføre LCA, beskrevet.

Presise, beskrivende og informative data av høy kvalitet i informasjonsuttaket øker effektiviteten og nøyaktigheten i prosessen, både under eksport fra IFC-programvare og import av informasjon til LCA-programvare.

De viktigste kravene:

Bygningselement

Klassifisering av bygningselementer i henhold til beste praksis. Bygningselementtypen brukes til å kategorisere utslipp i henhold til bygningselementet. Kategorisering i henhold til bygningselementet er avgjørende for LCA-vurderingen for å kunne vurdere utslipp på komponentnivå.

Komponenttype (klasse)

Avgjørende for import av data til LCA-programvare. Komponenttyper er f.eks. plate, søyle eller bjelke.

Viser hvilket verktøy komponenten er generert med i modelleringsprogramvaren, og gir en kvalitetssikring av at informasjonen i modellen er korrekt.

Type (referanse)

Byggelementtype i henhold til beste praksis og avhengig av hva som er avtalt i prosjektet. Beskrivende informasjon om elementet, som samsvarer med navngivningen i andre prosjekteringsdokumenter. For eksempel den bygde elementtypen til en dekkeplate i første etasje.

Informasjon om mengde

Volum

Avgjørende for bygningselementer med foretrukket enhet volum (m3)

Areal

Avgjørende for bygningselementer med foretrukket enhet areal (m2).

Løpemeter

Avgjørende for bygningselementer med foretrukket enhet lengde (m).

Antall deler

Avgjørende for bygningselementer med foretrukket enhet antall enheter (unit).

Materiale

Materialinformasjon for å beskrive materialet som brukes i konstruksjonen. Viser materialet benyttet i komponenten, f.eks. tre, betong eller stål. Ytterligere informasjon om materialet, f.eks. betongens styrkeklasse, kan oppgis i kilder for tilleggsdata.

Viser tykkelsen på materiallagene i konstruksjonen (hvis tilgjengelig).

Total tykkelse

Total tykkelse på en konstruksjon er avgjørende, spesielt for komponenter i konstruksjonsrammen.

Svenska

Instruktioner för BIM-baserad materialinventering

Denna specifikation är översatt från avsnittet "Instructions for BIM-based material inventory " i denna BIM-baserade slutrapport för byggnads-LCA-projekt. Rapporten beskriver mer detaljerade instruktioner.

BIM-modellering bör följa internationella standarder för byggnadsinformationsmodellering. Dessutom kan det finnas mer specifika krav eller riktlinjer på nationell nivå (t.ex. "RAVA3Pro" i Finland, "Tillämpningsanvisningar BIM" som håller på att utvecklas i Sverige, "SIMBA" för offentliga byggnader i Norge och DS/EN ISO 19650 i Danmark).

Allmänna krav för BIM

Den information som krävs för LCA liknar den information som behövs för kostnadsberäkningar. Byggnadselement måste modelleras så att mängderna genereras korrekt i designmodellen och därmed exporteras korrekt till IFC-modellen. För att BIM ska vara så användbart som möjligt vid LCA-beräkningar är de allmänna kraven för BIM-modellering följande:

- **Högkvalitativ modellering -** enligt nationell bästa praxis
- **Exakt -** Modellens innehåll är korrekt och elementen är modellerade så att de kan exporteras korrekt till IFC-modellen.
- **Beskrivande och informativ -** Modellens innehåll tar hänsyn till behoven hos slutanvändarna av BIM.
    - En beskrivningsfil tillhandahålls tillsammans med BIM-modellen som anger vilka informationsfält som innehåller relevanta data och för vilka ändamål modellen är avsedd. Programvara kan generera oavsiktlig information, som kanske inte är korrekt, och därför är det relevant att ange vilka fält som är avsedda att användas.
- **Korrekt namngivning och kategorisering -** Enligt nationella standarder eller bästa praxis (eller projektspecifik namngivning, i vilket fall namngivningskonventionerna måste vara desamma genom hela projektet)
    - Alla byggnadselement ges beskrivande typnamn, som även används i andra dokument. Till exempel har alla väggelement med samma struktur samma identifierare för väggtyp som definieras i BIM, vilket också finns i strukturplanerna. Detta gör det möjligt att hämta information från källor utanför BIM-modellerna.
    - När tillverkar- och produktnamnen på installerade produkter är kända (oftast när det gäller modeller som byggts) anges dessa i BIM för att stödja mappningen av produktspecifika miljövarudeklarationer (EPD).

Alternativt tillhandahålls en mappning av produkttypnamn i modellen till de installerade produkterna externt.

- Om installerade produkter inte specificeras namnges materialen på ett harmoniserat sätt i modellerna, med användning av etablerade klassificeringar där så är möjligt. Materialen registreras antingen i modellen eller refereras externt med typnamnet i BIM-modellen.

BIM-specifikationsdokument

BIM-modellernas innehåll och modelleringsprinciper ska dokumenteras och beskrivas i bilagor i enlighet med bästa nationella praxis. I specifikationsdokumenten ska det t.ex. framgå vilka informationsfält som genereras i informationsmodellen. Detta är viktigt, eftersom programvara kan generera information (ytterligare fält automatiskt) som kanske inte är korrekt.

Specifikationsdokumentet används också som ett verktyg för att kommunicera information om modellens fullständighet genom att t.ex. ange eventuella antaganden som gjorts av designern eller eventuella ännu inte modellerade element. Detta är särskilt relevant för modellering som görs i de tidigare stadierna av designprocessen. Information som läggs till som utkast (strukturtyp, material etc.) och som kan komma att ändras bör också tydligt anges i BIM-specifikationsdokumentet.

Nödvändiga data i BIM-modellen för informationsavtagning

Mängder och egenskaper i BIM-modeller extraheras genom informationsavtagningsfunktioner i BIM- eller IFC-programvara. Nedan listas de data som minst krävs för att utföra LCA.

Högkvalitativa, exakta, beskrivande och informativa data i informationsuttaget ökar effektiviteten och noggrannheten i processen både under exporten från IFC-programvaran och importen av information till LCA-programvaran.

De viktigaste kraven listas i följande avsnitt:

Byggnadselement

Klassificering av byggnadselement, enligt nationell bästa praxis. Typen av byggnadselement används för att kategorisera utsläppen enligt byggnadselementet. Kategoriseringen enligt byggnadselementet är avgörande för LCA-bedömningen, eftersom den möjliggör bedömning på komponentnivå.

Komponenttyp (klass)

Avgörande för import av data till LCA-programvara. Komponenttyper är t.ex. platta, pelare eller balk.

Visar vilket verktyg i modelleringsprogrammet som komponenten har genererats med och möjliggör en kvalitetssäkring av att informationen är korrekt i modellen.

Typ (referens)

Typ av byggelement enligt nationell bästa praxis och beroende på vad som har överenskommits i projektet. Referensen är beskrivande information om elementet, som motsvarar namngivningen i andra designdokument. Till exempel den byggda elementtypen för en bottenvåningsplatta.

Information om kvantitet

Volym

Avgörande för byggnadsdelar för vilka den föredragna enheten är volym (m3)

Area (yta)

Avgörande för byggnadselement för vilka den föredragna enheten är area (m2).

Linjär meter

Avgörande för byggnadselement för vilka den föredragna enheten är längd (m).

Antal bitar

Avgörande för byggnadselement för vilka den föredragna enheten är antal enheter (unit).

Material

Materialinformation som används för att beskriva använt material i konstruktionen. Visar det material som används i komponenten, t.ex. trä, betong eller stål. Ytterligare information som rör materialet, t.ex. betongens hållfasthetsklass, kan anges i källor för kompletterande data.

Visar tjockleken på materialskikten i konstruktionen (när sådan information finns tillgänglig).

Total tjocklek

Den totala tjockleken på en struktur är avgörande, särskilt för komponenter i den strukturella ramen.

Appendix F: Educational videos on BIM-based building LCA

The project produced seven educational videos that support practitioners in learning BIM-based building LCA. The videos can be found on the YouTube of Nordic Sustainable Construction[58]. The following provides a short description of each video:

1. Introduction to the BIM4LCA project

   Generic description of the results produced in the BIM4LCA project: BIM-based building LCA, process, BIM models, the operating environment report of building LCA and BIM in the Nordics.
2. BIM-based building LCA process and building LCA calculation principles

   The principles of the LCA process and how to calculate LCA using BIM-based material at the building permit phase model level.
3. Architect's building permit and as-built phases: information content, IFC export

   How architects can put the necessary information in the right machine-readable form and codes to the architectural model and take the IFC export for that content; how they can take the quantities out of the IFC model and use this machine-readable data in LCA calculation software.
4. Structural designer: information content, IFC export, Excel import

   How to make structural design model and data that can be used in LCA calculation, how to take the report of material quantities and different material lists out in machine-readable form, e.g excel files
5. HVAC designer: information content

   How to make needed information for HVAC LCA calculation in the native software Magicad
6. HVAC designer: IFC export

   How to make needed information to IFC export in Magicad so that the IFC file can be used based on LCA calculation
7. LCA expert: IFC export, LCA software import, example on calculating the CO2 of e.g. a wall structure

   Instructions for BIM-based material inventory, how to transfer the data to LCA calculation software, and examples of how to use different structural parts from the IFC file to be used in LCA calculation software.

58. https://www.youtube.com/playlist?list=PLKuMoWj9yd7Ww3rne-uU3iq-LM2lypfE9&jct=zFxiyDdah8WJ_MAxaWIYEA

About this publication

BIM-based building LCA – Instructions for material inventory for normative climate declarations

Authors: Rita Lavikka, Mikko Kouhia, Martin Excell, Tomi Henttinen, Markku Kiviniemi, Tero Järvinen, Minna Salonsaari, Anna-Riitta Kallinen, Katja Maununaho and Tiina Vainio-Kaila

Other contributors: Tarja Häkkinen, Charlotte Nyholm, Tytti Bruce-Hyrkäs, Jan Karlshoej, Oddbjørn Dahlstrøm Andvik, Alexander Borg, Iselin Idunn Østvedt, Anni Oviir, Charlotta Malmén and Maximilian Von Bahr

© Nordic Innovation 2024

This project is part of the Nordic Sustainable Construction programme initiated by the Nordic ministers for construction and housing and funded by Nordic Innovation. For more information on Nordic Sustainable Construction, visit our website at nordicsustainableconstruction.com

Cover photo: Rita Lavikka

US2024-439
Published: 11.09.2024

Nordic co-operation

Nordic co-operation is one of the world's most extensive forms of regional collaboration, involving Denmark, Finland, Iceland, Norway, Sweden, and the Faroe Islands, Greenland and Åland.

Nordic co-operation has firm traditions in politics, economics and culture and plays an important role in European and international forums. The Nordic community strives for a strong Nordic Region in a strong Europe.

Nordic co-operation promotes regional interests and values in a global world. The values shared by the Nordic countries help make the region one of the most innovative and competitive in the world.

The Nordic Council of Ministers
Nordens Hus
Ved Stranden 18
DK-1061 Copenhagen
www.norden.org

Read more Nordic publications on www.norden.org/publications