Nordic Innovation

The Operating Environment of Building LCA and BIM in the Nordics and Estonia

Contents

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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:

Work package 1 – Nordic Harmonisation of Life Cycle Assessment

Work package 2 – Circular Business Models and Procurement

Work package 3 – Sustainable Construction Materials and Architecture

Work package 4 – Emission-free Construction Sites

Work package 5 – 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. It is in this context the present 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 work has been carried out by VTT, Granlund, and the Nordic partners: Sberesearch, Rangi Maja OÜ, Bengt Dahlgren Stockholm AB, Gravicon DK and Asplan Viak AS.

Nordic Sustainable Construction

For more information on Nordic Sustainable Construction, visit our website here: www.Nordicsustainableconstruction.com

Summary

This report describes the current operating environment of building life-cycle assessment (LCA) and Building Information Modelling (BIM) in the Nordic countries and Estonia. It reports the findings on current building LCA and BIM practices and constraints and enablers for harmonising building LCA. It also provides an understanding of the enablers and hindrances for BIM-based building LCA in the Nordic countries and Estonia. This work sets the basis for further project work[1] that provides guidance for BIM-based building LCA and material declaration.

The results reported have been produced by systematically collecting data via interviews and analysing information on BIM practices and normative LCA methods to define needs and constraints for further development activities in the project.

The Nordic countries have developed country-specific normative carbon footprint assessment methods based on EN15978 and EU Level(s) methods. There are still significant differences between the local methods concerning methodology aspects, such as system boundaries, life cycle scenarios, and reporting requirements, which, to some extent, prevent the harmonisation of building LCA reporting in the Nordics. Denmark, Norway and Sweden already have obligatory (i.e., normative) LCA calculations for new buildings, whereas Estonia, Finland, and Iceland plan to start requiring it soon.

As a whole, 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 supporting the finding of optimal solutions. BIM-based building LCA is here defined as a process where BIM provides adequate information on quantities to enable the formulation of a list of materials/products. This information is then linked with emission data. However, currently, inaccuracy in quantity take-off is an issue. The information content and identification of objects and materials in BIMs are not standardised, and therefore, project-specific knowledge is required in interpreting model data.

Integration with BIM software is another current challenge. BIM tools are widely used in the architecture and construction industry, but their seamless integration with LCA tools is still a work in progress. The lack of efficient interoperability between BIM and LCA software can result in increased time and effort, as practitioners may need to input data manually or make assumptions.

1. Work Package 1 – Nordic Harmonisation of Life Cycle Assessment, Task 3 of the Nordic Sustainable Construction programme https://nordicsustainableconstruction.com/work-packages/nordic-harmonisation-of-life-cycle-assessment

A BIM-based LCA necessitates the technical integration of product data – product ID and quantity – and emission data in the right format. However, calculating product-related emissions is only part of the building's carbon footprint. In addition, information on energy consumption during use and energy sources is needed to include the emissions caused by them. These data are not retrieved from BIM.

Introduction

Building Information Modelling (BIM) provides an opportunity to reduce manual labour in acquiring data for building life cycle assessment (LCA). The amount of research in the area has been increasing, especially since 2007, when the first attempts to use digital tools and solutions for the whole-life optimisation of buildings were conducted[2]. Since then, lots of R&D has been put into developing BIM practices and technologies, digitalisation of product data and their use in environmental calculation[3],[4].

This report describes the current operating environments of Nordic countries and Estonia regarding building LCA and BIM. It reports the findings on current building LCA and BIM practices, constraints and enablers for harmonising building LCA. The report also explains the current enablers and hindrances for BIM-based building LCA in the Nordic countries and Estonia.

The results have been produced by the expert group, i.e., the authors of this report. The group has systematically collected and analysed national information on BIM utilisation and LCA methods to define the needs and constraints for the BIM-based building LCA process. The national information has been retrieved from existing national reports and by conducting expert interviews in each Nordic country and Estonia. The Nordic partners identified the best experts in either BIM, building LCA or their combination. The interviewees encompass a wide range of perspectives, including representatives from government authorities, non-profit associations, architectural firms, and engineering companies. The structured interview data collection (August–September 2023) focused on the national BIM utilisation and LCA methods.

After the interview data collection and desktop research, a workshop was organized in early October 2023 with the Nordic project partners to analyse the data, understand the differences and similarities between the countries, and define the needs and constraints for a harmonised BIM-based building LCA process. The interviewees were provided with a privacy notice following the GDPR. The interviews were conducted in the native language of the interviewee, and the interview data was translated into English by the interviewers.

2. Häkkinen et al. (2007) ICT for whole life optimization of residential buildings, VTT research report with Lund University, Skanska Sverige, Cementa and Skanska Oy. https://publications.vtt.fi/pdf/tiedotteet/2007/T2401.pdf
3. Vares, S., Sulankivi, K., Palos, S., Kojima, J., Kiviniemi, M., & Tuomisto, M. (2013). Tuotetiedon käyttö tietomallinnuksessa esimerkkinä ympäristövaikutusten laskenta. VTT Technical Research Centre of Finland. VTT Tutkimusraportti Nro VTT-R-01180-13, part of research project "BIM based product data management in industrialized construction supply chain", including e.g., Skanska, Parma, Ruukki, Saint-Cobain, Tekla and Aalto University. https://cris.vtt.fi/ws/portalfiles/portal/26657623/VTT_R_01180_13.pdf
4. Vares, Häkkinen & Sulankivi (2014) BIM-based environmental evaluation (in Finnish), VTT research report. https://publications.vtt.fi/julkaisut/muut/2015/VTT-R-04182-14.pdf

The following section describes the normative building LCA in the Nordic countries and Estonia. After that, the constraints and enablers for Nordic harmonisation of building LCA are explained. Then, the BIM maturity in the countries is presented. Finally, the needs and constraints for a BIM-based building LCA are discussed, and conclusions are provided. The appendices provide a more detailed description of each country's current building LCA and BIM practices.

Normative Building LCA in the Nordics and Estonia

All Nordic countries have either effective or planned regulations requiring the building LCA for calculating the carbon footprint part. Similarly, the limit values are either effective or planned. Table 1 presents the situation in the Nordic countries.

Table 1. The status of normative building LCA and limit values in the Nordics and Estonia

Country	Mandatory building LCA	Source of the method	Limit values
Denmark	Since January 2023	BR18	Since January 2023
Estonia	Will be in force in 2025	Proposed method for climate declaration (2022)	Under discussion
Finland	Will be in force January 2025	Proposed method for climate declaration (2021)	Will be in force January 2025
Iceland	Coming soon	Method under development (2023)	Maybe in 2026
Norway	Since July 2023	TEK17	Maybe in +5 years
Sweden	Since January 2022	Act (2021: 787) on climate declaration for buildings. Ordinance (2021: 789) on climate declaration for buildings. Provision (BFS 2021:7) on climate declarations for buildings.	Proposed July 2025

Similarities and differences exist in the methodology and system boundaries in the normative LCA calculation rules. Table 2 presents the modules in a building's life cycle[5] and those included in each country.

5. EN15978:2011 "Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method"

Table 2. Modules in the normative building LCA in the Nordic countries and Estonia. X = included in the regulation, O = planned but not in force yet.

Module	Denmark	Estonia	Finland	Iceland	Norway	Sweden
A1-A3 Product phase	X	O	O	O	X	X
A4 Transport	O	O	O	O	X	X
A5 Construction process	O	O	O	O	X*	X
B1 Use	-	-	-	-	-	-
B2 Maintenance	-	-	-	-	X	O
B3 Repair	-	-	-	-	-	-
B4 Replacement	X	O	O	O	X	O
B5 Refurbishment	-	-	-	-	-	-
B6 Operational energy use	X	O	O	O	-	O
C1 Deconstruction, demolition	-	O	O	O	-	O
C2 Transport	-	O	O	O	-	O
C3 Waste processing	X	O	O	O	-	O
C4 Disposal	X	O	O	O	-	O
D Re-use, recovery, recycling potential	X	-	O	O	-	-

*Limited to emissions related to production and transport to the construction site of materials that become waste during construction. Emissions related to the waste management of these materials are not included. Other emissions in A5, e.g., construction activities, are not included.

Besides mandatory building LCA, voluntary calculations are currently made in all countries. The main drivers are certifications, such as BREEAM and LEED, which require LCA calculations, and companies' sustainability goals.

Nordic Harmonisation of Building LCA – Constraints and Enablers

Denmark has already set normative limits for the carbon footprint of buildings, while other Nordic countries aim in the same direction. Harmonisation of the processes and calculation methods behind these carbon footprint requirements between the Nordic countries has several benefits. Although regional differences exist, the Nordic construction market is connected, and a more aligned methodology would be preferable. Common methodologies would help to create a common market for low-carbon buildings and products and thus help to boost decarbonisation efforts in the whole area[6]. Harmonised methods would also enable comparisons between countries and facilitate follow-up on decarbonisation efforts of the building stock in the Nordic countries. Even more wide-ranging harmonisation is needed to understand the role of buildings and the building sector's responsibility in relation to the European climate targets and to create a basis for the limit-value regulation of carbon emissions of buildings. The green funding based on the EU taxonomy creates challenges for the Nordic funding organisations if each country has its own calculation methods in the building sector. The harmonisation work between Nordic countries has been ongoing for several years, but there remains work to be done.

Total harmonisation of the methodology might not be possible, but a process for unified labelling of the building parts, handling of the BIM material inventory lists and tracking of assumptions could streamline life cycle analyses. The status of the legislation in the Nordic countries varies; some countries already have mandatory LCA calculations for new buildings and large renovations, while others are currently developing the guidelines and preparing the legislation. This creates possibilities and challenges for harmonisation. Those still developing their methods can learn from those with experience. The process of getting new legislation into force is slow, and many parties are involved. Therefore, the countries already applying the national LCA calculation methods will not likely change their methods or guidelines in the near future. These challenges could be partly tackled with smooth communication between the authorities in the Nordic countries. Also, the possibly forthcoming Energy Performance of Buildings Directive (EPBD)[7] might provide a harmonised LCA rule or a mandate to make a delegated act for it.

Issues of methodological harmonisation include which life cycle phases are included, which building parts are included, how the replacements of building parts and

6. Roadmap: Harmonising Nordic Building Regulations concerning Climate Emissions, 2023, Nordic Sustainable Construction programme, https://pub.norden.org/us2023-450/
7. Revision of the Energy Performance of Buildings Directive: Fit for 55 package, https://www.europarl.europa.eu/thinktank/en/document/EPRS_BRI(2022)698901

service life are calculated, how process-related (like transportation, construction and deconstruction) emissions are dealt with, the choice of units of the GWP indicators, the treatment of biogenic carbon, and the acceptability of different data sources (including generic and specific sources) and the need for conservative values. In addition, the consideration of decarbonisation of energy should be consistent, and common principles should be defined.

Finland and Sweden already have national databases for building products and energy, providing typical values for the LCA. When using the typical values for normative calculation, a conservative factor must be used for building products, which in Finland is 1,2 and in Sweden and Norway 1,25. A similar database exists in Estonia, following the Finnish system, but this database is not yet validated and will get an update with the BuildEST[8] project. Denmark uses generic data in BR18's table 7[9] and if the generic data does not cover the needs, then ôkobaudat can be used or any EPD. Iceland does not have a national database, and the country has little national production of building products. The differences in the data used for emission factors are a constraint for harmonising building LCA. Still, once the products have been chosen, the already existing standards for EPDs ensure that climate data for products that have an EPD, are comparable and verified. With the introduction of digital EPDs, this climate data will be even more accessible.

The differences in the indicators result from the treatment of biogenic content in the products. The use of biogenic content in the calculation creates differences between calculations. For example, the values for glued laminated timber in the databases used in the Nordic countries can result in remarkable differences in the calculations (Table 3).

Table 3. Values for the emissions of glued laminated timber for the nominal calculations in Denmark, Finland, and Sweden.

Database	GWP type in the recommended databases and value A1-A3
Denmark, Ökobaudat	GWP-total: -668kgCO2e/m^3
Finland, CO2data.fi	GWP-fossil, conservative: 56kgCO2e/ m^3
Sweden, Boverkets klimatdatabas	GWP-GHG, conservative: 58kgCO2e/ m^3

8. https://kliimaministeerium.ee/en/research-and-development-program-life-ip-buildest-starter-building-renovation-marathon
9. https://bygningsreglementet.dk/Bilag/B2/Bilag_2/Tabel_7#787e83a6-b7d9-4a83-a4be-37574156daef

The Finnish legislation requires using the GWP-total values and recommends using the national emission database CO2data.fi, which currently provides values for the GWP-fossil, but national harmonisation is still expected[10]. Sweden and Norway use GWP-GHG, which is calculated by subtracting the amount of biogenic content from the GWP-total. Denmark is using GWP-total, and Estonia will use GWP-fossil or GWP-GHG. If the national assessment method does not include module C, using GWP-total would be problematic as the biogenic carbon content would not be subtracted from the calculations.

The operational energy use creates a large share of emissions, strongly affecting the LCA calculation result. Although the basic principles have been agreed upon[11], there are differences in calculating the building energy consumption. An important issue is also that there are differences in energy scenarios: how the energy sector will develop and how the emissions decrease during the calculation period is assessed. In addition, there are large differences in the energy sectors between the Nordic countries and Estonia, which mandates different emission factors and scenarios.

The building parts included in the scope of LCA are defined differently in each country. Comparison is difficult because the naming is not always directly comparable or at the same level and also the level of detail in defining the included parts differs. For example, Denmark leaves most plumbing-related parts out from the calculations, Sweden and Norway leave out all technical equipment, and Finland includes most major parts of HVAC systems but excludes building automation and smoke extraction structures. Groundwork and foundations, especially pile foundations, can have a major impact on the results of the carbon footprint calculation (up to 50% of A1-A3)[12] and will generally increase emissions by 10% per 10-meter length of pile foundations for A1-A3 calculations. All countries include foundations in the LCA methodology, but there might be differences in how much of the site preparations are included in the scope and whether site structures are included in the limit values.

When considering BIM-based LCA calculation, the availability of models must be taken into account. Though, it must be noted that some LCA tools can be used to complement partially missing inventory data from the BIM quantity take-off. Table 4 presents the stage where mandatory LCA calculation is performed in different countries. The accepted emission sources and conservative emission factors are also presented.

10. Based on the calculation methodology and the true energy sources the assessed difference between GWP-total and GWP-fossil is minor as explained in Reports of the Finnish Environment Institute 48 | 2022 Section 4.1.2 page 15.
11. The set of Energy Performance of Buildings standards, developed by CEN under mandate M/480, provides a methodology to calculate overall energy performance of buildings supporting the EPBD.
12. Values from actual building LCA calculations done by Asplan Viak

Table 4. The stage of normative LCA reporting and accepted data sources.

Country	Building life-cycle phase of the mandatory LCA	Floor area definition	Accepted emission data sources	Conservative emission factor for general data
Denmark	As-built	Reference area (embodied part), heated gross floor area (operational part)	Generic data from BR18 §297, EPDs	-
Estonia (Proposed)	Building permit	Heated net floor area	Estonian database, EPDs	1,2
Finland (Proposed)	Building permit and as-built	Heated net floor area	National emission database (CO2data.fi), EPDs	1,2
Iceland (Proposed)	Building permit and as-built	Gross floor area, possibly later net floor area	Emission database, EPDs	1,25
Norway	Finished before the certificate of completion is issued	Gross floor area	EPDs	1,25
Sweden	As-built[13]	Gross floor area	Boverket database, EPDs	1,25

13. A climate declaration needs to be registered at Boverket before final clearance from the municipality

BIM Maturity in the Nordics and Estonia

According to the country-specific interviews (see Appendix 2: BIM practices in the Nordics and Estonia), the various design disciplines in all Nordic countries and Estonia use BIM authoring tools, such as ArchiCAD and Revit, for architectural modelling and, e.g., Tekla Structures or Revit for modelling structures. These software allow the export of IFC (EN ISO 16739-1), an established way of exchanging information in construction projects. The use of IFC supports the BIM-based building LCA process in a software-independent way. This is important since the use of specific software for building modelling is rarely required by the customers.[14] Currently, in some countries, IFC 2x3 is the most used IFC version, but countries are slowly adopting newer versions of the IFC, such as IFC 4.3[15] or IFC 4.0.2.1.

Many countries have BIM guidelines and requirements to support modelling in general, but they are rarely national or mandatory. Most often, BIM guidelines originate from certain customers, usually public organisations. Also, the guidelines rarely support BIM modelling specifically for normative building LCA. Finland is the first Nordic country that will adopt national BIM guidelines for building permitting. Project-specific BIM execution plans are becoming common in construction projects. They help various design and engineering disciplines in model coordination and role definitions.

The naming conventions and classifications for materials and structures vary by country. The classification systems are national, and the maturity and usage of those vary by country and, to some extent, by project. Currently, the naming conventions in BIM modelling and emission databases are not aligned. Table 5 provides more details on the country-specific BIM practices.

14. In general, it is not technically necessary to use IFC as an intermediate format for the data transfer from BIM authoring tools to LCA calculation tools. The export can be done directly from the native format, or via plug-in.
15. Standard to introduce a wide range of definitions to present a construction project in a harmonized way for the building and infrastructure industry (BuildingSMART, 2023). It is an open BIM standard for buildings and infrastructure.

Table 5. Maturity of BIM practices in the Nordics and Estonia

Country	BIM tools used by various disciplines	BIM guidelines	Naming conventions for structures and materials	Regulatory data archival
Denmark	• Architectural: Revit, Archicad • Structural: Tekla Structures • HVAC: Revit, MagiCAD • Electrical: Revit (PcSchematic) • Model coordination: Solibri, BIM Collab	• Molio's BIM guidelines • Dikon's level of detail and delivery specifications	• BIMTypeCode (developed by BIM7AA) • CCS/CCI in some public projects	pdf or excel version. Voluntary standard (excel) format for LCA declaration from January 2024. Working towards LCA declarations in a digital format such as json.
Estonia	• Architectural: ArchiCad, Revit and Bently Microstation • Structural: Revit, Tekla Structures • HVAC: Revit and MagiCAD • Electricity: Cadmatic, Revit • Model coordination: BIMcollab Zoom, Solibri, Trimble Connect	• Organisation-specific guidelines, such as ÜBN	• No specific classification system is used in projects today. • CCI-EE is developed and covers, to some extent, materials as well (Construction Classification International Follows EN ISO 12006-2)	From the beginning of 2024, it will be possible to apply for the building permit by uploading the BIM model to EHR (Estonian Building Registry), open format (IFC) and meet ÜBN BIM requirements
Finland	• Architectural: Archicad[16], Revit • Structural: Tekla Structures, Revit • HVAC: MagiCAD (Revit), Cadmatic • Model coordination: Solibri	• National BIM guidelines for building permitting based on specific use cases, e.g., accessibility and operational safety • Common BIM Requirements 2012	• Structures: national project-specific conventions (e.g., external wall US1) • Materials/building parts: national classification system Talo 2000 for building parts and some materials • Public sector code lists and reference data • Common terminologies of public administration • Data vocabulary tool for managing core component libraries and application profiles as linked data models	From 1.1.2025, architectural, structural and HVAC (excl. Electrical) will be archived in IFC 4.0.2.1. Also, the material declaration needs to be archived.

16. According to a recent study, 60% of Finnish architects use ArchiCAD, Janhunen 2021, https://www.theseus.fi/bitstream/handle/10024/504062/Tietomallinnuksen%20nykytilanne%20ja%20osaamistarpeet%20talonrakennushankkeissa.pdf?sequence=2&isAllowed=y

Country	BIM tools used by various disciplines	BIM guidelines	Naming conventions for structures and materials	Regulatory data archival
Iceland	• Architectural: Revit and other Autodesk software • Structural: Tekla Structures • HVAC: Revit and MagiCad • Model coordination: Autodesk cloud service, Solibri Model Checker, Autodesk Navisworks	• There is no national-level guidance for BIM usage, but large clients, especially public clients, have their own requirements and guides for BIM usage	There are no naming conventions, but some companies have created company-internal guidance for naming and storing BIM data	pdf version
Norway	• Architectural: Revit • Structural: Revit, Tekla • HVAC: Revit, MagiCAD	• SIMBA 2.1 is Statsbygg`s BIM requirements • Norwegian standard NS 8360 BIM objects for construction works	• ISO 23386[17] standard for building information modelling and other digital processes used in construction. • ISO 23387[18] standard for building informa-tion modelling. Data templates for construction objects used in the life cycle of built assets – concept or principle. • EN 3457-3:2013[19] is the standard classification of buildings.	pdf version
Sweden	• Architectural: Archicad, Revit • Structural: Revit, Tekla Structures • HVAC: MagiCAD for Revit, AutoCAD • Model coordination: Solibri, Navisworks	• Industry guidelines called Nationella Riktlinjer	• BIM data is classified using CoClass or BIP codes (developed within the BIM Alliance)[20]	pdf version

17. This standard is developed to make sure that all definitions that are needed in all BIM domains can be interoperable in tools and applications.
18. This standard describes the principles and structure of data templates and is in alignment with ISO 23386.
19. This standard represents the initial phase in establishing a comprehensive Norwegian system for organizing information related to buildings, construction, and real estate.
20. Boverket is currently (Sep 2023–Feb 2024) working on a governmental BIM assignment to develop support for public actors on BIM for buildings. The aim is to digitalise construction processes. Proposals must be submitted regarding standards and guidelines to be used in the first place, i.e., specifications on format, deliverables for use in public law proceedings. For more information in Swedish: Uppdrag att ta fram ett stöd för offentliga aktörer avseende byggnadsinformationsmodellering - Regeringen.se.

Needs and Constraints for a BIM-based Building LCA

BIM-based building LCA is here defined as a process where BIM provides adequate information on quantities to enable the formulation of a list of materials/products. This information is then linked with the emission data. The main benefit of BIM for normative LCA is reducing manual work in gathering correct quantities. This is one of the most time-consuming tasks when performing an LCA calculation today. However, inaccuracy in quantity take-off is still an issue and may affect the LCA outcome[21]. The information content and identification of objects and materials in BIMs are not standardised, and therefore, project-specific knowledge is required in interpreting model data and mapping correct emission data to perform LCA reliably. Interviewees considered this a major constraint for BIM-based normative LCA.

No unified system exists for the classification of BIM objects, which poses a challenge when computing quantities for the LCA and mapping emission factors to the objects. This work would be more efficient when the object classification was recorded in the models in a standardised manner. A challenge is also that few experts know BIM and LCA, making it harder to understand each other's needs and constraints.

In addition to time savings, the risks of human errors could be mitigated by applying documented BIM to LCA pipelines. Reducing the amount of manual labour in LCA would also make it easier to compare different design alternatives concerning the building design's carbon emissions. BIM-based LCA enables following the life cycle effects of design decisions in the design process, from rough estimations to more refined designs. This may increase the understanding of LCA amongst the other parties involved in a building project, thus resulting in more climate-aware decisions.

BIM models may encompass the majority of building components required for conducting an LCA calculation, but they may also feature components not within the scope of LCA. The LCA expert needs to consider the LCA scope when performing calculations from BIM-based material take-off lists. BIM checking and coordination activities are already present in the design process, and quality control is also essential to the LCA performers.

Conversely, certain components are typically not included in the early design stages or may be absent after detailed design, for example, screed, coatings, fittings, and

21. Nawrocka, N., Machova, M., Jensen, R.L., Kanafani, K., Birgisdottir, H. and Hoxha, E. (2023) Influence of BIM's level of detail on the environmental impact of buildings: Danish context, Building and Environment, Vol. 245 (2023) 110875, https://doi.org/10.1016/j.buildenv.2023.110875.

smaller pipes. In different projects, reinforcement may or may not be included in the model; typically, only the concrete structure is modelled. The LCA specialist must acknowledge the components not included in the BIM and make relevant assumptions.

The general calculation rules for building LCA set requirements for the system boundaries, life-cycle modules, reporting units, the result's accuracy, and the use of data sources. These demands vary between the Nordic countries and Estonia. In addition to the general rules, countries have varying guidelines for normative building LCA reporting, such as the life-cycle phase when the building LCA report is required (See section Nordic harmonisation of building LCA – constraints and enablers). All of these affect the requirements for the BIM modelling process. For example, Finland will require a climate declaration (building carbon footprint and handprint) in the building permit phase. At that phase, only the architectural model exists with a certain level of detail; typically, specific products are not selected. Thus, the building LCA calculation is to a great extent based on the general emission values using the national co2data.fi emission database. Surface materials are also not yet specified at this point; thus, assumptions about them are made for the LCA.

A BIM-based LCA necessitates the technical integration of product data – product ID or type and quantity – and emission data in the right format. However, the calculation of product-related emissions is only part of the building's entire carbon footprint. In addition, information on energy consumption during use (B6) and energy sources is needed to include the emissions caused by them. These data are not retrieved from BIM and may not be available in machine-readable format, which challenges the automation of building LCA.

When calculating product-related emissions, information about product lifespan is also needed, in addition to quantities and emission data to calculate the replacement of parts (B4) during the assumed 50-year calculation period. In addition, emissions from services and systems, such as transportation, construction operations, deconstruction, and building services systems, are at present calculated during the building permit phase based on general assumptions, such as building type and size.

Some emission databases, like Finnish CO2data.fi, contain some generic values to calculate some modules (e.g., A4-A5) or some systems (e.g., MEP) based on the type of the building and gross or heated area of the building. This enables calculation during early phases, e.g., building permitting phase, when details and systems are not yet modelled. Current practice allows for the building floor areas to be modelled as spaces in the BIM, but the modelling conventions are not harmonised, thus, human interaction is required if this data from the model is employed in the LCA.

The accuracy of BIM-based LCA depends on the level of detail of the models available, i.e., the phase of the construction project and the purposes of the available models. The normative LCA in Nordics and Estonia is done at least during the building permitting phase, handover phase or both. The models and datasets available differ quite significantly between these phases. Commercial building products are rarely specified at the permitting phase, and emission data need to be based on nationally accepted databases or generic EPDs. For structures and systems that are not included in the design models, it is up to the LCA specialist to make correct assumptions on their quantities.

The conventions on BIM usage for normative LCA in the handover phase vary. It is not typical that information on installed products is updated in as-built models even though the model may have been updated to match, e.g., the location of installations in geometry. LCA calculation in the handover phase may rely on contractors' information collection of installed products and quantities and manual gathering of EPDs and other reference data sources. The EPD databases may not include the same product identifiers, such as GTIN code, that are used in contractor's purchasing and logistics, and therefore, linking EPDs to collected information on installed equipment may require manual steps. Many products do not still have EPDs, and the products may be project-specific engineered-to-order (ETO) products. In these cases, generic emission data is still employed.

Conclusions

This report describes the current operating environment of building life-cycle assessment (LCA) and Building Information Modelling (BIM) in the Nordic countries and Estonia. Also, findings on constraints and enablers for harmonising building LCA are discussed. The report explains the current enablers and hindrances for BIM-based building LCA in the Nordic countries and Estonia. The findings set the basis for further project work that guides BIM-based LCA and material declaration.

Nordic harmonisation of building LCA would allow the comparison of building LCA calculations between the Nordic countries and allow the Nordics to take an important role in harmonising building LCA around Europe. Harmonisation also helps the Nordic authorities better understand the impact, significance, and potential of buildings regarding the overall carbon emissions, and it thus helps the similar efforts of the Nordic authorities to prepare new regulations for limit values. The Nordic countries are among the most active users of BIM in Europe[22], and it is a field continuously developing with the digitalisation of the world. Harmonising the methods for BIM-based LCA calculations will benefit the Nordic construction sector, but this will not happen without facing some challenges.

The main benefit of using BIM in building LCA is that one can effectively get quantity information from a specific model, combine it with the emission data and, therefore, quickly evaluate the environmental performance of the chosen solution, together with other criteria for decision making.

In order to harmonise BIM-based LCA calculations, both LCA methods and BIM modelling have to be evaluated and further aligned. BIM can provide information on the materials and geometry depending on the level of detail in the model when the calculation is made. It is important to ensure that elements in the model are classified in a harmonised way. Although standards exist, these are not always adopted by the various actors within the construction industry. The models of the various design disciplines – structural, architectural, HVAC – should also be harmonised, especially as duplicate elements exist between the models.

Not all information needed for an LCA calculation of a building is available in a BIM. Additional information is required for calculating the carbon footprint in modules, such as the operational energy use, the transports and processes at the end of life. Some of the general values used for these purposes are based on the area of the building or, in some countries, gross area or heated area, which might be available in the model or acquired from elsewhere. There is a need to define, identify and harmonise the common building area concepts.

22. Digitalisation within the architectural profession in Europe, Extract from the ACE Sector Studies 2018-2022, https://issuu.com/azizmirza/docs/topic_3-digitalisation.

Thus far, national calculation guidelines and the national emission databases have enabled comparing building LCA results within each country. In the future, BIM could partly help automate building LCA calculation and reporting. However, data security needs to be taken into account, especially if uploading BIM in cloud-based BIM and LCA services. At least public owners have policies to secure data management and block leaks from unwanted actors. Data ownership is also an ongoing debate. IFC resolves some data-sharing issues as designers' native authoring software-specific tools or additions are not included in the IFC file. However, the violation of design solution IPRs needs to be controlled in BIM-based LCA processes.

Appendix: Building LCA and BIM Practices in Denmark

Building LCA in Denmark

Interviewees' background

Four LCA specialists were interviewed. The first LCA specialist (LCA-specialist-1), is an engineer at the authority and holds an MSc degree in sustainability. The specialist has been actively involved in sustainable roles since 2019. The second LCA specialist (LCA-specialist-2) has an MSc in architectural engineering and specialises in LCA and sustainability at a large engineering company. The third LCA specialist (LCA-specialist-3 holds an MSc in Architectural Engineering and works as an LCA specialist at an architectural company. The fourth LCA specialist (LCA-specialist-4) has a BEng in Architectural Engineering, is employed by an association and has extensive experience working as a sustainability expert in various companies.

National building LCA regulation

As of January 2023, performing an LCA analysis has become a mandatory requirement for obtaining a building permit for most types of buildings in Denmark [23]. Additionally, a voluntary sustainable class system has been in place since 2021. There are expectations that a proposed plan to progressively reduce the allowable amount of CO2 emissions by 2029 will be implemented. Currently, the requirement entails a 10% reduction, but it is foreseen that by 2029, the requirement will entail a significant 90% reduction (LCA-specialist-1).

This mandatory requirement applies to buildings with an area exceeding 1000 square meters. For buildings with an area less than 1000 square meters, there is a demand for a declaration of compliance. Certain types of buildings, including cottages, retrofitting and transformation projects, as well as unheated buildings and structures in terrain, are exempt from LCA requirements. Infrastructure facilities are not included in the requirements, but administrators of state own roads and railway has started own initiative call InfraLCA[24] (LCA-specialist-1).

To secure a building permit, an LCA calculation is not required. The as-built LCA declaration must be submitted as a part of the completion report before the building can be put into use. LCA calculations are in practice conducted at a

23. BR18 (bygningsreglementet.dk)
24. https://via.ritzau.dk/pressemeddelelse/ny-model-bidrager-til-fremtidens-gronne-transportsektor?publisherId=13559844&releaseId=13640511

minimum during the building permitting phase and before the building is occupied. However, in numerous projects, they are continuously updated throughout the design and construction phases (LCA-specialist-2).

In Denmark, it is mandatory to provide BIM (Building Information Modeling) models for state, regional, municipal, and social housing projects to the client. Nevertheless, it is neither mandatory nor feasible to submit BIM models as a prerequisite for obtaining a building permit (BIM-specialist-1).

Methodology

Building LCA calculations should adhere to the standards set forth in EN 15978:2012 [25], and Environmental Product Declarations (EPDs) should align with EN15804 +A1 [26] or +A2[27].

LCA calculations are initiated during the design phase, although it's worth noting that certain certifications only necessitate an as-built LCA calculation to ensure the intended environmental goals are met upon completion of the building (LCA-specialist-2).

These LCA calculations are typically carried out by architects, engineering firms, or LCA specialists, and there is a general consensus regarding the responsible party for conducting the calculations (LCA-specialist-2). There can be discussions between architects and engineers regarding whether the responsibility for LCA calculations and any necessary changes should rest with one party or be divided between them (LCA-specialist-3).

The impetus for LCA calculations often comes from government regulations, particularly since they are mandatory for all new buildings. However, it's important to note that LCA calculations were initiated before becoming a prerequisite for building permits, driven either by client demand for LCA calculations or by a desire to achieve certifications such as DGNB, Svanemærke, or similar standards (LCA-specialist-2 and LCA-specialist-3). These certifications often require the inclusion of LCA calculations as part of the documentation.

System boundaries

In 2023, there is a requirement for buildings over 1.000 m2 to achieve a maximum of 12.0 kg CO2 equivalents per square meter per year, with an expected progressive reduction leading up to 2029. In the same year, a voluntary low emission class imposes even stricter limits, allowing only 8.0 kg CO2 equivalents per square meter per year. It is anticipated that by 2029, the requirements will be further tightened to

25. DS/EN 15978:2012 - Webshop Dansk Standard
26. DS/EN 15804 + A1:2013 - Webshop Dansk Standard
27. DS/EN 15804:2012+A2:2019 - Webshop Dansk Standard

7.5 kg and 5.0 kg CO2 equivalents per square meter per year for all new buildings and low emissions buildings, respectively. The assessment period for these calculations spans 50 years. For the government's LCA requirements, modules A1, A2, A3, B4, B6, C3, C4, and D are to be included. (LCA-specialist-1).

Operational energy use calculation

For assessing building energy consumption during operation, the mandated approach is to utilise the "SBI-anvisning 213[28] "/BE18 energy calculation programme[29], which is in compliance with the regulations outlined in 2018/844/EU [30] (BIM-specialist-3). The concept uses an energy frame that includes delivered energy to the property for heating, ventilation, hot water, cooling, and potential lighting, multiplied by the relevant energy factor for each energy carrier. The factor is 0.85 for district heating, 1.8 for electrical heating, and 1.0 for all other types of heating multiplied with its efficiency.

It is important to note that while Module D should be calculated, its results should not be included in the total when determining compliance with the specified threshold.

Level of detail in calculating and reporting building LCA

Throughout the design phase, generic and product-type-specific Global Warming Potential (GWP) values are employed, as dictated by regulations. These values may differ from the GWP of the actual installed products and materials.

It's worth noting that the Global Warming Potential (GWP) data provided by the authorities includes some numbers from 2018 that have not been updated to reflect the most current values (BIM-specialist-3).

Accepted data sources

The authorities provide emissions data in BR18's table 7 and EPD. The table containing emissions data is available in CSV or Excel format. The authority does not provide a predefined format for emission data. In most cases, emission data from product-specific EPDs is manually transferred to LCA tools (LCA-specialist-2).

Building LCA tools

LCAByg[31] has been made available to the industry free of charge. It is developed by Aalborg University and supported by public funding, the future of its continuous

28. Bygningers energibehov (build.dk)
29. Beregningsprogrammet Be18 (build.dk)
30. Energy performance of buildings directive (europa.eu)
31. https://www.lcabyg.dk/en/

development is currently uncertain, as questions arise regarding its funding model. LCAbyg is widely adopted in the industry across various disciplines, although several other tools are also in use. Some alternative LCA tools[32] that can be utilised during both the design and construction phases include Realtime LCA[33], DesignLCA[34], and One Click LCA, while Null Carbon[35] on the other hand, is typically employed later in the design process and during the construction phase. LCA estimator[36] is primarily intended for use during the early stages of design.[37]

BIM practices in Denmark

Interviewees' background

Three BIM specialists were interviewed. The first BIM specialist (BIM-specialist-1) is a project manager at the authority. The specialist has studied holds an MSc degree in urban design and a BSc in architecture and has previously worked for a landscape architectural company and participated in landscape design competitions. The second BIM specialist (BIM-specialist-2) is a trained construction architect and a BIM specialist at a large engineering company. The third BIM specialist, (DK BIM-specialist-3, 2023), has an architectural education and serves as a middle manager at an architectural company.

The use of BIM

Architects often commence their schematic design in Rhino, and in some cases, they use AutoCAD, SketchUp, or FormZ. However, the design is frequently transitioned primarily to Revit, with secondary use of ArchiCAD for design development. Among engineering companies, Revit is commonly the tool of choice, although Tekla may be used by structural engineers in certain cases Lund. For the majority of projects, Revit, ArchiCAD, or Tekla are employed for creating construction documentation from BIM. AutoCAD is still utilised to produce certain 2D drawings (BIM-specialist-2).

Molio which is a non-profit organisation, along with its predecessors, has gained wide acceptance within the sector, enjoying recognition from both public and private organisations. Over the years, Molio, has played a pivotal role in defining CAD/BIM guidelines and has significantly increased its activities in the sustainability realm. A notable proof of this commitment is LCAcollect, a cloud-based collaborative tool designed for gathering input for LCA calculations during the design and construction phases (LCA-specialist-4).

32. https://molio.dk/nyheder-og-viden/netvaerk/contech-lab/aktiviteter/research/baeredygtige-byggeprocesser-og-digitale-vaerktojer-1
33. Real-Time LCA
34. DesignLCA
35. Nullcarbon
36. LCA estimator
37. https://molio.dk/media/5fqntzmi/23w35-oversigt-over-digitale-baeredygtighedsvaerktojer-v01.pdf

Dikon represents a consortium of major industry players, established with the primary goal of implementing Molio standards. However, Dikon has gone further by delivering specifications and defining various levels of detail within the BIM framework.

On a different front, BIM7AA was created by a group of architectural firms that recognised the need for a more streamlined classification system. They introduced BIMTypeCode, which has become widely adopted across the sector (BIM-specialist-3).

BIM guidelines

Most BIM models adhere to the guidelines set by Molio, Dikon, and BIM7AA (BIM-specialist-2 and BIM-specialist-3). Some interviewees pointed out that BIM models generated during the design phases could be quite dynamic, making them less suitable for direct use in LCA without thorough quality control (LCA-specialist-2). Design progress often varies across different disciplines, and models may contain elements that do not pertain to the building or multiple alternatives for the same building component.

In general, building parts are modelled according to Dikon's level of detail and delivery specifications. Molio is currently in the process of aligning its guidelines with ISO 19650 standards.

BIM models are created for nearly all buildings during the design phases. These models are typically generated by the various design disciplines involved, although the responsibility for updating models may vary between contractors and designers.

Naming conventions

Denmark hosts several classification systems, yet the majority of projects classify their components according to the BIMTypeCode, a system developed by BIM7AA (BIM-specialist-3). Some companies opt for an internal naming convention and endeavour to have their system adopted by other project participants (LCA-specialist-2). However, given that projects typically have distinct organisational structures, reaching a consensus on naming conventions can pose challenges. In some instances, it may be feasible to pinpoint specific materials, such as an exact concrete recipe, but this is the exception rather than the rule (LCA-specialist-3). In most cases, only the quantity and the overall material for each building component or the sum of components are transferred.

Quantity take-off

The IFC format is commonly employed for transferring BIM models from proprietary BIM tools to Solibri Model Checker, which is utilised for quantity take-offs. On the other hand, some prefer to use plugins that leverage the internal quantity take-off tools within their BIM applications (BIM-specialist-2).

A number of plugins rely on the LCAbyg input format, which, although documented, does not serve as a universal LCA format for quantities. An ongoing GitHub project called LCAx, initiated by Kristian Kongsgaard, aims to develop an independent format for LCA results.

Given the varying methodologies employed by different tools for conducting quantity take-offs, it's important to note that the same BIM model may yield different quantity results depending on the specific tool used (BIM-specialist-3).

According to Danish LCA regulations, certain building components should only be partially included, a task not typically addressed by default quantity take-off applications. Compensating for this requirement can be accomplished through BIM, quantity take-off, and LCA applications. However, it's worth noting that this can be a complex process, as most applications used in Denmark are international and may not inherently support specific Danish national requirements (LCA-specialist-3).

Appendix: Building LCA and BIM Practices in Estonia

Building LCA in Estonia

Interviewees' background

The interviewed LCA expert has worked in LCA over 8 years and international working background, now working locally in Estonia.

National building LCA regulation

As of the current moment, Estonia does not have established national regulations mandating Life Cycle Assessment (LCA) calculations in the construction sector. However, the Ministry of Climate has set forth a roadmap for future regulations. According to this plan, all public buildings will be required to undergo LCA calculations in 2025, extending this requirement to all buildings later on.

An initial draft methodology[38] designed for new construction projects was introduced in early 2022. BuildEST[39] project funded by Life IP aims to refine the draft method and to adjust method to accommodate renovation projects. This adapted methodology is anticipated to serve as the foundational basis for the forthcoming regulations.

The scope of these impending regulations remains under active discussion and has yet to be finalised. Regarding the stage at which LCA calculations will be obligatory, it is anticipated that if the forthcoming regulations align with the Building Energy Performance requirement, LCA calculations will become a prerequisite for obtaining a building permit.

The methods for setting limit values in LCA calculations are currently being examined. Discussions are underway to decide whether these values should be determined through statistical analysis or by using reference buildings as a benchmark.

While Building Information Modeling (BIM) is not a mandated requirement for securing a building permit at present, it is often included as part of project requirements set forth by individual developers. In these instances, the national ÜBN [40] standards are most commonly applied.

38. https://eehitus.ee/timeline-post/uuring-ehituse-susiniku-jalajalg/
39. https://kliimaministeerium.ee/en/research-and-development-program-life-ip-buildest-starter-building-renovation-marathon
40. https://eehitus.ee/juhendid/bim/

Methodology

Currently, the Level(s) method predominantly serves as the methodology for conducting Life Cycle Assessments (LCAs) in Estonia. In some exceptional cases, the national draft method is also applied. The practice of conducting building LCAs is still relatively rare. Nonetheless, there is an emerging interest from certain clients in incorporating LCAs into their construction processes. These clients generally perceive the utility of LCAs for enhancing their understanding of sustainable construction and are keen to acquire practical experience. When LCAs are ordered, they are most frequently conducted during the Preliminary Design ("eel-projekt", EP) and Technical Design ("põhiprojekt", PP) phases of a project.

Since there is no requirement for LCAs then the assessments are typically conducted if there is interest from an international investor or if the developer is particularly innovative and future focused. In some design contests, participants have had to calculate the carbon footprint of their design using a special calculator provided by the organiser. However, it's still uncertain whether this requirement has actually helped to reduce carbon emissions. Greater collaboration with private businesses is needed to figure out the best way to include Lifecycle Assessments in regular practice.

System boundaries

In Estonia, there are currently no established national guidelines for building carbon footprint calculations. Concerning the time frame for these assessments, a 50-year period is proposed in the current draft, which is expected to be followed in future regulation. Modules A1-A5, B4, B6, and C1-C4 are planned, with Module D designated as an informative module. It should be noted that Module D falls outside the system scope and will thus be excluded from any limit values.

With respect to exclusions of building types or components, although not yet definitively decided, the draft currently includes all structures except for external areas and auxiliary buildings like asphalt coverings and stand-alone parking areas. However, parking facilities directly attached to the main building are expected to be included in the scope of the calculations.

Operational energy use calculation

In terms of the methodology for calculating energy use in the operational phase, the prevailing plan is to align with the energy performance minimum requirement methodology, although this remains subject to final confirmation.

Lastly, as for deconstructed building parts, there is currently no intention to account for deconstructions within the LCA framework. However, this aspect is slated for further investigation as part of the ongoing Life IP project.

Level of detail in calculating and reporting building LCA

In the preliminary guidelines for LCA calculation needed for building permits, various assumptions are outlined regarding LCA data. It is likely, but not yet confirmed, that these assumptions will become official parts of the LCA requirements for obtaining building permits. Among these assumptions are:

- Transportation Distances: Predetermined distances for the transportation of various types of materials are specified.
- Material On-Site Wastage Percent: Utilised specifically for calculating the A5 module, this takes into account the percentage of material wastage on the construction site.
- Construction site impacts: Impacts arising from construction sites are calculated using a default value, which is derived from a study specifically conducted for the Estonian context. This default value for average site impacts is correlated with the building's gross floor area.
- Building Material Service Life: For the B4 module, default values specifying the expected service life of various building materials are included.
- Operational Energy Consumption: In the B6 module, emission factors are supplied to facilitate calculations. It should be noted that these factors are due for an update in the near future as Estonia transitions from the draft to the finalised national method.
- Material Processing and Transport: Within the C module, default values are stipulated for material processing based on the material type. Additionally, default values for material transport distance and associated demolition and landfilling impacts are included.

Given that the methodology is currently in its draft stage, these assumptions are subject to review and potential revision as the national method is further developed.

In the current draft guidelines for LCA reporting, there are specific requirements for how the environmental impacts should be presented. The report should break down the impacts by each stage of the building's life cycle, as well as by different parts of the building itself. In addition, the guidelines ask for the total environmental impacts for the entire building to be reported. These should also be calculated and presented per square meter of heated floor area, and further broken down to show these impacts on an annual basis per square meter of heated floor area. As these are still draft guidelines, they may be updated in the final version of the national methodology.

Accepted data sources

Currently, Estonia possesses a draft version of a national material emission database[41]. It is anticipated that in the beginning of 2024, the newly established Climate Ministry will publish a dedicated website to consolidate this data, along with any Environmental Product Declarations (EPDs) issued by local building product manufacturers. As it stands, the database exists as a standalone spreadsheet within the draft method calculator and comprises 47 building materials, in addition to a selection of default values.

While final determinations have yet to be made, there is a plan to permit the use of EPD data alongside the national database during the building permit phase. Any such data must be structured to reflect the building's performance, rather than specifying which building product manufacturer will be utilised. This approach aligns with Estonia's tendering system, which prohibits the identification of specific manufacturers at the building permit application stage.

Presently, Finnish data from co2data.fi and generic data from ökobau.dat are also frequently employed in various instances.

Building LCA tools

Currently, One Click LCA is the main tool used for building LCA studies in Estonia. An Excel-based calculator designed to match the national draft method has not been validated yet, so it's not in use. The validation process for this tool is planned to be completed as part of the Life IP project. Additionally, a new open-source tool, being developed by the Tallinn University of Technology, is expected to be introduced to the market in 2024.

SimaPro is used in some places but isn't common because it's not specifically for construction LCA. One Click LCA is the preferred tool mainly because it works well with Building Information Modeling (BIM) data.

BIM practices in Estonia

Interviewees' background

Two BIM experts were interviewed. The first BIM expert has over 10 years' experience, international working background and now working locally in Estonia. The other BIM expert works as a BIM manager/coordinator for construction projects.

41. https://eehitus.ee/wp-content/uploads/2022/04/Lisa-3-Susinikujalajalje-kalkulaator.zip

The use of BIM

BIM is commonly used in larger projects across various disciplines. The use of BIM is not dictated by the type of building but rather by the specific requirements of the project. Today, BIM is usually not used for private house designing.

From the preliminary design phase onwards, BIM is used in any larger project and often extends to the as-built model stage. For reconstruction projects, BIM models aren't created if the reconstruction scope is rather small. For the reconstruction of unique and complex buildings, BIM is typically used.

Architectural design is modelled usually from the Schematic Phase and continues until the Technical Design Phase. Structural BIM modelling usually starts in the second half of the preliminary design phase by designing the main load-bearing systems. It gets more detailed in the following design stages (principal and operational building design phases). HVAC BIM design starts in the preliminary design phase by placing the main ducts for the ventilation system and shafts for the various communications. In the principal design phase, all of the main components of the HVAC system are modelled. Architecture mainly uses ArchiCad, Revit and Bently Microstation as BIM design tools. Structural engineers mainly use Revit or Tekla Structures. MEP designers use mainly Revit and MagiCAD, Cadmatic is main software for electricity and Autodesk Civil3d for infraBIM. IDA-ICE is also used for energy simulations.

Softwares such as BIMcollab Zoom, Solibri and Trimble Connect are most typically used to check the BIM models by comparing the various disciplines (Structural vs Architectural, HVAC vs Structural and so) for geometrical clashes, functionality errors and semantic content.

The most active local consortium in Estonia is Digital Construction Cluster, which has members across the construction sector, from material manufacturers to developers, including universities (Tallinn University of Technology, Tallinn Technical College, Estonian Academy of Arts). The cluster works with experts and authorities to advance digital construction and BIM through training and technology partnerships.

BIM guidelines

Separate organisations have their own internal guidelines for BIM use. Some have more detailed guidelines, while others are still developing theirs. Every project typically comes with a specific BIM Execution Plan, which outlines the rules for modelling. These plans and guidelines are generally created to meet ÜBN[42] BIM

42. https://eehitus.ee/juhendid/bim/

requirements. The requirements are developed by the public sector in hand with the private sector. Estonian Centre for Standardisation and Accreditation (EVS) TK 50 (Technical Committee nr 50 - BIM) is responsible for maintaining and updating ÜBN requirements. Delegates from Ministry of Climate are also participating in that group and giving input especially regarding regulatory information requirements.

The specifications for level of development (LOD) and element data are described with ÜBN requirements[43]. Level of geometry (LOG) is specified using BIM Forum guidelines.

It is planned that from the beginning of 2024, it will be possible to apply for the building permit by uploading the BIM model to EHR (Estonian Building Registry). If BIM-based building permit is selected, then models must be in open format (IFC) and meet ÜBN BIM requirements. However, there is no national BIM mandate for permitting processes or creating construction designs.

Naming conventions

In Estonia, there is no specific classification system used in projects today. CCI-EE is developed and covers, to some extent, materials as well, but still not in wide use as there is no requirement to do so. There are some forerunners like TalTech University and the Estonian Transport Administration.

In material type classification, structural engineers typically determine the materials and types for major building elements like walls, slabs, and roofs based on structural analysis. Architects usually follow these decisions. Architects primarily focus on selecting materials for the facade as well as the types and materials for openings.

ÜBN requirements do not have materials specified yet, but it is a work in progress, along with binding BIM data with CCI.

Quantity take-off

Design specifications (that include quantity take-offs) are done inside of the main authoring tools: ArchiCAD, Revit, Solibri, Trimble Connect, Tekla, SimpleBIM and others. For data transfer, an IFC format is used, as well as for handover delivery to the client. BCF format is used for model-based communication and issue management in a cloud environment (BIMcollab Server) and Trimble Connect also uses the cloud platform.

When it comes to BIM-based quantity take-off, often the problem lies in the underlying data. Still, also there are no clear rules for IFC export, and in some cases, there is a lack of skill among BIM practitioners on how to export IFC without losing any material data.

43. https://nouded.rkas.ee/images/Lisa_4_BIM_andmesisu_n%C3%B5uded.xlsx

Appendix: Building LCA and BIM Practices in Finland

Building LCA in Finland

Interviewees' background

Two LCA experts were interviewed. The first expert has been working with building LCA and other environmental aspects for five years. The second expert has been working on creating the national LCA regulations.

National building LCA regulation

In its plenary session on the 1st of March 2023, the Finnish parliament approved the new Building Act, which will enter into force from the beginning of 2025. With that, the calculation of the carbon footprint of new buildings will become mandatory (called climate declaration). Also, the material declaration of the building must be reported. Finland has a national method for evaluating the carbon footprint of a building (Finnish Ministry of the Environment, 2019; Kuittinen & Häkkinen, 2020). Also, a national construction product emission database for construction exists (Häkkinen, 2022), as well as an emission database for infrastructure. Finland doesn't yet have limit values for the buildings' carbon footprint, but they are currently being prepared and will be included in the National Building Code of Finland. The new Building Act aims to make construction smoother, improve the quality of construction and boost the circular economy and digitalisation. For example, BIM-based building permit processes will be the future, and building permits and land use plans will be made machine-readable and stored in the coming new Built Environment Information System[44].

A new information system for the built environment (Ryhti) in Finland will be launched in 2024 for land use information and in 2025 for building information. The data in the system consists of building permit data with all its appendices, including buildings' climate reports and material passports as structured information. Also, building models in IFC format (both as-planned and as-built) can be saved in the data storage. This data will be collected in interoperable and reusable format in the information system to be utilised by various stakeholders. There will be application programme interfaces (API) that allow authenticated stakeholders to analyse,

44. https://valtioneuvosto.fi/en/-//1410903/government-s-legislative-proposals-to-parliament-aim-to-reduce-emissions-from-building-and-promote-digitalisation

manage or download the information from the system. The information system is built and hosted by the Finnish Environment Institute SYKE.

The climate declarations will be required for all buildings and major renovations with the following exceptions:

- buildings with a floor area of less than 50 m^2;
- residential buildings intended for holiday accommodation intended to be used for less than four months of the year;
- temporary buildings planned for a maximum of two years;
- industrial or workshop buildings;
- non-residential farm buildings with low energy demand or used in an area covered by a national sectoral energy performance agreement;
- buildings used for worship and religious activities;
- buildings that are protected by virtue of the Act on the Protection of the Built Heritage (498/2010), a protection order issued in a town plan or an admission to the World Heritage List in accordance with the Convention for the Protection of the World Cultural and Natural Heritage (Treaty Series 19/1987) as part of a designated environment or because of its special architectural or historical merits, to the extent that its nature or appearance would change in order to comply with the minimum energy efficiency requirements; in an unacceptable manner.

The climate declaration must be submitted to achieve the building permit. If there are major changes between the plan used for the initial calculations and the realised building, the updated calculations must be delivered after the building is finished. The differences might arise from changes in plans, materials or more accurate knowledge of the products used (EPDs of products used instead of the general data).

The limit values will be taken into use as the law regarding the climate declaration will enter into force. They have not been defined yet, but the collection of the voluntary carbon footprint calculation results has been done to get an understanding of the baseline level.

Methodology

The general guidelines behind all Nordic methods are EN15978 standard and Level(s) framework, which leaves a lot of room for specification to create calculation methods. In Finland, the method for the normative calculations for building permits was first introduced in 2019. The method will be updated after agreeing on the details of the regulation, which might still change.

The results of the LCA studies of building projects are not collected systematically at the moment, but Helsinki, for example, has already introduced its limit values and received data through the building permit process. In smaller cities, the LCA calculation might not be as common. The same applies to construction companies: the bigger companies have already adapted the routine of calculating the building LCA, whereas smaller companies are not doing it as often. The factors driving the calculation of building LCA are partly preparation for the coming regulation and partly companies' environmental strategies.

System boundaries

For the normative LCA calculation in Finland, the building and the building site are considered, but for example, the temporary premises and scaffolding are left out. The calculation is made for a 50-year period and includes modules A1-5, B4, B6, C1-4 and D1-6. Module D needs to be reported separately and is not subtracted from the carbon footprint of the other modules.

Operational energy use calculation

The energy use has to be calculated based on the energy efficiency of the building. For the emissions of different energy forms, such as electricity, district heating or fossil fuels, there is a table in the "Method for the whole life carbon assessment of buildings"[45]. The table is based on the assumptions arising from research[46] that the energy in Finland will gradually get decarbonised.

Level of detail in calculating and reporting building LCA

Assumptions are needed in all future modules. In Finland, the information for modules A4, A5, B4, C and D can be taken from CO2data.fi or if the information is available in EPDs, this information can be used for B4, C and D modules. For the construction operations A5 and the transports A4 and C2, the realised energy use and transports can be calculated with the emission data from the CO2data.fi or EPDs. If the general data is used, the result is also general, and the results are more accurate when the real data is used.

Accepted data sources

In Finland, the accepted data sources for the normative LCA calculations are the national emission database[47] and verified EPDs. For the emission database, there are APIs available and active development work is continuing to make the database

45. Method for the whole life carbon assessment of buildings (valtioneuvosto.fi)
46. Koljonen, T., Soimakallio, S., Lehtilä, A., Similä, L., Honkatukia, J., Hildén, M., ... & Vainio, T. (2019). Pitkän aikavälin kokonaispäästökehitys.
47. www.co2data.fi

suitable for normative use. For the data in EPDs the digital accessibility is still very low. There are EPD databases with machine-readable EPDs and those can be accessed by API but finding automatically correct EPD is problematic as there are different product identifiers that are used in product data management in business processes. They are also exceptions at the moment and most commonly EPDs are available as pdfs.

Building LCA tools

The most common way of calculating the building's LCA at the moment is importing the bill of quantities from a BIM model to OneClickLCA-tool[48]. Besides this, there are a number of other tools being used. Ministry of Environment has prepared an Excel tool for the calculation purposes. The challenge with an Excel tool is to transfer all the parts of the building manually from other software.

BIM practices in Finland

Interviewees' background

Four BIM experts were interviewed with different competence backgrounds. The first expert (BIM-specialist 1) had long experience in using IFC data for production planning, which requires quantity take-off from model and mapping quantity items with production data for, e.g., scheduling. The second specialist (BIM-specialist 2) was BIM software developer with over 20 years expertise in IFC standardisation, BIM coordination and IFC-software development. The third specialist (BIM-specialist 3) had worked over 30 years in quantity take-off and was the quantity take-of consultancy service manager. He was involved in developing and implementing BIM-based quantity take-off. The fourth specialist (BIM-specialist 4) was not a BIM-specialist but a developer of software for estimating costs and LCA of a building with a computational model that produces quantities of structures and systems by client needs of spaces or other usage information.

The use of BIM

In Finland, BIM is used widely in design and construction. Practically all multistorey residential buildings, public, commercial, and industrial buildings are modelled. Some smaller buildings and buildings outside of cities may be, in some cases, designed in 2D (BIM-specialist 2). The BIM usage in renovation is not as comprehensive as in new construction. Laser scanning is used for producing inventory models of existing buildings, fully or partially, in bigger or specific renovation projects. Inventory models are used for BIM-based design. The inventory models and BIM-based design are seldom used in typical residential building renovations.

48. https://www.oneclicklca.com/

In BIM-based design projects, all disciplines, including architectural, structural, HVAC, and electrical, models are created. Models cover the whole building, including all repetitive floors modelled separately. The level of detail of modelled structures and components is fairly well established in practice in different design phases. There is no clear level of detail (LOD) definitions for the phases, and there are some differences based on company practices and clients' demands.

In Finland, architects are using Archicad and Revit. Structural designers mainly use Tekla Structures for general structural design and in detailing concrete and steel structures, but Revit is also used for structural design. MEP designers use mostly MagiCAD for Revit/Autocad and Cadmatic, which is often used for electrical design. Solibri Model Checker (SMC) is most used for combining and coordinating the discipline-specific models that are imported in SCM in IFC format.

Sharing the models between disciplines is based on IFC, currently in 2x3 version. Sharing models is used mostly for coordinating and clash detection by BIM coordinators (BIM-specialist 2). In construction projects, there is usually an appointed consultant for BIM coordination even though legal design coordination responsibility is on the main designer (architect).

Finland has approved a new Building Act[49] that will enter into force on 1.1.2025. There is a requirement that building design for building permit application must be provided as a building information model (BIM) or in machine-readable format. In practice, this will mean building permit application with the IFC model in most cases. This will affect practices, especially in architectural modelling, as the building permit is applied based on architectural design. Preparations for BIM-based building permitting have been done in the municipalities' common Rava3Pro[50] development project, and requirements and data contents for permitting BIM have been defined and will be detailed later. The new Building Act also requires LCA calculation for permitting. Currently (October 2023), new decrees for defining official requirements for BIM-based permitting and the climate declaration are under development.

The main community in Finland for BIM-related developments and harmonisation is buildingSMART Finland (bSF), which is a chapter of buildingSMART International. Operations of bSF are organised in Rakennnustietomalli Oy, which is a subsidiary in a group of companies owned by the foundation Rakennustietosäätiö. bSF has four major working groups for buildings, infra, cities and competence & skills.

Due to the above-mentioned new regulation, other development groups are working on BIM and digitalisation topics related to authorities' work at national and municipal levels, e.g., Rava3Pro and previous building permit (Rava)-projects. The Ministry of Environment has also organised an ongoing project, started in 2019, to develop the interoperability of the built environment

49. 751/2023 Rakentamislaki, https://finlex.fi/fi/laki/alkup/2023/20230751
50. Municipalities building authorities' development project Rava3Pro 2022-2023 http://www.rava3pro.fi/.

information[51]. The project is not directly providing methods or guidance for BIM-based interoperability but creating high-level data models and vocabularies that would also be utilised in BIM-based data exchange. All developed data definitions are documented on the Web[52] to be used as public digital data dictionaries in the future to increase semantic interoperability in the domain.

The new regulation changes also building registries and archiving. Under development is a national-level registry for building permit data and city plans[53]. This data is currently stored at a municipal level, and only main building and dwelling information is stored in the national building registry. All design disciplines' IFC models are required to be stored in this central registry in the handover phase of a construction project. Also, The National Archives of Finland has made 2023 an official decision[54] to approve the IFC format for long-term archiving. The approval covers, at this point, the IFC version 4.0.2.1.

BIM guidelines

BIM modelling in Finland has been guided at the national level since 2012. Common BIM Requirements (COBIM)[55] are presented in 13 parts for different design disciplines and use cases. Even though those were named "requirements", in practice, those are more like guidance, but some clients' have set selected content of those in design contract requirements. COBIM guidance has harmonised, at some level, what to model in different design phases and had a real impact on modelling practices. The COBIM documentation has not been updated, and buildingSMART Finland has launched a development project[56] in 2022 to create new guidance for modelling and BIM usage in the domain. Participating organisations fund the development.

Large public client organisations and some private clients and developers have their own documented BIM requirements and guidance for the designers. Senate Properties, owner of the buildings used by the state, prepared the first general BIM requirements and guidance in 2008. The current requirements typically include a procedure to create a project-specific plan for BIM modelling, and usually, the BIM coordinator-consultant prepares the plan and is responsible for the follow-up of the implementation. Beyond the current approach, there are first indications for a more formal approach to managing modelling content. Those are based on the ISO 19650 standard series for managing information and BIM in buildings and civil engineering works.

In practice, the modelling has been concentrating on managing the 3D geometry and visual quality of the models. This has enabled better coordination of different

51. Interoperability of the built environment information, Ministry of Environment. https://ym.fi/en/interoperability-of-the-built-environment-information
52. Yhteentoimivuusalusta. https://www.suomidigi.fi/ohjeet-ja-tuki/yhteentoimivuusalusta
53. Ryhti project https://ym.fi/en/project-ryhti
54. https://kansallisarkisto.fi/-/rakennuksen-ifc-tietomallista-kansallisarkiston-paatos
55. Common BIM Requirements 2012, https://wiki.buildingsmart.fi/en/04_Guidelines_and_Standards/COBIM_Requirements
56. RYTV Project Program, buildingSMART Finland. https://www.buildingsmart.fi/en_GB/rytv

disciplines' designs, clash detection, and management of common coordinates in the models. However, the alphanumeric information content of the objects in the models has more variability, and information may be ambiguous or just missing. This is due to missing detailed requirements, and the client's general requirements are considered as guidance (BIM-specialist 2).

In detailed design, the modelling provides added value to stakeholders. Large prefabricators in Finland use detailed BIM data in their concrete or steel component production and supply chain management. HVAC modelling software enables simulations with detailed system models, like ventilation systems, but this intelligence is lost in IFC-export.

Naming conventions

In Finnish design practice, the main structures of the building are identified with established project-specific naming conventions referring to the structure type (like an external wall) and a number identifying the type. Designers also use in detailed design other national naming and coding conventions for different components like windows, doors or precast components. These identification practices are not fully standardised, and designers apply those according to their needs at the project level.

The Project classification codes of the national Talo-2000[57] system are not used systematically in architectural and structural BIM for classifying structures or components. The Talo-2000 system also contains Building product classification codes that are sometimes used in architectural models for classifying materials and components, but this depends on company practices and often all materials or products have not been classified.

The naming of the products and material layers in the architectural model is based on a typical plain language description that is understandable by human professionals, but naming is not standardised or harmonised in the domain. Also, there might be some variability in expressions even in the same project, and some naming might be missing. Sometimes, even material layer dimensions may be missing. In general, fully automated semantic identification of the materials and products is not reliable, and some semi-automated mapping to emission data is usually needed.

The Rava3Pro development project has defined national IFC custom property sets and properties and allowed enumerated coding of values to enable improved semantic interpretation of IFC model data contents and identifying components. Those developments include, e.g., how to define building type in IFC data with

57. Talo 2000 -nimikkeistöt, Construction 2000 Classification. https://www.rakennustieto.fi/nimikkeistot/talo-2000-nimikkeistot

officially required codes. There is the same kind of approach for defining room usage types or common naming for MEP components. The allowed values for these properties will be published in a national Web-based data dictionary. Also, the usage of the buildingSMART Data Dictionary[58] for publishing this coding is under evaluation.

In Finland, the regulation for BIM-based building permitting and normative LCA are under development until 2025, when the new Building Act comes into force. The BIM-based permitting will affect the modelling practices in the domain, but it is still unclear whether there will be official modelling requirements supporting BIM-based normative LCA.

In Finland, LCA is already calculated in many projects in the design phase. The specific LCA consultant usually calculates with OneClickLCA as it provides several emission data sources. The current guidance for normative LCA allows the use of emission data sources, either national emission database (CO2data.fi) or EPD data (this guidance is not yet approved). Only in a few cases the designer selects a commercial product in design, so most of the calculation will be done with national conservative data. The national database includes some options to select, e.g., low-emission concrete in design. Still, in general, there is no other possibility that the designer could set a limit value for components or materials for the contractor to reach as any other design requirement.

Quantity take-off

IFC-based quantity take-off is done in Finland with BIM software like Solibri Model Checker or Simplebim, or with some cost estimation software like Tocoman BIM3 or RIB iTWO, which have the capability to extract quantity information from BIM. It is also possible to do quantity take-off directly from the native BIM software.

The interviewed specialists (BIM specialist 2 & 3) compared LCA calculation to cost estimation. The contractor's cost estimation is based on cost data of resources like different materials. In an advanced method, the quantities are taken off at the building structure or component level and attached to predefined cost structures in the company's cost estimation software. The cost structure defines how much material is needed per structure or component unit. The cost estimation system contains material cost data per material unit to calculate the costs of the structure or component. Besides the cost data, the material item can have emission data to calculate LCA based on the same quantity information as cost estimation.

In this quantity take-off procedure, the detailed material data possibly defined in the IFC is not calculated. The cost estimation procedure is not a fully automatic workflow and requires manual mapping to detailed cost items. Some companies

58. buildingSMART Data Dictionary, https://www.buildingsmart.org/users/services/buildingsmart-data-dictionary/

use Simplebim to re-process the IFC file to make this mapping semi-automatic. In this process, the company-specific identifiers are added to the IFC file with Simplebim's functionality of modifying IFC data with user-defined rules, and as a result of the process, some quantities can be automatically mapped to cost items.

Quantity take-off from IFC data is based on reading quantity property sets where native software exports the calculated values. Another approach is that above-mentioned software imports IFC data and can calculate quantities by the geometry of the objects.

The input data format in the abovementioned software is IFC, as the software can handle IFC data for the quantity take-off. In Finland, the most used LCA software, OneClickLCA, can import quantity data in MS Exel and gbXML[59] formats. OneClickLCA also has plugins for several BIM authoring software, enabling designers to produce LCA for own discipline in the native software.

The contractor's cost estimation is based on a more detailed level of detail of design that is required for building permit application. There are other cost estimation services that clients are applying for budgeting in the earlier phase. For example, Haahtela TVD software can produce a budget for a building with simulated quantities based on the needs of different spaces in the building, and LCA calculation will be added to the service. When the design is developed, the input for simulation will be detailed, and the budget will be updated.

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59. Green Building XML (gbXML), https://www.gbxml.org

Appendix: Building LCA and BIM Practices in Iceland

Building LCA in Iceland

Interviewees' background

The interviewed LCA-expert is a "Technical draftman" (AutoCad, Revit, Inventor) and studied architectural technology and construction management in Denmark and the final project was about LCA. Currently works in the government projects to help this big change in Iceland.

National building LCA regulation

National building regulation is being planned, and this has been announced in June 2023. According to plans, the regulation will come into force in the year of 2024, and the work for defining the regulation is ongoing. The harmonisation with the other Nordic countries is considered to make it possible to make comparisons. Using BIM in LCA calculations is not going to be required, but nearly all in Iceland use it anyway.

The regulation is planned for all types of buildings for new construction projects, including single family houses, apartment buildings and all most common building types. The plan is to have LCA calculation required in the planning phase and in the as-built phase. The limit values are planned to be in use in 2026.

Methodology

The general guidelines behind all Nordic methods are EN15978 standard and Level(s) framework, which leaves a lot of room for specification to create calculation methods. Iceland is cooperating with the other Nordic countries to define the more precise method.

Most of the new governmental building projects in Iceland are BREEAM projects, which leads to LCA calculations in the design phase and repeated in handover. In handover the EPDs are collected but those do not exist for all products. If no EPD data is not available, other Nordic data or OneClickLCA database data is used. Sometimes the emission data has to be evaluated with some reference data. This is the main driver at the moment for the LCA calculation of building projects but the legislation which is being prepared will also be a driver.

System boundaries

The calculation is planned to cover A1-A3, A4-A5, B4, B6, C and D and the calculation period will be 50 years. As the legislation is still being developed, very precise definition of the system boundaries does not exist yet. The goal is to make the transition smooth and are therefore trying to get industry involved in the process.

Operational energy use calculation

New construction will need to do energy calculation with the future emission values from energy authorities. As 90% of the buildings in Iceland use geothermal heating, which is green energy. There will be less variation over the years compared with many European countries with varying heating energy sources.

Level of detail in calculating and reporting building LCA

Assumptions are made for the material selection in the beginning phases, which will then evolve and maybe change later. General average values will be needed, for example in the A4 and A5 phases.

Accepted data sources

The regulations do not exist yet but there is a desire to have traceable data. There is also a plan on creating a database with Icelandic construction products and Icelandic typical building elements.

Building LCA tools

The most common way of calculating the buildings LCA at the moment is using OneClickLCA-tool but also LCAbygg is used. The calculators will be allowed to decide which tool they want to use, Excel might be sufficient in the beginning.

BIM practices in Iceland

Interviewees' background

The interviewed BIM expert is a board member in BIM Iceland and has practical experience in BIM modelling from several years.

The use of BIM

BIM is applied in the design of larger projects in Iceland, like multistorey buildings in general, and is almost mandatory for those. In private housing projects and renovation, BIM is not used widely. In BIM projects, all disciplines are modelled, but only architects may use modelling in all design phases. With the new building regulations that are under development the plan is to allow model-based submission for building permit, but it's unclear when that will be applied and what requirements the models will have. Currently drawing submission is needed for applying for building permit.

Most used BIM software include Revit and other Autodesk software, and some usage of Tekla Structures. For BIM-coordination and clash detection is used Autodesk cloud service (BIM360) and for more detailed checking Solibri Model Checker and Autodesk Navisworks.

At the national level, the BIM Iceland committee is coordinating developments and brings stakeholders of the domain together for this. A few public and private clients, authorities, architects, engineering consultants and contractors are attending the work of the committee on a voluntary basis. There is no buildingSMART Chapter in Iceland, although it is under discussion in the committee to become part of BuildingSMART.

BIM guidelines

There is no national level guidance for BIM usage, but large clients, especially public clients, have their own requirements and guides for BIM usage. During the past years, also private clients have started to create company-specific procedures and documentation for BIM utilisation. In the private sector, usage concentrates on larger companies.

At the project level, the modelling practices and level of detail in different phases may be planned, but the plan may be more indicative and not implemented on a detailed level.

Naming conventions

The naming depends on the modeller and the quality of the quantity take-off can vary. The naming matching the naming in OneClickLCA programme would be beneficial to enhance the quality of LCA calculations.

Quantity take-off

Quantity take-off from BIM depends on design discipline, e.g. quantities of steel structure can be obtained from modelling software. In general, the quantity take-off is used for benchmarking and evaluating the level of quantities but some disciplines can use quantity take off directly from the models. In the latest hospital projects (public) the aim is for BIM quantification. One or two large contractors in Iceland can do BIM-based quantity take-off.

The problem in using BIM data for LCA is the material naming in BIM. There is variation in the naming, and those differ by public and private clients' projects or in building and infra construction. Also, the usage of wrong modelling tools makes it more difficult to automatically identify and calculate quantities correctly. This concludes in situations where LCA specialists have collected data from different sources or in the early design phase to check correct assumptions of missing information from designers.

In using OneClickLCA, only a few data types from original BIM data are read, and those shall be in the correct property field in native authoring software; otherwise, those are not read in LCA software. The interviewees' company have created guidance for naming and storing information in BIM to make data transfer more fluent.

Appendix: Building LCA and BIM Practices in Norway

Building LCA in Norway

Interviewees' background

Four LCA experts were interviewed. The first expert has 10 years of work experience with environmental management in the construction industry, such as greenhouse gas calculations of buildings and BREEAM. Special expertise in reducing greenhouse gas emissions in ambition projects with objectives within ZEB, BREEAM, and FutureBuilt. The second expert has worked with life cycle assessment (LCA), input-output analysis and material flow analysis focusing on the carbon footprint of building materials, household consumption as well as preparation of environmental product declarations (EPDs). The third expert has also worked with life cycle assessment (LCA), input-output analysis and material flow analysis with focus on carbon footprint of household consumption, municipal service production and environmental impact of buildings and water and wastewater treatment, as well as preparation of environmental product declarations (EPDs). The fourth expert has worked with reuse mapping within the construction industry and has coursework in subjects such as life cycle assessment, sustainable constructions, ecology, and renewable energy.

National building LCA regulation

Building Acts and Regulations in Norway are described in TEK 17: Regulations relating to technical requirements for construction works (Building Technology Regulations) sets in §17-1 Climate gas calculations for materials, requirement that a building LCA for materials shall be included for construction of commercial and apartment buildings (Byggtekninsk forskrift (TEK17) med veiledning, 2017). The TEK 17 guide describes the regulations on technical requirements for buildings, i.e., the minimum characteristics and what buildings must have in order to be legally erected in Norway.

The TEK17 Regulation is intended to ensure that projects are planned, designed and executed on the basis of good visual aesthetics, universal design, and in a manner that ensures that the project complies with the technical standards for safety, the environment health and energy. The requirements for climate gas calculations for materials were introduced on 1 July 2022, and one year transition period was given. This means the requirements are mandatory from 1 July 2023. These requirements apply to materials in the building. The requirement is valid for new construction and major remodelling of buildings. A major remodelling is not precisely defined in the regulations, but it entails changes or repairs that are so extensive that the entire building essentially appears to have been renewed.

In the TEK17 Regulation chapter 17, there are requirements to what building parts that must be included in the building LCA and which parts of the life cycle are minimum required. The building LCA must at least include seven building parts according to Norwegian Standard NS 3451:2022 Bygningsdelstabell (table of building elements):

- 215 Pile foundation
- 216 Direct foundation
- 22 Structural frames
- 23 Outer walls
- 24 Interior walls
- 25 Floors/slabs
- 26 Outer roofs

Other building elements, like outdoor areas and technical systems, are not included. The included life-cycle modules (according to standard EN15978) are as follows: A1-A3, A4, A5 (only waste from construction site), B2 and B4.

The requirements for building LCA were introduced 1 July 2022, and one year transition period was given after which building LCA of materials has become mandatory. The requirement is valid for new construction and "major remodelling" of buildings. A major remodelling is not precisely defined in the regulations, but it entails changes or repairs that are so extensive that the entire building essentially appears to have been renewed. The building LCA must be based on NS 3720:2018 standard (Standard Norge, 2018). According to the technical regulations (TEK) calculations shall be done for new apartment buildings and commercial buildings.

New apartment buildings

Apartment buildings are all housing buildings that are not "småhus" (small house in Norwegian). "Småhus" are defined in the guidance document for TEK17 §1-3 as single-family homes, semi-detached homes (up to four units), townhouses, and terrace homes up to three floors. This is coherent with the definition of apartment buildings in NS3457-3:2013 (Standard Norge, 2013). Low-rise block in with two floors and more than four housing units are defined as apartment buildings and not as "småhus". This is for instance semi-detached houses with 6 and 8 units. The requirement for carbon footprint calculations is also valid for vacation homes that are not "småhus".

New commercial buildings

TEK17 does not specify what is meant by commercial buildings. In this context commercial buildings are all building types which are not defined as housing. According to NS 3457-3:2013 (Standard Norge, 2013) this means the following buildings:

- 2 Production and storage buildings
- 3 Office and business buildings
- 4 Transport and telecommunication buildings
- 5 Accommodation, dining and service buildings
- 6 Educations, sport and culture buildings
- 7 Healthcare buildings
- 8 Buildings related to national security.

The carbon footprint calculation according to TEK17 § 17-1 shall be based on actual use of materials.

The quantities of building materials used can be found in different ways, the most common being getting the quantities from drawings or BIM. The quantities can also be sourced from cost calculations or taken directly from invoices based on what is ordered and used in the project.

The carbon footprint calculation does not need to be delivered with the general permission application but shall be finished before the certificate of completion is issued, together with all other documentation related to the project. The carbon account shall be verifiable and shall be shown in the case of a revision.

This means that there are no absolute requirements for when the carbon footprint calculation should be performed, other than that it shall include actual use of materials and the calculation shall be finished upon building completion, without having to send the carbon footprint report to the planning authority.

Limit values for the LCA

It does not seem probable that limit values for carbon footprint of a building will be included in the regulations in the near future (<2 years). The technical regulations are not frequently updated, and the new requirements for carbon footprint calculations was introduced on July 1st. It is assumed that limit values will be introduced in the long term (+5 years), but this is highly uncertain.

Methodology

Building LCA has not been common in the Norwegian construction sector. Mostly ambitious projects have done it in order to get a certification e.g., BREEAM and FutureBuilt (described later). Another driver has been requirements set in public procurement of buildings, which more and more commonly include limit values for Carbon footprint of a building. In later years, private companies, large public real estate companies, contractor trade associations in the construction industry have been important drivers for LCA in construction. This is even more increased with the EU-Taxonomy which drives especially large public companies to get a good carbon footprint to increase their competitive advantage, through certifications like BREEAM.

The regulations for LCA of buildings are thus less stringent than what the large actors are doing. This is driven mainly by a fear of reducing the competitiveness for smaller actors who might not have resources to follow stringent regulations.

BREEAM-NOR

BREEAM-NOR certification: BREEAM certifications is managed by Building Research Establishment (BRE) in the UK, the Norwegian adaption is BREEAM-NOR (Grønn byggallianse, 2023). Today BREEAM-NOR is the most used environmental certification for new buildings and major renovations in Norway. When a building is built according to BREEAM-NOR, is shows that projects have qualities beyond the minimum requirements. BREEAM-NOR shall reflect current "best practices" in Norway and be a driver for innovation for the environment and increased sustainability. In BREEAM-NOR there are nine categories that have to be taken into account.

BREEAM-NOR 2016: (BREEAM-NOR, 2016)

BREEAM-NOR V.6.0: This is the newest version of BREEAM.NOR and got published in February 2022 (BREEAM-NOR, 2022). In this manual Mat 01 is the criteria for climate gas calculations of materials:

Mat 01: absolute requirements for residential buildings, offices, schools, shops, nursing homes heated and unheated basements.

The calculation shall include building parts 22, 23, 24, 25, 26 and 28 in NS 3451:2009. Please note that building parts 21 and 49 should not be included.

The calculation shall include modules A1–A3, A4 and B4

All BREEAM project minimum 20% reduction (1 point Mat 01), 30% 2 points, 40% 3 points

FutureBuilt ZERO.

These criteria should contribute to the achievement of the national and international objective of a low-emission society by 2050 (FutureBuilt ZERO, 2021). The criteria should be both ambitious and readily understandable, aiming to support Norway's goal of reducing greenhouse gas emissions by 50–55% by 2030 and 90–95% by 2025, compared to the 1990 level. Figure 1 illustrates the required emissions reduction by 2050. This figure displays greenhouse gas emissions for buildings today, current practices and current best practices, as well as projected reductions in accordance with national climate goals (Resch, et al., 2020).

In the starting point at the curve the emissions are based on nearly zero-energy building, emissions from materials are based on the top 25% performing exemplary building and has a one-site electricity generation from solar panels covering an arear equivalent to 10% of the heated usable floor area (BRA (Resch, et al., 2020). The criteria apply per heated usable floor area (BRA)^2 over a 60-years lifespan. These criteria apply to the year of planes building completion or the year it becomes operation. To make sure that the emissions from materials and energy, there are established a maximum criterion for emissions from building material and operation energy use.

In calculation for Built Zero buildings elements 21–29 and 49 are mandatory inclusions in the Building LCA, but it is advisable to document other building elements as well, as these may be incorporated at a later stage (FutureBuilt ZERO, 2021). The calculations rules for Built ZERO mainly follow the NS 3720 method, but there are introduced some additional elements (Resch, et al., 2020). The sum of greenhouse gas emissions associated with buildings element 21–29 and 49 calculated for life cycle modules A1-3, A5, B2-5, B6, as well as additional modules D-energy, BC-consumptions, D-reuse, B-biogenic, B-carbon, must not exceed the red FutureBuilt curve[60]

Powerhouse

Powerhouse Paris Proof is a new standard for the buildings of the future, based on the Paris Agreement's 1.5-degree target. For more information: https://www.powerhouse.no/en/

The standard lists maximum and total CO2 emissions per square meter, including the construction phase, energy in operation, materials, and disposal. FutureBuilt's energy positive buildings definition is used as a basis for energy production.

Achieving the Powerhouse Paris Proof standard will require zero-emission construction sites, climate-friendly materials, recycling, and reuse as part of the

60. https://www.futurebuilt.no/FutureBuilt-kvalitetskriterier

solution, in addition to renewable energy production and energy efficiency.

To be defined as Powerhouse Paris Proof, the buildings total carbon footprint (A1-C4) must be less than the carbon budget for the specific opening year of the building. The carbon footprint budget is defined by a reference building (standard construction and energy use) for 2010 multiplied with the reduction curve for 1,5-degree target by IPCC.

System boundaries

The calculation period has traditionally been set to 60 years in Norway, as this is the timeframe used for building cost calculations. The calculation period in the new technical regulations is now changed to 50 years to be in line with the EU taxonomy requirement through Level(s). It is probable that 50 years calculation period will be the new standard calculation period in Norway as the requirements in TEK become more widespread. Table 6 presents the life-cycle modules in the current Norwegian methodologies.

Table 6. Life-cycle modules (according to standard EN15978) in the current Norwegian methodologies.

Life-cycle modules	Norway TEK17	Norway BREEAM-NOR-v6.0	Norway FutureBuilt ZERO	Norway Powerhouse
A1-A3	X	Mat 01	X	X
A4	X	Mat 01	X	X
A5 waste from construction	X		X	X
A5 energy use construction		Man 03	X	X
B1			X	(X)
B2	X	(Mat 01)	X	X
B3			X	(X)
B4	X	Mat 01	X	X
B5			X	(X)
B6 (operational energy)		Ene 01	X	X
B8 (transport of users in operation)		Tra 01		
C1				X
C2				X
C3			X	X
C4				X
D			X	

According to the Norwegian standard NS3720, demolition and waste treatment of existing buildings or constructions for plot preparation are allocated to the building being demolished (C1-C4) and are not included in the carbon footprint calculation of the new building. If the purpose of the calculation is to compare different plot development alternatives, and only one solution includes demolishing the existing building, the demolition should nevertheless be included.

Waste from future demolition (C1-C4) is not required to include according to calculations in TEK17 but is usually included in other calculations according to NS 3720 (Standard Norge, 2018), and for BREEAM-NOR, FutureBuilt and Powerhouse.

Reporting of biogenic carbon may have a large impact for the carbon footprint calculation. This is especially important for wood-based products but is also relevant for other biogenic products. Biogenic carbon is carbon accumulated in biomass through photosynthesis from carbon dioxide in air. This is again released into the atmosphere as carbon dioxide when the biomass is incinerated or decomposed. As a standard rule, the uptake and emission of biogenic carbon throughout a building materials lifetime shall sum up to zero. NS-EN 16485:2014 (Standard Norge, 2014) gives calculation rules for emissions and uptake of biogenic carbon.

Since uptake of biogenic carbon is included in module A1 for EPDs, the sum of GWP for A1-A3 can result in a negative value as emissions are only included in module C.

Since the carbon footprint calculation according to TEK17 §17-1 shall not include module C, the GWP values from EPDs must be corrected to not account for biogenic carbon stored in the product. This is solved by using the mandatory indicator GWP-IOBC[61] in EPDs from GWP Norway. In EPDs from the international EPD system the indicator GWP-GHG gives the same effect, e.g., excluding biogenic carbon stored in the product. For EPDs following the new standard EN15804+A2:2019 the indicator "GWP, total" subtracting "GWP, biogenic" could be used, with the problem that release of biogenic methane is included in GWP, biogenic, thus omitting this impact if it is significant.

Operational energy use calculation

The source data for greenhouse gas calculation from energy use in operation is related to heating, cooling, ventilation, hot water, and lighting. The calculation must be carried out according to either NS 3031:2014 (Standard Norge, 2014) or SN/TS 3031:2016 (Standard Norge, 2016) or be based on actual measurements for energy consumption for the building in operation. When analysing a completed building structure, greenhouse gas calculations do not include emissions related to the production, distribution, and installation of local energy production equipment in B6,

61. GWP-IOBC Follows the principle of instantaneous oxidation of biogenic carbon, meaning it sets storage and emission of biogenic carbon to 0 in all modules.

this will be reported in A1-A5. If the equipment is installed after the building is put into operation, it should be reported in B4-B5. Emissions related to local energy supply (e.g., solar panels) can be obtained from EPDs, third party-verified documentation, or reputable LCA databases. After an energy supply system is chosen, specific emission factors for specific systems and selected energy products should be applied.

According to the Norwegian standard for Building LCA two different scenarios for electricity supply should be used. Both scenarios must be presented in the result report. Both scenarios use an average baseline of consumption mix for the last three years, but scenario 1 uses Norwegian consumption mix (~24 g CO_2 eq./kWh), and scenario 2 uses European (EU28+NO) Consumption mix (~110 g CO_2 eq./kWh). In both scenarios the emission factor for the grid mix is calculated using a linear function to approach near-zero emission by 2050, which is then maintained at this level unit the end of the period. In addition, the result report must indicate whether an agreement for Guarantees of Origin for purchased electricity has been made.

For calculation of energy demand at the construction site, the Norwegian grid mix is typically used, to be in line with electricity emission factors used in most EPDs.

Level of detail in calculating and reporting building LCA

The main challenge in general for early-stage building LCA is the level of data detail during the given phase of the project. A lot of time is spent in converting data to the "right format", which is often done manually through material-take-off in Solibri or another IFC-reading programme. There is a risk of error when making assumptions on what materials are included in for example "wall type 1". The model is constantly evolving in the design phase, so there is an issue to get a complete enough version of the model before it is finished – it is nevertheless important to have enough time to extract the material quantities.

There are also challenges with setting the right emission factor for the materials. Especially in the early phases of the project assumptions must be made for "standard" material types, when it is not known what material supplier will be used. In later phases when material suppliers are chosen, EPDs can be used.

Uniform reference service life of the products is also a challenge, as the EPDs often declare technical service life, even though a realistic replacement of elements happens more often than the technical service life. In general, all reference values and building LCAs should use the same service life and number of replacements for the same building type. To get a better service life, the project should need to make a compelling case for why a different service life is used.

Accepted data sources

According to the technical regulations (TEK) generic emission factors shall have an added impact of 25% unless such added impact is already included in the emission factor. Primarily, product specific EPDs shall be used in these calculations.

For other building LCA methods, the data sources for generic data are not clearly defined and often an EPD representing a common product in the market is used as a proxy to generic data. For concrete the Norwegian concrete association has standard emission factors for concrete of different environmental performance which are updated every few years.[62] The Norwegian Green Building Council also has a Green Material Guide which gives guidelines for standard emission factors for different material types.[63]

EPD-databases are the main source of emission data for building LCA. The main EPD-Programmes used which have available APIs are:

- EPD-Norway is the Norwegian EPD-Foundation and got established in 2002 by NHO and the Federation of Norwegian Construction Industries (BNL) because business and organisations demanded environmental documentation, preferable standardised according to international standards (EPD-Norge, 2023). EPD-Norway guides business in communicating the environmental performance of their products. The EPD are created based on a life cycle analysis according to ISO 14040-14044. EPD-Digi is EPD-Norway`s digital EPD database, which is made available to the public.
- EPD-International
- Environdec
- EPD-Germany
- Ecoinvent is a not-profit association based in Switzerland, developed supporting high-quality science-based environmental assessments (ecoinvent, 2023). The ecoinvent database is used worldwide as a background database in LCA and other environmental assessments. The newest version is ecoinvent v.3.9.
- Concrete: standard for low emission concrete NB 37
- Green material guide, Norwegian Green Building Council

62. 37 PDF Lavkarbonbetong (2020)
63. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwj-xJaQjbmBAxWeVPEDHTGaBuAQFnoECBUQAQ&url=https%3A%2F%2Fbyggalliansen.no%2Fkunnskapssenter%2Fpublikasjoner%2Fgronn-materialguide-versjon-2-2%2F&usg=AOvVaw0Qf5T1nV8hl_60i0jWc_fh&opi=89978449

Many EPD systems are connected to the InData platform which has a common API for EPDs from the following EPD systems,

- Institut Bauen und Umwelt (IBU), Germany
- The International EPD ® System, Sweden
- The Norwegian EPD System, Norway
- EPD Italy
- EPD Danmark

The EPDs are available in a common database, but there are still some inconsistencies with use regarding use of GWP indicators. GWP factors excluding biogenic carbon are not included in the digital database. For EPDs according to EN 15804+A2 the indicator "GWP total" excluding "GWP, biogenic" could be used. There is nevertheless an issue outlined earlier that biogenic methane should be included which falls under the indicator "GWP, biogenic".

Building LCA tools

Four tools are mainly used for building LCA:

- OneClickLCA: it is a software tool and platform used for life cycle assessment (LCA), environmental product declarations (EPD), and low-carbon best practice. In the programme it is possible to choose from global generic data or manufacturer specific. Third-party verified EPDs. There is constantly being added new EPDs in the platform and it`s possible to request EPDs directly from manufactures.
- Reduzer is both software and a platform designed to facilitate emission reducing in constructions (Reduzer, 2023). This software enables the generations of design based on available information and facilitates comparisons of different design. Reduzer also offers the capability to compare results from different calculations methods of carbon footprint, where is possible to choose which method you want and make a customised calculation method.
- LCAByg NOR is freely available tool that can used to assess the environmental performance throughout their life cycle of both new and existing buildings (LCAbyg, 2023). This tool can be used for the assessment and documentation of the environmental performance of buildings in accordance with the requirements for greenhouse gas calculations in TEK17 and BREEAM-NOR 6.0. It is original developed in Denmark, then made a Norwegian version. EBA have developed he tool with assistance from SINTEF, Grønn Byggallianse and BUILD from Aalborg University.

- ISY Calcus is a tool which calculate both construction cost, lifecycle costs and greenhouse gas emissions all in one tool (Norconsult, 2023). ISY Calcus generates these data in a single system, this makes it possible to analyse and optimise both environmental consideration and costs in one operation. It can be used in early-stage projects, and then develop the estimate as the project progresses. The tool is developed by Norconsult.

Primarily Solibri model viewer or other IFC reader is used to extract material quantities. OneClickLCA has a possibility to connect to BIM. Some consultants also use self-made tools through parametric design in for instance Grasshopper in Rhino to connect LCA-data to the BIM model.

BIM practices in Norway

Interviewees' background

Two experts were interviewed. The first expert has over 40 years of experience within the building and construction sector. BIM strategist with many years of experience with developing digital building design. The second expert has worked over the past 25 years with BIM, visualisation, engineering and interaction. Expertise in standards, methodology such as VDC and SCRUM, BIM, collaboration, model-based engineering and production, GIS, information management and digital tools.

The use of BIM

From the interviews, it seems that BIM is widely used in all design disciplines. In practice, some 3D modelling is done in all stages of the project, although different tools might be used in the schematic design phase, for instance, Sketchup. Some chose not to call it BIM because the information part sets expectations for the details which should be included in the model. Nevertheless, all seem to be using 3D modelling to some degree, even for renovation projects and when delivering traditional 2D drawings.

There is naturally some difference in the level of detailing in different stages. For instance, different layers of a wall might not be modelled early; the wall will only be one object. The main shafts are modelled early for the technical systems, e.g., HVAC, with more detailing later in the project. However, technical disciplines use pre-defined libraries with many details for the objects being modelled.

Maturity of the model is the main problem. The paradox is that the model is not completely mature until the design stage is finished, and therefore other methods must be used to make LCA-based decisions in the earlier stages of the building planning, e.g., the schematic design phase.

The main tools being used are sometimes Sketchup in the early design stages. Revit for technical, architectural and structural disciplines, and also Tekla for structural engineers. Outdoor architects use the Quadri database in Revit and Novapoint.

Consulting Engineers Association, named Rådgivende Ingenørenes Forening (RIF) in Norwegian (RIF, 2023). RIF has an Expert Group on BIM consisting of members from different consultancy companies. Their goal is to be subject experts and to be a driving force in the development of BIM use in RIF and for its members. The group is a member of important forums for BIM and digitalisation, among other buildingSMART's cross-disciplinary user forums. The group also holds BIM courses based on buildingSMART's curriculum.

The BA-Network is a network which is developed to improve collaboration and data flows in construction and infrastructure projects (ba-nettverket, 2023). The network is mainly focused on transportation and infrastructure projects; however, they are also concerned with good collaboration between building and infrastructure. BA-network organises network events to disseminate knowledge and enthusiasm.

BuildingSMART is an international nonprofit company within the Construction, Building and infrastructure industry, which develops standards to help the entire supply chain work more efficiently and facilitates collaboration among all stakeholders (buildingSMART, 2023). To shape the future of construction, buildingSMART strives to make use of BIM, digital twins, and data collaboration standards. BuildingSmart Norway is one of the buildingSMART international 15 national chapters.

BIM guidelines

The main drivers in documenting BIM practices are the large public construction companies, for instance, Statsbygg (national government buildings)[64], Sykehusbygg (public hospitals)[65] and Forsvarsbygg (national defence). They have their own requirements for what should be included in their BIM model, and all companies doing modelling work for these need to follow them. There are also available API plug-ins to include these BIM requirements directly in the Revit models.

SIMBA is a collective term that describes Statsbygg`s BIM requirements (SIMBA, 2023). Statsbygg is the central advisor to the state in construction and property matters, the client for state building projects, property manager, and property developer. These requirements describe how BIM models should be made, what information they must contain and how the information is structured. To make sure that the requirements are being enforced, the BIM model must be controlled. The newest version is SIMBA 2.1.

64. SIMBA - Statsbyggs BIM-krav - SIMBA 2.1 (gjeldende) (google.com)
65. Digitalisering og BIM - Sykehusbygg HF

Based on these requirements and national practices, a Norwegian standard has been developed. NS 8360 BIM objects for construction works (Standard Norge, 2021). This standard is also following ISO 19650 methodology. These practices are independent of the building type, and all building types are modelled.

The information standard ISO 19650 (Standard International, 2018b) is more and more commonly adopted in the Norwegian construction sector. But the standards developed nationally still take precedence, and even these are not always followed.

Naming conventions

Aside from previously mentioned standards, the following standards are relevant for building classification and naming. They are all, to some degree, being used in the Norwegian construction sector.

ISO 23386 International standard for building information modelling and other digital processes used in construction. This standard is developed to make sure that all definitions which are needed in all BIM domains can be interoperable in tools and applications.

ISO 23387 International standard for building information modelling (BIM). Data templates for construction objects used in the life cycle of built assets – concept or principle. This standard describes the principles and structure of data templates and is in alignment with ISO 23386.

IFC 4.3. – is the first international standard to introduce a wide range of definitions to present a construction project in a harmonised way for the building and infrastructure industry (BuildingSMART, 2023). It is an openBIM standard for buildings and infrastructure.

EN 3457-3:2013 is the standard classification of buildings. This standard represents the initial phase in establishing a comprehensive Norwegian system for organising information related to buildings, construction and real estate.

prEN 17473 Product data templates, for products and systems used in construction works, stored in a data dictionary framework – Part 2: Specification of Product data templates based on harmonised technical specifications under the Construction Products Regulation (CPR).

For actual building products, considerable resources have been used to develop product data templates (PDTs) according to ISO 23386 and ISO 23387. These are being adopted by the construction industry, but there is still some pushback from the users who prefer doing it the way they have always done it.

Quantity take-off

The main tool being used seems to be Solibri Model Viewer, and similar IFC readers, with IFC being the main format for data transfer between disciplines. During data transfer, the person exporting to IFC format chooses what data shall be transferred. This means that some information is lost in data transfer, but this is not necessarily an issue as long as predefined requirements are set and met, and there is no need to import the IFC file back into the modelling programme.

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Appendix: Building LCA and BIM Practices in Sweden

Building LCA in Sweden

Interviewees' background

Two LCA specialists were interviewed. The first LCA specialist interviewed (LCA specialist-1) has experience from producing LCA within different types of building projects, mainly relating to specific certifications such as BREEAM, LEED and NollCO2 but also relating to the new climate declaration in Sweden. The interviewee's role as consultant in these types of projects is to coordinate the work, gathering LCA-data and perform the calculations.

The second LCA specialist interviewed (LCA specialist-2) works as a consultant with climate calculations and analysis for climate-neutral buildings. The work also includes tasks within several climate forums, such as Klimatarena Stockholm and Hållbart Stockholm 2030.

National building LCA regulation

Since the 1st of January 2022, a mandatory climate declaration (*klimatdeklaration*) has existed in Sweden for new buildings to obtain the final clearance of the building permit (LCA-specialist-1, 2023). At the moment, there are no limit values on climate performance, the only demand is to perform the LCA according to the outlined methodology. However, the introduction of limit values from July 2025 has been proposed by the Swedish National Board of Housing, Building and Planning (*Boverket*) (Boverket, 2023c). The proposed limit values include module A1-A5 (kg CO_2/BTA[66]). The limit values are also proposed to be lowered to stricter values every five years. It is proposed that the limit value should cover all building elements, from the foundation and its insulation, excluding solar cells and fixed equipment.

66. *Bruttototalarea*: Gross floor area

Building type	Proposed limit value A1-A5 (kg CO_2/BTA)
Multi-residential building	375
Office building	385
Educational building, except preschool	380
Preschool	330
Single-family homes	180
Special housing (students, elderly, etc.)	385
Other building types	460

The climate declaration must represent the finished building; thus, it is mandatory to perform the LCA on the completed design. There are no regulations regarding calculations in earlier stages of the design, but with the introduction of limit values, calculations throughout the design process will be of importance to monitor the climate footprint (LCA-specialist-1, 2023).

Methodology

A law, ordinance and provision[67] on climate declaration for buildings exist. Boverket is giving guidance to this regulation. The LCA calculations should be made on the finished design of the building and are most often performed by an LCA-consultant in cooperation with the design team. Since it is now a mandatory demand for new buildings, the number of LCA calculations will increase and become a common part of the building process. (LCA-specialist-1, 2023)

Organisations also perform voluntary LCA-calculations based on their internal sustainability goals and ambitions of reducing their climate impact. By setting project-specific goals for climate performance in the early stages of the design phase and then working actively with climate optimisation, they can ensure that these goals are met (LCA-specialist-2, 2023).

There are also other types of voluntary standards related to environmental certification systems such as BREEAM, LEED and the Swedish net zero carbon system NollCO2. These certification systems along with the climate declaration is the main drivers for calculating building LCA in Sweden today (LCA-specialist-1, 2023).

67. Act (2021: 787) on climate declaration for buildings. Ordinance (2021: 789) on climate declaration for buildings. Provision (BFS 2021:7) on climate declarations for buildings.

The most ambitious voluntary system in Sweden for calculating LCA is the certification system NollCO2. It is developed by the Swedish Green Building Council (SGBC) along with their members. To achieve the certification, a building must fulfil the demands in NollCO2 and meet a minimum grade of an environmental certification such as Miljöbyggnad (min. Silver), Svanen, BREEAM-SE (min. Very Good) or LEED (min. Gold) (Sweden Green Building Council, 2023). When registering a NollCO2 certification, the building receives a specific limit value for carbon emissions that must be met. The rest of the emissions must be compensated through selected climate compensation activities to achieve a net zero balance (Sweden Green Building Council, 2023).

NollCO2 has its roots in EU Level(s) and is based on several international standards such as SS-EN 15978:2011 regarding the system boundaries, SS-EN 15804:2012+A2:2019 regarding calculations for A1-A3 (EPD) and SS-EN ISO 14021:2017 regarding environmental labels and declarations (Sweden Green Building Council).

System boundaries

The system boundaries for the mandatory climate declaration include calculations for modules A1-A5 (Boverket, 2021). Module A5 is separated into two parts; A5 energy for climate emissions related to all use of electricity, heating, and fuels on the construction site and A5 material waste relating to the emissions (A1-A4) for materials that will go to waste during construction. The climate data that must be used is the GWP-GHG, which means that biogenic carbon in materials is not included in the calculation (Boverket, 2021). The climate declaration also states the building parts that are to be included in the calculation; all load-bearing structures, the whole building envelope, and internal walls (Boverket, 2022a).

New buildings in Sweden today need to have a climate declaration before final clearance can be given by the municipality t but there are some exempts from these rules; buildings that do not need building permit or have a temporary building permit, industrial buildings, buildings related to agriculture or forestry or similar businesses, buildings with a total area of less than 100 m2, buildings related to the armed forces and some buildings owned by the state and a developer who is a private individual and is not constructing a building in business.

(Boverket, 2023b).

In the LCA calculation for NollCO2, all modules A-C are included in the calculation (Sweden Green Building Council, 2023). The calculation period is 50 years, and most of the building parts are to be included. The GWP data that is to be used is GWP-GHG, so emissions or uptakes from biogenic carbon are not to be included in the calculation.

Operational energy use calculation

The mandatory climate declaration covers modules A1 to A5, so the operational energy is not part of the climate declaration (LCA-specialist-1, 2023).

In NollCO_2, module B6 is included in the calculation. If the project has a specified contract with an energy supplier that has an EPD made according to "Product Category Rules, PCR 2007:08 version 3.0 CPC 171 & 173: Electricity, Steam, and Hot and Cold Water Generation and Distribution", "General Programme Instructions for Environmental Product Declarations, Ver. 2.5" ISO 14025 and ISO14044, the climate data from that EPD can be used (Sweden Green Building Council, 2023). If the electricity supplier has a "green electricity" marking from the Swedish Environmental Protection Agency, there are stated climate data values in the NollCO_2 manual for solar, wind and water-powered electricity. When a project does not have a specified energy supplier, or if the supplier does not have an EPD, generic climate values for energy in the database from Boverket are to be used.

The generic climate data regarding energy presented in the database from Boverket are calculated mean values for district heating, electricity, and fuels in Sweden (Boverket, 2023d). These data are not conservative as opposed to the generic climate data for materials in the database.

Level of detail in calculating and reporting building LCA

Since the climate declaration is to be made on the finished design of a building, information regarding most of the materials is often available at the stage of calculation (LCA-specialist-1, 2023). However, there are usually some materials not specified or quantified, or there might be a lack of accurate climate data. Therefore, it is mandatory within the climate declaration to calculate a coverage rate (Boverket, 2022c). This coverage rate is calculated based on either the cost of materials or their weight. By adding the cost/weight of all materials included in the LCA and dividing it by the total cost/weight of all mandatory materials, the coverage rate (%) is found. This rate is then multiplied by the total climate performance from the LCA-calculation to receive a final result. All documentation regarding the climate declaration must be stored by the developer for five years (Boverket, 2022b).

Accepted data sources

In the climate declaration, it is acceptable to use either specific climate data or generic conservative data from a database provided by Boverket (LCA-specialist-1, 2023). The specific climate data must be from a third party verified environmental product declaration (EPD) that has been calculated using the international standard EN 15084 or equivalent (Boverket, 2022b).

The database with generic data has been developed by Boverket in cooperation with the Swedish Transport Administration, the Swedish Environmental Protection Agency, and the Finnish Ministry of Environment (Boverket, 2023d). It is provided for free online and can also be accessed using an open API. It is possible to retrieve data files in the form of Excel, JSON, and XML. The generic data for a material has been calculated by the Swedish Environmental Research Institute using a mean value of the climate data in EPDs used in Sweden corresponding to that material. 25% is then added to the mean value to ensure the generic data is conservative. This is done to promote the use of materials with low carbon emissions ensuring that it is better to use specific climate data for a material with high carbon emissions.

If there is no available data in the accepted databases that matches a specific material or product, and there are no similar materials either, this can be left out but noted as a missing data point and then included in the coverage rate calculation (LCA-specialist-2, 2023).

In the NollCO2 system, there are priority rules when choosing what climate data should be included in the calculation (Sweden Green Building Council, 2023). A project must choose data from the highest available priority. The highest priority is given to product-specific EPDs followed in order by the database from Boverket, the Finnish database co2data.fi, and the German database Ökobaudat. The two lowest priorities are given to data calculated using so called LCEs (life cycle emission calculations) and proxy EPDs that have been calculated using EN 15804+A2 or EN 15804+A1.

Building LCA tools

There are several different tools used for LCA calculations in Sweden, but some of the most common ones are OneClick LCA[68] and the Swedish system BM (Byggsektorns Miljöberäkningsverktyg) (LCA-specialist-1, 2023).

BM is a climate calculation tool for buildings created by the Swedish Environmental Research Institute (IVL) based on the methods of the international standards EN 15804 and EN 15978 (IVL, 2023a). Users can input material quantities manually or import them from cost calculations or adjusted digital formats. IVL is currently investigating techniques for importing data to BM from BIM-models in a cooperative project between property owners, architects, contractors, and suppliers (IVL, 2023b).

In OneClick LCA, there is a function allowing the user to make climate calculations in conjunction with the BIM model throughout the different stages of the design phase (OneClick LCA, n.d.)

68. https://www.oneclicklca.com/

Both mentioned tools are open for all users, however they both require a subscription. There are also tools used in Sweden that are developed and used internally, for example, by environmental consultants and architects (LCA-specialist-2, 2023). One start-up company that has developed a BIM-based LCA tool is called Plant An Idea and they are growing rapidly on the market as one of the most digital solutions available so far (LCA-specialist-1, 2023).

BIM practices in Sweden

Interviewees' background

The BIM specialist interviewed (BIM specialist) has a long experience working with BIM, with the overall responsibility for coordinating the modelling work in construction projects. The interviewee also teaches courses at the university level for various of the most used BIM-tools and have been participating in national research projects regarding BIM practices in Sweden.

The use of BIM

Using BIM is a common practice in construction projects in Sweden today (BIM-specialist, 2023). In the schematic design phase of a project, the model usually consists of input data from the architect outlining the shape and the envelope of the building. As the design development continues, information from the other disciplines is added to the model.

The most used BIM tools in Sweden today are Solibri, Navisworks, Revit, Archicad, Tekla, MagiCad for Revit, and AutoCad. The use varies between different design disciplines. (BIM-specialist, 2023)

In Sweden, the main forum for discussing and developing BIM-related practices is BIM Alliance Sweden (BIM-specialist, 2023). This non-profit organisation's overall aim is to facilitate the flow of digital information within the building process, and it consists of members from different organisations and companies within the Swedish building sector (BIM Alliance, n.d. -c)

There have also been several research projects regarding BIM with funding from SBUF (Svenska Byggbranschens Utvecklingsfond). One such ongoing project is investigating methods on how to use the information that already exists in the BIM model to make LCA calculations for the different design stages of a construction project (SBUF, 2021). These methods will be based on a combination of using AI with a rule-based definition of materials.

Another SBUF-funded project, finished in 2019, investigated the potential of using BIM for climate calculations in the early stages by using a combination of tools; parametric and set-based design and digitalisation (Rempling, Mathern, Ek, Roupé, & Johansson, 2019).

BIM guidelines

There are no existing national requirements for BIM modelling in Sweden today. However, there are industry guidelines called Nationella Riktlinjer maintained and published by BIM Alliance Sweden (BIM-specialist, 2023). Nationella Riktlinjer is a digital platform aiming to provide standardised guidelines regarding digital information within building projects in Sweden (BIM Alliance, n.d. -b). The guidelines are based on already existing standards as well as common practices regarding digital building information.

Nationella Riktlinjer are now aiming to align with the Norwegian national guidelines with an emphasis on not specifying or favouring the use of any specific BIM tool (BIM-specialist, 2023).

The Swedish National Board of Housing, Building and Planning (Boverket) got an assignment[69] by the Swedish government as of September 29, 2023, to investigate guidelines on a national level regarding public procurers' use of BIM. Boverket was also tasked to assess the municipalities readiness to handle building permits and associated processes with the support of BIM as well as investigate the readiness and implementation of BIM internationally.

The assignment follows a report released in January 2023 (Boverket, 2023a) where Boverket was tasked to investigate their role and responsibility with regard to national guidelines for BIM. The report concludes that there is a need for a national framework regarding information management to facilitate a common approach. The guidelines would be produced to reduce errors and improve the quality and interoperability of building information processes. Boverket also concludes that there is a need for a national knowledge centre working on these issues to establish national guidelines.

A common practice when starting a building project in Sweden today is to create a project-specific BIM manual based on common practices stating the level of detail for the model and what should be included at which stage (BIM-specialist, 2023). The BIM manual and subsequent demands are also included in the contracts for the building project. Thus, to get as-built model as a deliverable it needs to go into the contract.

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69. https://regeringen.se/regeringsuppdrag/2023/10/uppdrag-att-ta-fram-ett-stod-for-offentliga-aktorer-avseende-byggnadsinformationsmodellering/

All different kinds of buildings are modelled in BIM, but the practice sometimes varies depending on the building type (BIM-specialist, 2023). For example, when modelling a residential building with several identical floors, the detailed modelling concerning MEP is usually only made for one of the floors. Building projects with many prefabricated structural elements often need to specify and order these parts early in the process to have the material ready when production starts. In these cases, good coordination between disciplines still in the design phase is important to avoid collisions within the model.

Naming conventions

BIM data in Sweden is classified using CoClass or a system called BIP codes developed within the BIM Alliance (BIM-specialist, 2023). CoClass is a Swedish classification system that is an upgrade of the previous system used, BSAB (Svensk Byggtjänst, n.d.). The aim of CoClass is to have a digital, standardised classification of data that all involved parties can use during the whole lifecycle of a building. The classification is based on international standards such as SS-EN ISO 12006-2:2020, SS-EN IEC 81346-1:2022, SS-EN IEC 81346-2:2019 and SS-ISO 81346-12:2019.

BIP codes are another system for the classification of BIM data used in Sweden. BIP stands for Building Information Properties, and the system has been developed within the BIM Alliance, aiming at facilitating the identification of objects within the model in a systematic way (BIM Alliance, n.d. -a). BIP is applied to systems and objects within BIM by adding properties to them, which then can be exported to IFC, generating a set of object data. These datasets can be used to perform, for example, quantification and cost analysis.

There is no harmonisation regarding the classification of data between CoClass and BIP codes (BIM-specialist, 2023).

To make up for the lack of detail in material data during the early phases of the design stage, it is common to use standard specifications (e.g., standard wall structure, standard sewage pipe) within the model (BIM-specialist, 2023). When more information regarding the materials is available, these standard specifications can be replaced with accurate data to accurately depict the design.

Quantity take-off

BIM-based quantity take-off tools in Navisworks and Solibri are most used in Sweden today (BIM-specialist, 2023). There are also tools used mainly for financial calculations, such as Vico Office and Wikells sektionsdata. Quantity take-off for financal calculation is usually done in the BSAB system in conjunction with the normative work description framework (AMA).

The main format when transferring BIM data between disciplines is IFC, but other types, such as DWG and RVT, are also used. Not all CAD programmes can handle each other's data formats and some information can get lost when transferring data, but this is mitigated by using the IFC format (BIM-specialist, 2023).

Boverket also points out that the question regarding the specification of data (delivery, format, etc.) from building information models should be investigated further in cooperation with other government bodies and, for example, BIM Alliance (Boverket, 2023a).

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