Nordic Innovation

Harmonised Carbon Limit Values for Buildings in Nordic Countries

Analysis of the Different Regulatory Needs

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 the climate impact of buildings.

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

This report is one of the deliverables for Work Package 1 led by the Finnish Ministry of Environment.

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Nordic Sustainable Construction

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Summary and Recommendations

The Nordic region has long been a pioneer for life-cycle-oriented building assessments. A legal framework for disclosing life-cycle GHG emissions, with or without limit values, is planned to be introduced in all Nordic countries by the beginning of 2025. This means that all Nordic countries will probably have had at least two years of experience with mandatory national life-cycle regulation before the expected implementation of the revised Energy Performance of Building Directive (EPBD) with mandatory assessments for buildings greater than 1000 m^2 in 2028, and all buildings in 2030. By 2027, EU member states must publish a roadmap for progressive carbon limit values for new buildings towards the EU climate neutrality goal in 2050. By 2030, binding carbon limits have to be introduced. With Denmark issuing the earliest limit values in 2023, and Sweden and Finland with plans to follow in 2025, all Nordic countries are preparing themselves to take the next step in order to exploit the climate protection potential of the building sector and initiate innovations.

Nordic countries currently exhibit different approaches to limit values. Harmonising methods is crucial for fair competition to mobilise the market to develop the most efficient low carbon solutions. Therefore, the following recommendations are proposed:

A cost-effective implementation strategy

- There is an urgent need to reduce greenhouse gas emissions drastically in the Nordic countries if the countries are to reach the Paris Agreement. Limit values for the climate impact of buildings need to combine a high ambition level with a smooth adoption by the industry.
- Currently, Denmark and Sweden are the Nordic countries with an implemented plan for how and when limit values are introduced into regulation and tightened progressively. Two distinct strategies are observed in order to facilitate the adoption of climate declarations and limit values at the time of their introduction. (a) First introduce a declaration without limit value, and then introduce a somewhat ambitious limit value a few years later (i.e. Swedish approach), or (b) introduce a limit value from the beginning alongside the climate declaration, but ensure that the limit value initially can be met by most "regular" building projects without particular efforts. Then, tighten the limit value over time (i.e. Danish approach).

- Either way, it is particularly important for politicians to send a clear signal about future milestones of the building stock decarbonisation pathway (e.g. timeline and ambition level for future updates to the limit values). A cost-effective process of tightening the limit values should be established. If countries start with a limited scope (in terms of life cycle modules and building elements covered) and/or a limited number of building types and sizes, countries should also include milestones related to the expansion of the scope for the limit value, as in Sweden, for example.
- Although Nordic countries serve as positive examples in the EU with respect to proactive and coordinated development of climate regulation for buildings to be consistent with the Paris Agreement, building stock decarbonisation pathways need to show a higher level of ambition than what is currently implemented or planned. In addition, limit values need to be tightened rapidly in order to mitigate climate impacts in the building sector.

Carbon limit differentiation per building type

- Although Denmark so far has introduced one limit value for all building types, most recent limit value studies in both Sweden and Denmark show more obvious differences between several building categories. Nonetheless, it is expected that differentiation will be necessary at the point where limit values begin to put pressure on the way we build. It would be unreasonable to set the same limit value for building types that are already optimised and the types presenting a higher decarbonisation potential.

Carbon regulation of renovations

- A great interest in learning more about the climate impact of deep renovations is observed in Nordic countries, with The Swedish National Board of Housing, Building and Planning (Swedish name: Boverket) proposing to include renovation projects in the climate declaration in Sweden from 2027. A stakeholder panel in Denmark has recommended a pathway for carbon regulation starting with climate declarations of larger renovations in 2025 and eventually leading to limit values by 2027. However, discussions and analyses are ongoing and no official policy for additional carbon regulation of renovations has been issued.

Building reference area

- While Denmark, Norway and Sweden consider the gross floor area (GFA) as the reference area unit of climate declarations, with differences in how common facilities in multi-units and external spaces are considered, Finland and Estonia are applying the heated floor area (HFA). For uniformity with Level(s) and EPBD, the reference unit per m^2 useful floor area should ideally be used in addition to the units currently determined in the various Nordic methods. Whether the definition of the useful floor area will be common among all EU countries, or there will be freedom in how to define it nationally is expected to be clarified by 2025 as part of the Delegated Act to be adopted by the European Commission. It is recommended that, in any case, the Nordics work towards harmonising this aspect by 2025, to be ready for an implementation by 2027 according to the EPBD.

Upfront carbon

- The rationale for special attention to upfront emissions is firstly that this is the part of the life cycle that can be confirmed with real values at the building delivery. Second, it places the emphasis on reducing emissions today, not far in the future. Third, the ongoing transition of energy systems and industry towards low emissions means that future emissions are likely to be comparatively low. At the moment, Nordic countries use varying approaches for upfront carbon emissions. Sweden is the only country restricting the limit value scope to upfront carbon. As the Swedish limit value report proposes an extended declaration of remaining modules in 2027, the remaining Nordic countries could increase harmonisation by a separate declaration of upfront embodied carbon emissions in addition to the planned whole life carbon limit value. Upfront carbon declaration requires data developed after the latest EN 15804:2012+A2:2019 EPD standard. For those products, where updated data is not available, a temporary solution has to be developed for the remaining products declared after the old standard, where biogenic carbon is not declared separately.

Biogenic carbon

- The Nordic countries currently use varying definitions of carbon emissions (Global Warming Potential, GWP). Finnish and Danish legislation use GWP-total, which includes biogenic emissions and emissions from land-use and fossil fuels. Sweden and Norway only include emissions from land-use and fossil fuels in their indicator GWP-GHG. In the case of Sweden where only upfront carbon is included, biogenic carbon cannot be included as it is based on the complementary modules A1-3 and C3 for the carbon calculation. Estonia proposes using GWP-fossil or GWP-GHG. A separate upfront carbon declaration requires the use of the latest EN 15804:2012+A2:2019 EPD standard, see also upfront carbon above.

Conservative standard values for building components and systems

- Conservative standard values support the introduction of industry-wide carbon declaration by providing preliminary inventory data for the building model in early design stages and where specifications are not available. While standard built-ups can be provided by authorities or marked actors, the question is what standard solutions may be used directly in climate declarations and what the threshold between standard and specific as-built solutions shall be. This also includes a differentiation between prefabricated and in-situ deliveries such as timber elements, curtain-wall facades or space modules. Harmonisation can clarify these definitory questions.

Conservative generic values for construction products

- Most Nordic countries have already developed a national database of generic emission factors. Generic data allow complete modelling independently of the availability of EPD. This is especially important in early design stages, but also in as-built declarations, where specific data lack for some products. Conservative levels of data encourage building product manufacturers to publish EPDs and assessors to use specific data rather than generic data. This is important in the current regime, where the use of EPDs cannot be required by legislation due to EU marked rules. Potential areas for harmonisation include the structure and content of the national generic emission factors databases and the guidelines for EPD developers by the national programme operators. The selection and specification of building products in the generic database are obvious potentials for harmonisation. Today, some countries use regular and lower emission versions of selected products. Also, the level of detail in product variants is different, for example the number of concrete classes or the differentiation between in situ and prefab deliveries. Other products are presented in a version for indoor use and a version for outdoor use. Lastly, some products are classified in broad categories such as timber or in more detail such as pine, cedar, spruce.

Building model classification

- There exist varying national ways of describing a building model and its components. Even though classification systems for building components are governed by the ISO 12006 standard "Building Construction - Organisation of Information about Construction Works", there are significant differences between the nomenclatures used in different countries, in terms of their level of detail and their decomposition of elements and systems. Even within some countries, varying systems are used. At the EU scale, the Level(s) framework also includes a simple nomenclature of building elements, currently under revision, which is expected to facilitate the standardisation of building descriptions within the European Union. If the final EPBD text does not require a specific classification system, the recommendation for the Nordic countries is to develop a common platform with mapping tables in order to allow the translation of variation in design practices and national standards. More specific recommendations will be developed in Task 2 “Data for LCA” and Task 3 “BIM for LCA - calculating the climate impact of buildings through digitalisation” in the Nordic Sustainable Construction Programme.

1 Existing Pathways to Limit Values

This section provides a background and overview of the current state of building LCA declarations and limit values in Europe as a whole, with a focus on Nordic countries.

1.1 Building LCA in Europe

All over the European Union (EU), initiatives are taking form to push for a reduction of climate impact in the building sector. At the EU level, a Whole Life Carbon Roadmap for the reduction of the climate impact of buildings by 2050 is being developed as of 2023. The roadmap will consist of a series of milestones and targets, which are designed to guide the construction industry to achieve a net-zero carbon built environment. The roadmap will include specific targets for reducing the whole life carbon of buildings, encompassing in-use emissions caused by the operation of buildings and embodied emissions related to the production, construction, renovation and deconstruction of buildings. A technical study supporting this development has already been published, providing information on the strategies and technologies required to achieve the necessary reduction for staying on track of the EU targets. This study also shows how the European building sector pathways and strategies can be translated into building-level life cycle carbon values considering improving material efficiencies and implementation of technological solutions (Table 1).

Table 1. Estimated trajectory of building level upfront embodied carbon and renovation embodied carbon based on archetype modelling and considering the implementation of material efficiencies and technological solutions (so-called "TECH-Build scenario")[1].

Year	2020	2025	2030	2035	2040	2045	2050
Upfront embodied carbon (A1-5) ($kgCO_2e/m^2$ useful floor area)							
Average	810.41	706.55	603.12	500.66	398.48	398.48	398.48
Best practice	344.21	296.27	248.54	201.26	154.10	154.10	154.10
Renovation embodied carbon ($kgCO_2e/m^2$ useful floor area)							
Average	273.81	260.30	246.60	233.62	222.06	222.06	222.06
Best practice	46.81	44.51	41.93	39.49	37.32	37.32	37.32

Note: "average" represents the average value across archetypes for all regions and building types, "best practice" represents the lowest value observed in any individual archetype.

To support this harmonised effort tackling the environmental impacts of buildings, the methods used to calculate these impacts are becoming more and more consistent and standardised. The EN 15804+A2 norm, revised in 2019, governs LCA for construction products, while the EN 15978, under revision in 2023, standardises LCA at the building level. The Level(s) framework, expanding on the two EN norms, proposes a common method, indicators and reporting system for building life cycle assessment (LCA). Although its use is voluntary, more and more LCA-related tools and initiatives in the European building sector are designed to be consistent with Level(s). The most important of these initiatives is perhaps the EU Taxonomy for green activities, established to standardise the definition of what constitutes a sustainable investment. In order to fit the Taxonomy's criteria, buildings erected after 2023 with a floor area of more than 5000 m^2 must provide a calculation of global warming potential (GWP) based on EN 15978 and Level(s). Furthermore, on the regulatory side, the EU Energy Performance of Buildings Directive (EPBD) is currently under revision and a provisional agreement between the Council and the Parliament has been reached in December 2023[2]. The agreement includes a requirement for a mandatory LCA-based climate impact calculation from 2028 for new buildings with at least 1000 m^2 useful floor area, and 2030 for all new buildings. Furthermore, all member states need to launch binding carbon limits for new buildings in 2030. As a consequence, national climate impact declarations and associated limit values will likely evolve to be consistent with the new EPBD climate declaration, e.g. in terms of which building elements and life cycle stages are to be included in the declaration.

1. See: https://op.europa.eu/en/publication-detail/-/publication/923706b7-8f41-11ee-8aa6-01aa75ed71a1/language-en
2. See: https://ec.europa.eu/commission/presscorner/detail/en/ip_23_6423

In addition to EU-wide initiatives, individual countries have also been pioneering LCA-based mandatory declarations and limit values for newly constructed buildings. The Netherlands have introduced LCA-based limit values as early as 2018, using a particular metric called MPG (Milieu Prestatie Gebouwen – Building Environmental Performance). The MPG is determined by first carrying out an LCA consistent with EN 15804+A2, including 11 different impact categories. These 11 results are then converted into a single metric expressed in €/(m^2year) using a set of standardised weighting factors. In 2018, the MPG limit value was set to 1 €/(m^2year) for all residential buildings and office buildings over 100 m^2. As of July 1st 2021, the limit value for residential buildings was lowered to 0.8 €/(m^2year). A reduction of the threshold and adaptation of the weighting is expected in 2025. However, no limit values particularly for the climate impact will be implemented in the short-term future.

In France, a voluntary sustainability label called "E+C-" (Energy + Carbon -) was introduced in November 2016 by the Ministry of Housing with the explicit purpose of preparing the introduction of a mandatory declaration of climate impact. The label was a way of trying out an LCA methodology building up knowledge within the industry and public authorities and supporting a stakeholder consultation for the introduction of a mandatory declaration. Following this consultation, the method and indicators were revised and turned into a mandatory energy and climate declaration with limit values (RE2020). The RE2020 was adopted in 2021, took effect in 2022 and is planned to be updated every 3 years. The RE2020 requires a separate reporting of life cycle greenhouse gas (GHG) emissions linked to operational energy and emissions linked with materials and on-site activities. It uses dynamic emission factors, which implies that carbon emissions happening in the future have a lower importance (and that the temporary storage of carbon in biogenic products provides climate benefits). Limit values depend on the typology, area and location of a building. Overall, the assessment method and reporting requirements are rather complex.

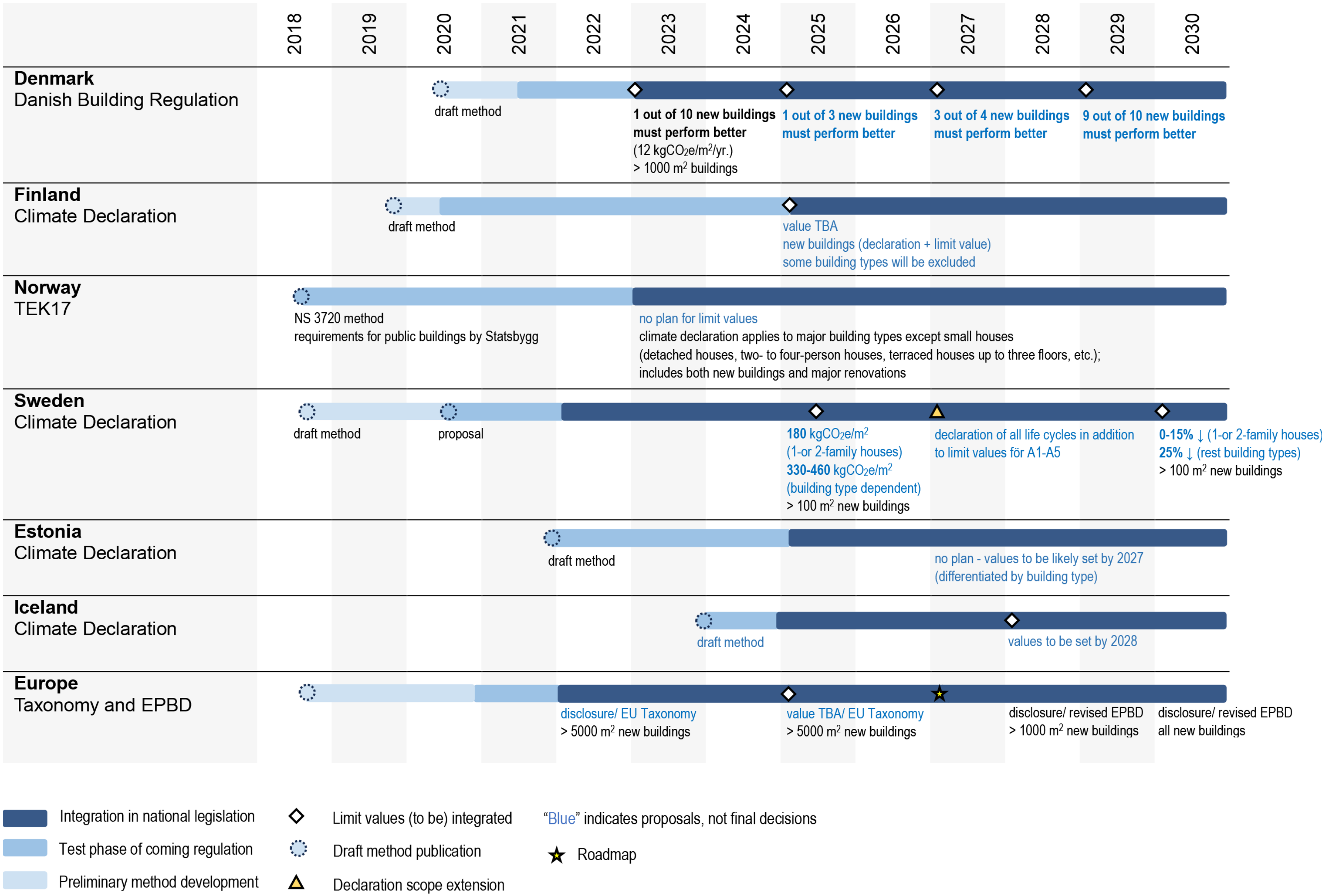
In the Nordic countries, the beginning in mandating climate declarations was made by Sweden in 2022. The first carbon limit for large buildings was placed by Denmark in 2023, and the rest will soon follow as described in the next section.

1.2 Mandatory LCA-based Declarations in the Nordic Countries

The main aspects of the Nordic countries' pathways towards decarbonisation are presented in Table 2. In all five Nordic countries and Estonia, mandatory climate declarations for new buildings have either been introduced or are currently under development. Current mandatory LCA declarations (Sweden and Denmark) do not include building renovations, except in Norway, where mandatory climate declarations include existing buildings undergoing major renovation. This aligns with the EPBD revision proposal, which includes LCA-based regulation of new buildings while at the same time strengthening current operational energy regulation for existing buildings. By the end of 2024, all Nordic countries are expected to have published a preliminary national calculation method for the climate impact of buildings, which is then used as a methodological foundation for regulation. As the industry's competence with LCA will evolve in the new regime with climate declarations, the scope of the methods is expected to be adjusted to secure effective carbon mitigation. Implementing LCA on a building project basis needs very specific calculation rules and preconditions. Building professionals must have the possibility to perform assessments rapidly and at low cost. This differs from other LCA use cases, such as expert-led assessments in other industries' large-scale serial production. The methods used throughout the Nordic countries therefore exceed the level of detail of the technical standard EN 15978, with more detailed national specifications as well as guidelines for interpreting them. This reduces complexity, makes assessments more straightforward and enables the use of project templates with a minimum reliance on expert judgement.

In all Nordic countries, mandatory climate declarations (with or without limit values) are planned to be introduced by the beginning of 2025, which is three years after the pioneering regulation in Sweden. The Swedish mandatory declarations have been introduced at the same time as the EU Taxonomy's requirement of LCA-based declarations for large buildings at the end of 2021. The countries have adopted different timelines for testing the method prior to implementation. Sweden and Denmark have had short testing periods which have more the character of a transition period. However, the lack of time to evaluate as-built projects with the new method has been compensated by the existence of voluntary schemes in these countries (e.g. Miljöbyggnad, BREEAM-SE and DGNB-DK), which allowed them to evaluate rules and practice outside legal frameworks. The Swedish and Danish declarations were also implemented with a limited scope (ignoring certain life cycle stages, as well as most finishes and installations in the case of Sweden), with the intention to facilitate the initial implementation by focusing on the parts typically causing the greatest climate impact and complementing the scope later on.

Table 2. Timeline of climate declaration and limit values integration (as of January 2024).



The process in Finland and Norway has included a longer transition period since the first draft methods published to evaluate projects and revise the method before it becomes mandatory. For example, in Norway, several reports have been published before introducing mandatory life cycle assessments in the Norwegian national building code (TEK)[3]. Estonia is somewhere in the middle, when it comes to testing duration. On the other hand, Iceland plans to have only one year of testing period, the shortest of all Nordic countries, partly owed to the close collaboration and peer-learning among Nordic countries (Nordic Council of Ministers).

Mandatory declarations have proven a useful preparation and set the ground for binding carbon limit values. Denmark has combined the introduction of declarations with limit values as the first Nordic country in 2023. While the Danish limit values have been notably generous in 2023, the next revisions for tightening the limits will take effect in 2025, 2027 and 2029. In Sweden, the first version of the mandatory declaration does not include limit values, but Boverket has already proposed that specific values become mandatory by mid-2025, so the industry can prepare for this level. Finland has yet to announce the magnitude of the limits taking effect from 2025. At the same time, the EU Taxonomy will introduce mandatory limit values for large buildings (above 5000 m^2). The Swedish approach can be regarded to be aligned with the European pathway, while the Danish appears to be slightly ahead. By the expected implementation of the revised EPBD with mandatory assessments for large buildings in 2028, all Nordic countries will have had at least two years of experience with mandatory national life-cycle regulation.

Unlike the Netherlands and France, the Nordic countries use a limited number of life cycle modules at implementation. This decision is a compromise between preparing industry and investors for the decarbonisation transition on the one hand and introducing an agreeable and manageable method at affordable cost on the other. At least Denmark and Sweden are preparing an extension of the current system boundary with more life cycle modules in order to end up with a more complete life cycle scope in the future, while Finland is planning to include the most relevant modules from the beginning. The provisional EPBD agreement on life cycle completeness according to the full scope of Level(s) as referred to in Annex

3. Examples are: a study published by Enova in 2020 with proposed national reference values for embodied carbon for six building categories and two types of basements on the basis of building archetypes, as well as a report published by the Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN) the same year investigating the empirical foundation for Norwegian limit values for buildings, on the basis of 130 Norwegian building case studies. The Norwegian Agency for Public and Financial Management (DFØ) has also been active with the provision of reference values since 2021, which values have been revised along the years to reflect changes in the climate declaration method and advancements in materials.

III[4] may require including all modules in most countries. A more detailed view on this aspect is provided in the method-focused Section 2.2.

1.3 Limit Value(s) Development and Basis

This section provides an overview of how various Nordic countries worked with establishing limit values for the climate impact of new construction, and what rationale they used to decide on the level of these values, if any (Table 3).

In Denmark, limit values were recommended by a stakeholder panel[5] on the basis of a reference report on 60 Danish case studies, published in 2020. The limit values took effect in January 2023, and they are being revised based on learnings from their early application. By the beginning of 2024, a political decision will be made on a revision proposal for 2025. The revised 2025 limit value will be set at a level that ensures that approximately two thirds of new construction already perform better in terms of climate impact (in other words, the proposed limit value is the 67th percentile of climate impact in a building sample representative of new construction). Whether the new limit value will be mandatory for all buildings regardless of size is negotiated at the time of writing. Additionally, the revised limit values will include an updated environmental database for building products and energy carriers, as well as a slightly adapted building model.

In Estonia, no limit values have been defined yet, but a construction roadmap for 2040 (Green Tiger Construction Roadmap 2040) proposed setting limit values for 2027.

Iceland has established a Roadmap to Sustainable Construction which sets 74 actions and goals for 2030. Furthermore, Iceland expects to introduce limit values for climate impact of buildings in 2028. A base has not been defined yet.

In Finland, the definition of limit values is under development at the moment. A preliminary report developed reference values for various building types, as well as recommendations on the adoption of limit values[6]. The reference values were developed by analysing a large number of building cases (482 cases for embodied emissions, 3748 energy certificates for operational energy use) to come up with reference building models. The LCA covered the full life cycle but used fixed **standard values** for modules A4, A5, B3 and C1-C4. The authors

4. See: https://www.europarl.europa.eu/doceo/document/TA-9-2023-0068_EN.pdf
5. The Climate Partnership for Construction has handed its recommendations to the government in on March 16th 2020. https://climatepartnerships2030.com/the-climate-partnerships/construction
6. One Click LCA, 2021. See: https://mrluudistus.fi/wp-content/uploads/2021/01/Bionova_MinEnv_Finland_embodied_carbon_limit_values_report_FINAL_19JAN2021_ed.pdf

calculated an average climate impact for various building types. For each building type, the difference between the average and the 80th percentile was quantified, as well as the share of this variability that is due to factors outside of the project's control (zoning and site-dependent constraints). Additionally, a decarbonation potential was estimated for each building type, corresponding to the share of GWP that could be reduced by using easily available technologies (low-carbon concrete, ground heat pumps and better insulation). Finally, a limit value was proposed for each building type, based on the average climate impact of this building type, plus the variability outside of the project's control, minus roughly two thirds of the decarbonation potential. Finland is also now gaining experiences through a new initiative run by the Helsinki municipality where a carbon footprint limit for new residential buildings at 16kgCO_2e/(m^2year) in 50 year timeframe is placed.[7]

In Sweden, the limit values have been recommended by Boverket on the basis of a reference report with 68 case studies of buildings published in 2021 by The Royal Institute of Technology (KTH, commissioned by Boverket) and the method and background research defined in the report "Gränsvärde för byggnaders klimatpåverkan och en utökad klimatdeklaration"[8]. The proposed limit values, to be introduced in 2025, are meant to cover life cycle stages A1-A5. The rationale for this limitation is that focusing on product and construction process stages concentrates efforts on reducing emissions happening today, which can also be verified (i.e. the limit values do not need to rely on assumptions about the future). The risk of burden shifting and suboptimisation was considered to be low, and Boverket's position is that other policy instruments will be more appropriate to incentivise energy efficiency, reuse, flexibility, etc. At this stage, no other Nordic country has (or plans to have) limit values differentiated by life cycle modules or sub-part of the lifecycle (e.g. embodied/operational).

In Norway, in June 2021, the Government suggested to include a comprehensive LCA scope regarding lifecycle modules and building elements, along with the establishment of limit values based on building LCA. However, the proposed voluntary limit values were rejected in January 2022, and no plans for extending the current scope or introducing limit values are in place. After that, a report was prepared with GHG calculations for reference

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7. See: https://www.hel.fi/en/urban-environment-and-traffic/plots-and-building-permits/applying-for-a-building-permit/carbon-footprint-limit-value
8. See the report: Gränsvärde för byggnaders klimatpåverkan och en utökad klimatdeklaration - Boverket: https://www.boverket.se/sv/om-boverket/publicerat-av-boverket/publikationer/2023/gransvarde-klimatpaverkan/

buildings for single-family homes, four-family homes, apartment buildings and office buildings using three different calculation tools so that the Norwegian Building Authority (DiBK) could build a better knowledge base to assess whether there is a basis for regulating a level for embodied carbon emissions in TEK[9]. The current focus of the Norwegian government is first of all to establish a climate partnership with the construction industry to cut emissions [10].

9. This report concludes that ca. 20 % CO2-reduction has no cost and that the tools are calculating differently. See: https://www.dibk.no/om-oss/Kalender-DiBK/klimagassutslipp-fra-byggematerialer.
10. See: https://www.regjeringen.no/no/aktuelt/vil-invitere-til-klimapartnerskap-med-tre-naringer/id2966212/?expand=factbox2966214

Table 3. Overview of development status (as of January 2024).

	Denmark	Estonia	Finland	Iceland	Norway	Sweden		
	BR18	Proposed draft method for climate declaration (2021)	Proposed climate declaration (currently under revision)	Proposal under development (2023)	TEK17	Climate declaration 2022	Limit values 2025 (proposal)	Climate declaration 2027 (proposal)
Administered by	Danish Authority of Social Services and Housing	Ministry of Economic Affairs and Communications (later Ministry of Climate)	Ministry of the Environment	The Housing and Construction Authority	Directorate for Building Quality	Swedish National Board of Housing, Building and Planning		
Climate Declaration: Status	In use	Under development	Test phase	Under development	In use	In use	Proposed	Proposed
Climate declaration: (Expected) year of introduction	January 2023	2025	January 2025	2024	January 2023	January 2022	July 2025	2027
Limit value(s): Status	In use	Under development	Under development	Under development	No plan yet	-	Proposed	
Limit value(s): (Expected) year of introduction	January 2023	Not decided yet, likely by 2027	Likely to be introduced later than climate declaration, date not yet decided	likely by 2028	No plan yet	No earlier than 2025	2025	
Limit value(s): Level	12 $kgCO_2e/m^2$/year	Under development	Not yet decided	Under development	No plan yet	-	Proposed 2025 limit values in $kgCO_2e/m^2$, valid for five years: Office buildings: 385 Special housing: 385 Residential buildings: 375 Pre-schools: 330 Other educational buildings: 380 One or two-family home: 180 Other buildings: 460	

1.4 Limit Values for Various Building Types

An important point of difference between climate declarations and associated limit values in the various Nordic countries is the type of building concerned by the declaration. Table 4 specifies which buildings are covered by the declaration in each country.

In the Nordic countries, residential buildings make up the highest share of new construction (and are therefore the top priority when it comes to regulating climate impact). However, no building type can be said to fully dominate construction trends (agricultural, industrial and office buildings, for instance, represent significant shares as well). It is thus relevant to mitigate the impact caused by other building types as well. Buildings that do not have a standard form (e.g. concert halls, etc.) are also expected to have a great variation in the climate impact.

In terms of building types and sizes included (Table 4), the Danish regulation covers all buildings larger than 1000 m^2 for which energy requirements apply. Meanwhile, Norway excludes some types such as detached homes and other small homes like semi-detached houses, town houses and small terraced houses. Sweden has quite detailed rules about which buildings are exempted from the declaration. For instance, buildings with a temporary construction permit, industrial and agricultural buildings, buildings constructed by private individuals without business purposes, as well as buildings necessary for safety and defence are excluded from the declaration.

Additionally, different building types might have different limit values or other special rules. In Sweden, limit values differ between one or two-family houses, other residential buildings, pre-schools, other educational buildings, office buildings and special housing, and other buildings. These **differentiated limit values** were proposed based on the analysis of 68 building case studies.[11] It is noteworthy that one- and two-family houses have much lower limit values compared to other building types. This is because the vast majority of one- and two-family houses in Sweden are already built with a timber structure which has a low embodied climate impact. Since the Swedish declaration only covers embodied impacts, this results in large proportional differences with other building types. Furthermore, the fact that these houses are constructed based on homogeneous techniques and material choices leads to a lower variability in LCA results for these building types. Other building types were shown to have a very high variability in LCA results[12].

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11. Boverket (2023). *Limit values for climate impact from buildings and an expanded climate declaration.* REPORT 2023:24. Swedish National Board of Housing, Building and Planning
12. Malmqvist, T., Borgström, S., Brismark, J., Erlandsson, M. (2023). *Referensvärden för klimatpåverkan vid uppförande av byggnader*. Version 3. KTH Skolan för Arkitektur och Samhällsbyggnad. ISBN: 978-91-8040-754-0

Table 4. Building uses and sizes covered by the current and proposed requirements (as of January 2024).

Building type	Denmark	Estonia	Finland	Iceland	Norway	Sweden	
	BR18	Proposed climate declaration	Proposed climate declaration + limit value	Proposed climate declaration	TEK17	Proposed limit values 2025 (likely in line with climate declaration 2022)	Climate declaration 2027 (Boverket's proposal)
Single-family home	√	-	-	√	-	√[1]	
Other residential building	√	√	√	√	√	√[1]	
Office	√	√	√	√	√	√[1]	
Retail and restaurant	√	√	√	√	√	√[1]	
School and daycare	√	√	√	√	√	√[1]	
Laboratory	√	√	√	√	√	√[1]	
Hospital and health	√	√	√	√	√	√[1]	
Sports facilities	√	√	√	√	√	√[1]	
Cultural and other public	√	√	√	√	√	√[1] (some public authorities are exempted)	
Religious	√	-	√	√	√	√[1]	
Industrial	√	-	-	√	√	-	-
Holiday cottages[4]	-	-	-	-	√3	√1	
Other	√	√	-	√	√	√1	
Renovation projects	-	-	-	√2	√	-	√[2]
Size of buildings	**2023-2025:** > 1000 m^2 **From 2025:** under political negotiation	unspecified	no size requirement, just building type	unspecified, buildings under scope classes 2 and 3 in Building Regulation	no size requirement, just building type	> 100 m^2	-

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

√= included

[1] Sweden provides detailed requirements on which buildings are exempted from declarations and are independent of the building type, such as temporary building constructions, buildings built by private individuals and that do not take place within commercial activities, building for industrial or workshop purposes, etc. (https://www.boverket.se/sv/klimatdeklaration/vilka-byggnader/inte-deklareras). This means that any building included in the building types listed above could be excluded if they fulfill the indicated requirements.

[2] when building permit is needed according to definition in building regulation (and along additional exemption rules in the case of Sweden)

[3] included when they are in blocks

[4] called "leisure homes" in Norway

In Finland, debates are ongoing regarding which buildings might be exempted from the climate declaration, as well as whether differentiated limit values will be introduced based on building type. A preliminary report was published with reference values differentiated for apartments, offices, service buildings, schools and commercial buildings, as well as proposed limit values for each building type[13]. The reference values for residential, office, school and commercial buildings are all comprised between 12 and 14 $kgCO_2e/(m^2year)$ (excluding modules A4-A5, B3 and C1-C4 - the study was done with a different scope than the current legislation draft). However, service buildings had a significantly higher reference value of 19.2 $kgCO_2e/(m^2year)$, due to a higher operational energy use. Another major difference between building types came from internal walls, with residential buildings having by far the highest surface of internal walls and commercial buildings by far the lowest.

In Estonia, ongoing discussions have partly concluded to align the inclusion of the building types with EPBD exemptions from the minimum energy for building energy performance. This means that Estonia most likely will not include carbon calculation requirement for industrial or religious buildings nor for holiday cottages. The setting of different limit values or calculation rules for different types of buildings remains open.

On the contrary, Denmark uses one single limit value for all buildings above 1000 m^2. The Danish limit values were based on 60 building cases, and no significant difference was found across building types. There was a higher variance within each building type than among building types[14]. Instead of differentiating limit values regarding building use, **exception rules** have been implemented in the Building Regulations § 298 (4) for components with a high impact, when they are unavoidable due to specific conditions for a building related to its function or location[15]. To determine the future limit value for the climate impact of new buildings with building permits in the period between 2025-27, a new study was conducted with 163 representative building. The new results show significant differences between several building uses[16].

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13. Carbon footprint limits for common building types. 2021. One Click LCA Oy Ltd.
14. Zimmermann, R. K., Andersen, C. M. E., Kanafani, K., & Birgisdottir, H. (2021). Whole Life Carbon Assessment of 60 buildings: Possibilities to develop benchmark values for LCA of buildings. BUILD Report No. 2021:12
15. Nielsen, L. H., Tozan, B., Birgisdottir, H., & Wittchen, K. B. (2022). CO2-krav og særlige bygningsforudsætninger: Udformning af model til beregning af overskridelse af grænseværdi ved øget klimapåvirkning grundet særlige bygningsforudsætninger. Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet. BUILD Rapport Bind 2022 Nr. 27 https://build.dk/Assets/CO_2-krav-og-saerligebygningsforudsaetninger/CO2-krav-og-saerlige-bygningsforudsaetninger.pdf
16. Tozan, B., Olsen, C. O., Sørensen, C. G., Kragh, J., & Rose, J. (2023). Klimapåvirkning fra nybyggeri - Analytisk grundlag til fastlæggelse af ny LCA baseret grænseværdi for bygningers klimapåvirkning fra 2025.

Similarly, in Norway, no differentiation of limit values based on building type is planned. A report from the Norwegian Research Centre on Zero Emission Neighbourhoods (ZEN) developed reference values for buildings based on an analysis of existing LCA case studies, and the report found no statistically significant difference in total impact between types[17]. Contrary to the Swedish report, the Norwegian study found that single-family houses have a higher variability in their emissions compared to other residential buildings. However, it should be noted that the pre-existing case studies analysed in this report did not all use the same system scope, method and background data, which limits the validity of the statistical analysis. More analyses have been performed by various organisations over the last two years using reference building models of different types to derive reference values per building type. The latest analysis was published in December 2023 by DFØ[18].

Interestingly, a greater interest in learning more about the climate impact associated with **deep renovation**[19] measures is also observed. The expected renovation wave will trigger an immense potential for decarbonisation both in operational energy, but also in added materials. Boverket proposes that renovation projects are included in the climate declaration in Sweden from 2027. In most Nordic countries, various projects are currently in progress on developing the climate calculations specifically for renovation projects. In Sweden this is done partly within the framework of Local Roadmap Malmö (LFM 30) and partly within a newly launched E2B2 project to gather knowledge about the climate impact of various renovation measures in a Swedish context, done in a similar way for Boverket in the reference value study. In Denmark, initiation of development work towards comparable calculations for renovations is part of the National Strategy for Sustainable Construction, leading to related investigations in 2022 to draw up different proposals for limit values both at building level and building component level[20]. However, no decision on whether and how to regulate the life cycle impacts of renovations has been taken yet.

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17. Wiik, M. R. K., Selvig, E., Fuglseth, M., Resch, E., Lausselet, C., Andresen, I., ... & Hahn, U. (2020). *Klimagasskrav til materialbruk i bygninger. Utvikling av grunnlag for å sette absolutte krav til klimagassutslipp fra materialbruk i norske bygninger.*
18. See: https://anskaffelser.no/sites/default/files/2023-09/Endring_referansenivaaer_versjon_2_til_3.pdf
19. substantial renovation is defined differently in the various countries. Alias terms are: deep renovation, refurbishment and reconstruction
20. Lund, A. M., Zimmermann, R. K., Kragh, J., Rose, J., Aggerholm, S., & Birgisdottir, H. (2022). *Klimapåvirkning fra renovering: Muligheder for udformning af grænseværdier til LCA for renovering.* Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet. BUILD Rapport Nr. 33

1.5 Compliance Control Regime

The need for verification and possible sanctions depends on the chosen point of intervention (building permission phase or post-handover phase), how specific reporting requirements are and who is authorised to check them. Elements of reporting to be checked include inventory, scenarios, environmental data and calculation procedure. Error in reporting these elements can be reduced by using data from existing workflows or by narrowing methodological choices. Existing workflow data includes BIM files, tender lists or delivery notes, while methodological predefinitions may include default scenarios, generic data or verified LCA tools, which can secure correct calculation procedure to some extent.

In a legal perspective, clients pass the responsibility of compliance to a consultant or contractor through power of attorney. Since reporting includes data from several suppliers, the client/consultant transfers parts of the responsibility to any suppliers, who must provide data for reporting. This may include the contractor, sub-contractors, retailers, manufacturers, waste handlers and so on. Table 5 gives an overview on similarities and differences in control regimes for building carbon regulation in the Nordic countries.

Table 5. Compliance control regimes.

	Denmark	Estonia (Proposed)	Finland (Proposed)	Iceland (Proposed)	Norway	Sweden
Technical compliance control	10% of cases checked	No specific procedure yet decided	No specific procedure yet decided	No specific procedure yet decided	Yes	10 % of cases checked
External verification	No	Not decided yet	Not decided yet (possibly BIM file)	Not decided yet	No	No
Reporting stage	As-built	Building permit	Building permit + As-built	Building permit + As-built	As-built	As-built
Public building LCA register	No	Not decided yet	Not decided yet	Not decided yet	No	Yes
LCA tool requirement	No	No	No	Not decided yet	No	No
Market-based tools allowed	Yes	Yes	Yes	Yes	Yes	Yes

1.5.1 Control and Verification

In all participating countries, control routines are about to be developed as the requirements are being implemented. Sweden has published information about their process for supervision. Since the building life cycle spans require data from different sources and actors, the balance between effective and feasible procedure will take several years to test and refine.

Countries with existing carbon regulation require post-completion reporting for achieving a permit for operation. Estonia, Finland and Iceland are additionally considering including carbon reporting at building permit level, which then has to be updated at operation permit. No country requires the use of a specific official tool.

In Sweden, the national authority responsible for the supervision of climate declarations is Boverket, which performs spot checks, control of 10 % of registered climate declarations at Boverket. In Norway and Denmark, the building authority is placed at municipal level. In Denmark and Norway, the municipalities do not control technical aspects of building or operation permits without specific cause. Instead, the owner is responsible for legal compliance of building projects. In Denmark, technical aspects are only spot checked in 10% of cases. Sanctions for infringement are legally possible.

In Sweden, the client must register a climate declaration at Boverket before final clearance can be given by the municipality, and then save documentation for five years in case they are selected for random control by Boverket. Boverket handles a template[21] for the documentation. Documentation shall include the LCA calculation and environmental data as well as verification on delivered products. Current regulation requires 50% (75% in 2025) of material impacts to be verifiable. The share of verifiable impact has been discussed widely in Sweden. The idea behind is to limit the administrative cost of documentation to a share of building impacts, which is sufficient for achieving the regulatory purpose. The current limitations of delivery note procedures are planned to be replaced by a digital workflow suited for LCA by 2025[22]. At this point, the share of verifiable impacts could be increased to 95% due to the expected decrease of administrative burden. When setting this verification rate, the potentially allowed use of **standard values** has to be considered. In Sweden, the verification rate has to be achieved for the part of the calculation

21. See: https://www.boverket.se/sv/klimatdeklaration/gor-sa-har/spara-underlag/
22. Byggbranschens elektroniska affärsstandard, https://beast.se. Downloaded on 2 May 2023.

which does not use standard values. Other selection criteria for reducing verification burden have also been discussed.

The possibility of limiting climate assessments to the building components or materials, which are the main contributors to climate impacts has also been discussed in Sweden as well as in Denmark. During the preparation of the climate regulation in Denmark, this possibility was discarded for several reasons. Firstly, material impact contribution may change over time and as a consequence of technological development. Secondly, the desired competition between different component and material options and related manufacturers and building design options would be disturbed. And lastly, the desired increase in simplicity and feasibility obtained by limiting the inventory is uncertain compared with a simpler approach of including all delivered materials without the need for selection.

1.5.2 Reporting Stage

In general, whole-life carbon assessments can only be controlled based on the built result, because the specific type and quantity of purchased materials cannot be predicted exactly. All Nordic countries therefore require documentation of the as-built stage. Finland and Estonia require additional assessments already at the building permit stage. In all cases, building owners may want to make sure to comply with carbon limits throughout all project stages to reduce the risk of infringement. Finland and Estonia formalise this need through their requirements, which may be viewed as a way to avoid problems, before construction has begun. On the other hand, building permits cannot guarantee compliance of the finished result and may send a false signal of safety. Besides national variation in legal practice, building permit reporting can be an additional scaffolding for implementing the novel carbon limits, which may help practitioners and clients to take assessments more seriously compared to the legally minimum of as-built reporting, when no changes can be made to the building fabric anymore.

1.5.3 Public Register

Building cadastres and address registers are as old as the first cities. Today, GIS-based databases are a valuable tool for research-based policy making and often accessible for the public. A public register of building carbon assessments can provide very valuable database for the development of carbon limits. Currently, only Sweden has a public register with climate declarations to be used for compliance control and the development of limit values. It is planned to be open when the quality is assured. It is available for researcher on request. A first set of simple statistics will be published in January 2024 in Boverket's handbook for climate declarations. The statistics will be updated on a yearly basis. Conversely, Denmark has extensive data publicly available for any building in the country (the BBR database). However, this database does not include information from the climate declaration. Building permission files such as climate declarations will only be available in the public registry in a case-by-case manner. This question is related to the general availability of building stock data, which is relevant for policymaking in all societal areas, not only environmentally. However, the ongoing digitalisation of administrative and permission procedures as well as building archives is slow, and the quality control is difficult to achieve.

Carbon assessments will likely extend to include more indicators and life cycle stages. Most certainly, they will not only include environmental aspects, but also other types of information, because buildings are entangled in many affairs of public interest and regulation. Digitalisation offers other ways of public regulation, which are useful in the complex regulation of buildings. The development is driven by processes that already use digital workflows such as building design (digital twins), facility management or LCA, which are paving the way to a more holistic digital representation of building through time. This workflow can be utilised by public authorities. However, many open questions have to be solved on the way. Building passports or logbooks aim at establishing a database for structured digital building information, which reflects the current status of material, properties and environmental impacts and make them accessible from the outside without new assessments. They will also be valuable for facility management and later renovations and can serve as an enabler for urban mining and the reuse of building products. The building passport practical guideline by the Global Alliance for Buildings and Construction gathers current initiatives in one guideline[23]. Building passports are an evolution of existing real estate registers or cadastres, both in terms of content and accessibility. In short, digital cadastres could include more temporarily updated or real-life data and also capture monitored data instead of indirect monitoring. Besides the many existing voluntary initiatives, the best-known examples are the public mandatory Energy Performance Certificates repositories[24] in the EU member states.

23. See: https://globalabc.org/resources/publications/building-passport-tool-capturing-and-managing-whole-life-data-and
24. Energy Performance of Buildings Directive (2010/31/EU)

Being a keystone in climate declarations, the systematic reporting of the building fabric demands for a harmonised building classification system that would be beneficial for ensuring that impacts and quantities are assigned to building parts in a uniform manner. Today, all countries have different systems, while some use a variety of systems. The correct use of classification is a precondition to be able to perform control and related delivery notes and other product documentation to the model.

Ideally, building product data is provided by suppliers together with the products and stored in a digital building repository. This data can then be used to inform the material related LCA and be shared with the authorities for permissions and verification. This would bypass or reduce the role of consultants in this part of LCA and instead create a more direct reporting flow from manufacturer, supplier and contractor to the client and authorities. The ongoing development and successive implementation of the EU Construction Product Regulation (CPR) is expected to play a vital role for new ways of handling environmental data of building products throughout the construction value chain. In the future, all building products will have to declare their environmental performance by default and in a uniform structure, which will change building climate declarations considerably. A more thorough account on recent developments of the CPR and expected ramifications can be found in Task 2 "Data for LCA" in the Nordic Sustainable Construction Programme.

1.5.4 LCA Tools

LCA can be performed in a variety of workflows in the construction pipeline. Some tools integrate carbon assessments in tender calculation tools, others provide carbon screenings in geometric design tools (CAD, BIM), and some tools are stand alone and work with different kinds of data integration. Since regulation is based on the as-built status, we focus on tool functions for this stage. No country makes the use of tools as such or one national tool in particular mandatory. Given the availability of calculation methods and allowed environmental data, everybody can perform LCA without the use of any tool as a starting point.

When using publicly available or commercial tools, the question of compliance verification arises. Using a tool means delegating responsibility for parts of the assessment to the tool provider. As a minimum, tools should provide a complete declaration of calculation procedure and data sources. This should also include the status of user choices. This may require some degree of assessment, which places responsibility on the user, not the tool. As an alternative to a full functional declaration, national authorities may require tools to be verified. For example, a Norwegian study shows that using different tools in the market may lead to different results for the same building and scope, notably because the tools use different assumptions for the service lives of building products among others[25]. The official verification of tools is implemented in France and the Netherlands, but not in the Nordic countries.

1.6 Reduction Roadmap

In some Nordic countries, the planning of the limit values is accompanied by a certain plan for their progressive tightening. In Denmark, there has been a policy decision that future reductions of the limit value will be based on a percentile value of a representative sample of Danish buildings. For instance, by 2025 the limit value will be set so that two thirds of a representative building sample would be able to reach it without improvements (the 2023 limit value is set so that 90% of a building sample would be able to reach it without improvements, and the building sample is not fully representative of new construction). The voluntary CO^2 class[26] follows a parallel tightening process. Along with the official trajectory, there is also a voluntary initiative attempting to translate the Paris Agreement and the Planetary Boundary for Climate Change into an industry-specific Reduction Roadmap[27]. This roadmap finds that the target for Danish residential buildings needs to reach 0,4 $kgCO_2e/(m^2year)$ within the next 10 years to be within the safe operating space (top-down budget-based target) with a 67% likelihood. This initiative provides more timelines based on the likelihood to stay within Denmark's budget.

In Sweden, the suggested plan is to reduce the limit values by 25% in 2030 for all building types other than single-family homes, which are already more optimised, which deems a reduction of up to 15% sufficient. If this trajectory continues linearly, this means that from 2025 and up to 2045, which is when Sweden aims at a climate neutral building and construction, the limit values will be reduced by 60-100% depending on the building type.

The main rationale behind selecting a certain limit value pathway is to make it cost-effective. I.e. a pathway that ensures a stable marginal cost of reducing emissions over time, also considering that today's costs are heavier than costs

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25. See: https://www.dibk.no/om-oss/Kalender-DiBK/klimagassutslipp-fra-byggematerialer. There is no conclusion yet on all reasons behind why the tools give different results, this is still under investigation. Another main purpose of this report was to investigate how much one can reduce the GHG emissions without costs and with costs.
26. See: https://im.dk/Media/637602217765946554/National_Strategy_for_Sustainable_Construktion.pdf
27. See: https://reductionroadmap.dk

postponed to the future. This means lower emission requirements in the beginning and increasing requirements over time, as the emission cost increases with stricter emission requirements. In this endeavour, countries are trying to strike a balance between the need to push for faster climate impact reductions and the consideration of small and medium-sized stakeholders with fewer resources to build up expertise to work on reducing projects' emissions as well as buy climate-improved construction products.

Another aspect is frequency of adjustments. Denmark applies two-year adjustments, while Sweden suggests a much longer adjustment time-step of five years. Sweden's rationale is that less frequent adjustments allow time for evaluations and necessary regulatory amendments as well as reduce administrative costs. Furthermore, the plan to expand the scope is associated with update of the national database and development of standard values, which also considerably adds to administrative cost. On the other hand, a more frequent reduction interval facilitates a more gradual industry transition for all parts of the value chain and ensures that up-to-date environmental data is used.

2 National LCA Definitions

This section provides a more detailed description of the technical aspects that differ between LCA declarations used in the Nordic countries, including their reference unit; the scope of life cycle processes and building parts covered; methods used to calculate energy use, exported energy and biogenic carbon.

2.1 Reference Unit

The choice of area unit has gained increasing interest during the development of legal frameworks for climate declarations in Nordic countries as it plays a significant role in the level of a climate declaration result. A climate impact calculated per gross floor area (GFA) cannot be compared with using the heated floor area (HFA) or net heated area, as this will give different results. Currently, different reference units and definitions for the same reference unit, are used across Nordic countries to calculate the climate impact of buildings (Table 6), which makes it difficult to compare results between countries.

The latest communication of the EPBD revision suggests that the useful floor area (UFA) may become mandatory through the reference to Level(s). The current Level(s) definition of UFA is based on the International Property Measurement Standards (IPMS). This has not been previously defined. Following the development of Level(s), the taxonomy and the EPBD would mean that the regulatory frameworks in Nordic countries, upcoming or in place, would need to be amended if the useable floor area unit or any unit different from what is currently prescribed is introduced to the EU regulations.

Norway and Sweden use GFA as the reference unit, while Finland and Estonia use net heated area to match energy claims. Denmark uses two area units to calculate the total climate impact: the total GFA for the embodied part and the HFA for the operational part (B6 module). The usual GFA definition is extended exclusively for use in climate declarations in order to correct undesired reference/impact relations. For semi-external elements, such as balconies, rooftop terraces, external stairs and access corridors, only 25-50% of the element's floor area is included in the total floor area of the building. Iceland uses HFA as the official reference unit and will request the additional reporting of results in GFA.

In Sweden, the reference value study behind the proposed limit values for 2025 investigated whether underground storeys in buildings generally give higher carbon emission results than in buildings without. It was found that the use of heated floor area as a reference unit tends to disadvantage buildings with underground (non-heated) storeys, while there was no influence when results were calculated per square metre of GFA, and therefore the results were more robust when using GFA. Using heated floor area as a reference unit may lead to developers avoiding building basements or underground car parks. This would probably require differentiation of levels for limit values depending on whether or not the building has storeys below ground level. The question about a full or partial inclusion of the basement in the reference unit area and calculation in general is now seen in Denmark with a view to the gradual tightening of the limit value in the building regulations as well[28]. There are more limited choices in the optimisation of the underground spaces and hence building structure on top of the basement is expected to predominantly carry the optimisation burden as limit values become tighter.

The choice of a **reference study period (RSP)** is necessary when the use stage modules are included in the climate declaration. RSP represents the temporal boundary over which a building is assessed. The choice of RSP is necessary to quantify the impact associated with use stage modules (stage B). The Nordic countries, like most countries internationally, favour a 50-year[29]. Denmark, Finland and Estonia already apply a fixed 50-year RSP in their LCA calculations, while Norway recently changed from 60 years – the common practice in the Norwegian construction industry – to 50 years. The latter decision affects Norwegian environmental product declarations (EPDs) which is the main input for Norway's building LCA calculations, since they typically generate LCA scenarios based on a 60-year RSP for buildings. Furthermore, 50 years is the RSP currently applied in the Level(s)[30], the methodology to which the Taxonomy regulation refers to. Sweden currently does not need a RSP in their climate declaration, since it only covers **upfront** impacts, but the proposed extension of the declaration to cover operational stages in 2027 will use a RSP of 50 years.

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28. Tozan, B., *Olsen, C. O., Birgisdottir, H., Kragh, J., Rose, J. (2023). Klimapåvirkning fra nybyggeri: Analytisk grundlag til fastlæggelse af ny LCA baseret grænseværdi for bygningers klimapåvirkning fra 2025.* (1 udg.) BUILD, Aalborg Universitet. BUILD Rapport Bind 2023 Nr. 21
29. Balouktsi, M., Lützkendorf, T. (2023) *Survey on the use of national LCA-based assessment methods for buildings in selected countries - A Contribution to IEA EBC Annex 72. In: IEA EBC Annex 72* - Background information - Assessing life cycle related environmental impacts caused by buildings. Available at https://annex72.iea-ebc.org/publications
30. The first version of Level(s) used a 60-year RSP, but switched to a 50-year RSP after the test phase

Table 6 Reference unit definitions (as of January 2024).

					Within the building enclosure								Outside the building enclosure			
Country/ Region	(in place or proposed) **Regulation**	**RSP**	**Floor area definition**	**External wall thickness**	Primary functions	Secondary functions (e.g. circulation areas, storage)	Internal walls and columns	Basement/ cellar	Stairs	Common facilities (in multi-units, incl. staircase, lift, vertical voids)	Enclosed car park connected to building	Attic	Rooftop terrace	Plantrooms on roof	Balcony	External area including car park
Denmark	Danish Building regulation (BR18) – embodied part	50	GFA	√	√	√	√	if ceiling height > 1.25 m	√	counted for all floors	included with 50%	only if > 1.5 m high	included with 25%	√	included with 25% (for external areas only when connected to the building)	
	Danish Building regulation (BR18) – operational part	50	HFA	√	√[2]	√[2]	√	if ceiling height > 1.25 m	-	counted for all floors	-	only if > 1.5 m high	-	-	-	-
Estonia	Proposed method for climate declaration (2021)	50	HFA	-	√[2]	√[2]	√	√[2]	√	√	√[2]	√[2]	√[2]	√	√	-
Finland	Proposed method for climate declaration (2021)	50	HFA	-	√[2]	√[2]	√	√[2]	√	√	√[2]	√[2]	√[2]	√	√	included in the calculation of "site"[1]
Iceland	Method under development (2023)	50	HFA (official) & GFA (additional)	√	√	√	√	√	√	√	√	√	√	√	√	
Norway	TEK17	50	GFA	√	√	√	√	included if > 1.9m high for a width of ≥ 0.6m	-	-	√	included if > 1.9m high for a width of ≥ 0.6m	included if enclosed by glass	√	-	-
Sweden	Climate Declaration 2022	N/A	GFA	√	√	√	√	√	√	-	√	included if > 1.9m high for a width of ≥ 0.6m	-	√	only if glazed/-climate-protected	-
Europe	Level(s) – Office	50	IPMS 3 UFA	-	√	√	√	if in exclusive use	-	-	-	-	√ separate item	-	√ separate item	-
	Level(s) – Residential	50	IPMS 3B UFA	-	√	√	√	√ separate item	only on ground floor	-	√ separate item	√ separate item	√ separate item	√ separate item (unless common facility)	√ separate item	-

Note: "blue" indicates that an item is included; "light blue" indicates that an item is included and also separately reported for transparency. GFA = Gross Floor Area; HFA = Heated Floor Area.
1 "Site" is not part of the limit value calculation in Finland, but t it is proposed to be part of the climate declaration. 2 the inclusion depends on whether these particular areas are heated/semi-heated or unheated. The background behind this distinction may vary from country to country.

2.2 Life Cycle Stages Considered

A building goes through different stages during its lifetime. This includes the product stage, the construction process stage, the in-use stage, and the end-of-life stage. Furthermore, some decisions during a life cycle of a building have potential benefits and loads beyond the system boundary. EN 15978 standard provides a modular framework to define each stage and is used as a reference by all current regulations. Therefore, following the modular framework for the life cycle of a building adopted in the revised draft EN 15978 (according to the recently revised standard EN 15643), Table 7 summarises what life cycle stages and modules are required or optional according to the LCA methods in regulations in Nordic countries and in Level(s). Carbon emissions during product stage (A1-A3) and construction stage (A4-A5) are often grouped and commonly referred to as **upfront embodied carbon emissions** since they are released before the building operation begins.

The coverage of different system boundaries limits the comparability of limit values between Nordic countries. In Denmark and Finland, limit values and climate declaration have the same life cycle scope with only module D reported in addition in the declaration. Sweden currently only considers upfront impacts in the mandatory declaration and plans to keep this limited scope for limit values in 2025. They will introduce an extended scope for the climate declaration in 2027, but not for the limit value. For Estonia, Iceland and Norway, the scope that will be selected for the limit values, and whether it will differ from the climate declarations is not settled yet.

What can be observed is that Nordic countries are likely to reach a consensus regarding reporting upfront emissions in the short run. Although Denmark does not include A4 and A5 in its 2023 limit values, the effects of inclusion of the missing modules (A4, A5, B1, B2-3, B6.2, C1, C2) in the 2025 and 2027 climate declaration and limit values are currently investigated[31]. As experiences are gradually gained with calculating and documenting A4-A5 through the voluntary sustainability class, the likelihood of their inclusion in 2025 limit values is high compared to the rest of the missing modules (B1, B2, C1, C2). In the case of Norway, A5 is not fully included in its climate declaration, i.e. only the production of the materials that become waste in the construction process is considered (emissions from excavation and blasting, emissions from mobile or stationary machines, etc. are not included, however, there is an ongoing

31. Balouktsi, M., & Birgisdottir, H. (2023). *Analysis of new modules in connection with calculation of the climate impact of buildings.* (1st ed.) Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet.

work to propose relevant claims in other regulation). Waste, including the waste management part (which is not included so far in the Norwegian declaration), has been reported in some studies to be the biggest contributor to the A5 module[32],[33]. Furthermore, the use of fossil oil for heating and drying on construction sites has been prohibited since 2022.

In the case of Level(s), while the application of the full life cycle scope is recommended, the framework also provides two options for simplified reporting to be used in the short-term until better availability of data and software tools are in place. The framework also requests to state any omission from the full scope in the reporting clearly. As data and tools are continuously improved, it is expected that the full scope reporting will become mandatory as part of EPBD.

Beyond upfront emission, the most significant discrepancy is the inclusion or exclusion of **operational emissions** associated with **energy consumption**, i.e. module B6. While the relative share of operational carbon to embodied carbon is decreasing due to energy services decarbonisation, still operational carbon is reported to represent a notable share of whole life cycle emissions[34], depending on energy performance and climate (energy use is climate dependent, hence energy use comparisons among regions can be misleading). Sweden chooses to focus on today's emissions in the limit values with the following rationale. First, this is the part of the life cycle of the buildings that has the highest climate emissions (Swedish conditions) and which can be confirmed with real values at the building delivery and calculated without making assumptions about the future. Second, it places the emphasis on reducing emissions today, not far in the future. Third, the ongoing transition of energy systems and industry towards low emissions means that future emissions are likely to be comparatively low. Boverket considers that other policy instruments can be used to mitigate operational impacts (such as energy performance regulations). Boverket suggests that more life cycle stages should be included in the climate declaration 2027 (not in the limit value). However, the final rulemaking about the life cycle stages included needs to be adapted to the rules decided by the EU. This mainly applies to the revised

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32. Kanafani, K., Magnes, J., Lindhard, S. M., & Balouktsi, M. (2023). Carbon Emissions during the Building Construction Phase: A Comprehensive Case Study of Construction Sites in Denmark. *Sustainability,* 15(14), 10992.
33. Kanafani, K., Magnes, J., Garnow, A., Lindhard, S. M., & Balouktsi, M. (2023). *Ressourceforbrug på byggepladsen: Klimapåvirkning af bygningers udførelsesfase.* (1 udg.) Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet. BUILD Rapport Bind 2023 Nr. 14
34. close to 10% of whole life carbon according to the latest limit value study in Denmark, but without considering B6.2 and B6.3 (unregulated part of energy use), see: Tozan, B., Olsen, C. O., Birgisdottir, H., Kragh, J., Rose, J. (2023). *Klimapåvirkning fra nybyggeri: Analytisk grundlag til fastlæggelse af ny LCA baseret grænseværdi for bygningers klimapåvirkning fra 2025.* (1 udg.) BUILD, Aalborg Universitet. BUILD Rapport Bind 2023 Nr. 21

Energy Performance Directive (EPBD), which is still under negotiation between the European Parliament, the Council of the European Union and the European Commission.

Norway also follows a more limited scope in its declaration and possibly also its future limit values. However, when it comes to embodied carbon of in-use stage, currently it includes the more complete scope as Norway is the only Nordic country already mandating the calculation of B2 module. A reason behind not including B6 is that Norway has already banned fossil fuel heating of new buildings since 2016, as well as the use of fossil oil for heating in existing buildings since 2020. In addition to regulating energy consumption separately, B6 aspects are considered as already sufficiently optimised. In this case, energy consumption is intended to be regulated through other policy instruments, such as energy performance regulations. Demand management is a key strategy to enable a high share of renewable low-carbon electricity on the grid.

Table 7 Life cycle assessment scope (as of January 2024).

Life cycle stages and modules included according to current and upcoming regulations		A0 Pre-construction stage	Upfront embodied carbon: A1-3 Product stage	A4 Transport to site	A5 Construct works	Use-stage embodied carbon: B1 Use in building	B2 Maintenance	B3 Repairs	B4 Replacements	B5 Refurbishment	Operational carbon: B6.1 Regulated operational energy use	B6.2 Unregulated operational energy use, building - related	B6.3 Unregulat operat energy use, user-relatec	B7 Operational water use	B8 Users activities not covered in B6 and B7	EoL embodied carbon: C1 Demolition works	C2 Transport	C3 Waste management	C4 Final disposal	Beyond the building system: D1 Reuse, recovery, recycling potential	D2 Exported utilities potential
Denmark	BR18	-	√	included in the voluntary sustainability class		-	-	-	√	-	√	-	-	-	-	-	-	√	√	√*	√*
Estonia	Proposed method for climate declaration (2021)	-	√	√	√	-	-	-	√	-	√	-	-	-	-	√	√	√	√	√*	√*
Finland	Proposed method for climate declaration (2021)	-	√	√	√	-	-	-	√	-	√	-	-	-	-	√	√	√	√	D1 * D2 *	D3*
Iceland	Method under development (2023)	-	√	√	√	-	-	-	√	-	√	√	-	-	-	√	√	√	√	√*	-
Norway	TEK17	-	√	√	only waste	-	√	-	√	-	-	-	-	-	-	-	-	-	-	-	-
Sweden	Climate declaration 2022	-	√	√	√	-	-	-	-	-	-**	-	-	-	-	-	-	-	-	-	-
	Limit values 2025 Climate declaration 2027 (proposal)	-	√	√	√	-	√	-	√	-	√	-	-	-	-	√	√	√	√	-	-
Europe	Level(s): Simplified reporting option 1	-	√	-	-	-	-	-	√	√	√	(√)	-	-	-	-	-	-	-	-	-
	Level(s): Simplified reporting option 2	-	√	-	-	-	-	-	√	-	√	(√)	-	-	-	-	-	√	√	√*	√*

limit values scope

climate declaration scope

proposed limit value scope

proposed climate declaration scope

√= included, (√) = likely included, * = separate reporting

** Although B6 is not mandatory in the climate declarations in Norway, it is not allowed to heat new buildings with fossil fuel (oil and gas) according to the building code in TEK17.

Note 1: the modular structure is according to the most recent European standard EN 15643:2021 (to also be adopted in the upcoming EN15978); A0 includes the non-physical pre-construction processes and is not usually used as part of building environmental assessments but is typically part of life cycle costing (LCC).
Note 2: In the Finnish method D1-D5 constitute the carbon handprint. D5 carbonation is taken into account only beyond system boundary. The coverage of any module beyond the indicated scopes is considered optional.

In the short-term, Finland's declaration covers the most complete life cycle scope: A1–A5, B4, B6 and C1–C4. Finland also adopts the "carbon handprint" concept, which refers to "non-life-cycle net climate benefits or enabling factors that would not have arisen without the project". Carbon handprint consists of module D elements (recycling, energy recovery, surplus energy generation denoted as D1-3 in carbon handprint, respectively), supplemented with other benefits like biogenic carbon storage (D4) and cement carbonation beyond system boundary[35] (D5). However, no Nordic country includes **refrigerant impacts** due to losses from technical systems like heat pumps and air-condition systems, either under B1 module or as a separate issue. This is an aspect covered for instance in the French building LCA regulation. A recent Danish study that investigates the impact of the refrigerant losses based on ten building cases shows that this aspect can add up to 1kgCO_2e/m^2year and year to the total impact[36].

The selected life cycle scope depends on the availability of data for calculating the included modules. Finland supports the introduction of a wider scope compared to the other Nordic countries with the provision of standard values for entire modules on building level (kgCO_2e/m^2year of building) for some of the modules (A4, A5, C1, C2) without prohibiting project-specific calculations when feasible for the construction process stage. The provision of standard values, either at the building level or lower levels (processes, calculation inputs, etc.), is often necessary in the first introduction of new requirements so that an expanded scope does not become costly for the industry to produce the necessary data and perform detailed calculations. There are various approaches to how countries are facilitating the calculations with standard values (Table 8, B6 is analysed in detail in a following section). Standard values are usually set conservatively with an adequate supplemental factor. However, the effect of a regulation risks being reduced when standard values are allowed as an alternative to project-specific calculations. When standard values are used, the potential climate impact is not accurately calculated, and the developer is not required or encouraged to take mitigating measures.

35. Carbonation during use, an aspect described in B1 module in the upcoming revised EN 15978, is not considered as it is often prevented with repairs which adds complexity to its calculation
36. Balouktsi, M., & Birgisdottir, H. (2023). *Analysis of new modules in connection with calculation of the climate impact of buildings.* (1st ed.) Institut for Byggeri, By og Miljø (BUILD), Aalborg Universitet.

Table 8 Standard values applied by the Nordic countries for the calculation of life cycle modules (as of January 2024)

Standard values		Upfront embodied carbon		Use-stage embodied carbon			EoL embodied carbon				Beyond the building system	
		A4	**A5**	**B1**	**B2**	**B4**	**C1**	**C2**	**C3**	**C4**	**D1**	**D2**
Denmark	BR18	under invest.	under invest.	under invest.	under invest.	service lives	under invest.	under invest.	standard scenarios selected from industry EPDs		standard scenarios in accordance to C3-4	-
Estonia	Climate Declaration (proposal)	Yes*	default material wastage%	-	-	service lives	impact/m^2 (building)	distance 50km	recycling and disposal share applied to three material classes		benefit/kg (product) * based on post-life scenarios	-
Finland	Climate Declaration (proposal)	impact per type of transport service (ton km) & impact/m^2 (building)	impact/m^2 (building)	-	-	service lives	impact/m^2 (building)	impact per type of transport service (ton km) & impact/m^2 (building)	impact/kg (product)*	No, product-specific	benefit/kg (product) * based on post-life scenarios	-
Iceland	Climate Declaration (proposal)	unclear	unclear	-	-	unclear	unclear	unclear	unclear	unclear	unclear	-
Norway	TEK17	No, product-specific	A5 can be given as a % of A1-A3 and A4	-	No, product-specific	No, product-specific	-	-	-	-	-	-
Sweden	Climate Declaration 2022	impact/kg (product)*	waste factor (product)*	-	-	-	-	-	-	-	-	-
	Climate Declaration 2027 (pro-posal)	impact/kg (product)*	waste factor (product)*	-	under invest.	under invest.**	under invest.	under invest.	under invest.	under invest.	-	-

*per product type and subtype; the use of the standard values in the legislation is not a must. Project specific data on transportation and amount of waste can be used. However, Bereket's emission factors for different kinds of transportations have to be used.
** some first service lives are provided in the national database

2.3 Building Model Scope

What building parts are important to include in limit values depends on the life cycle scope covered. For example, when a scope is limited to upfront emissions A1-5, the structure tends to be more important. However, when performing a whole life carbon assessment, frequently replaced components such as mechanical, electrical and plumbing (MEP) systems increase in significance, and refrigerants of heat pumps have major influence on the LCA of HVAC systems.

System boundaries in regulation and limit values in Nordic countries vary in this aspect (Table 9). The biggest discrepancies lie in the partial or full inclusion or exclusion of site preparation, building services, external works and furnishing. Finland and Denmark already include most installations and services. Looking ahead in 2025, Boverket in Sweden suggests that building services currently not accounted for are included in the limit value except for solar panel installations (all types) which must be included in the actual declaration of the climate impact of the building but must be declared separately. If Norway also decides to include building services in their future limit values, which is a significant part of B4 currently missed, an important harmonisation step can be achieved.

For example, a European study that collected more than 700 cases shows that a major contribution to the life cycle embodied carbon emissions[37], on average, stems from the technical services with a mean value of around 190 kg CO_2e/m^2, ranging from 170 to 230 kg CO_2e/m^2. This also is confirmed by other studies on MEP systems for individual building cases which could account for about 20-50% of the embodied GHG emissions of new-build projects depending on the building type, the extent of the use of PVs and the level of detail of MEP description (Hoxha et al., 2020[38]; George et al., 2019[39]; Birgisdottir et al., 2017[40]).

Given the importance of technical services and considering that the data availability is still not at the level of building products, it has been possible to

37. See: https://fs.hubspotusercontent00.net/hubfs/7520151/RMC/Content/EU-ECB-2-Setting-the-baseline.pdf
38. Hoxha, E., Maierhofer, D., Saade, M. R. M., & Passer, A. (2021). Influence of technical and electrical equipment in life cycle assessments of buildings: case of a laboratory and research building. *The International Journal of Life Cycle Assessment*, 26(5), 852-863. https://doi.org/10.1007/s11367-021-01919-9
39. See: https://www.elementaconsulting.com/wp-content/uploads/2019/08/Whole-Life-Carbon-of-heat-generation-April-23.04.19.pdf
40. Birgisdottir, H., Moncaster, A., Wiberg, A. H., Chae, C., Yokoyama, K., Balouktsi, M., ... & Malmqvist, T. (2017). IEA EBC annex 57 'evaluation of embodied energy and CO2eq for building construction'. *Energy and Buildings*, 154, 72-80

use standard values for technical equipment up to now in Denmark and Finland (Table 10). Alternatively, both Finland and Denmark provide generic emission factors data for different types of technical equipment in their respective databases per various units (e.g. kg, kWh, piece). IVL and KTH (commissioned by Boverket) recently developed standard values covering technical services, internal finishes and fittings for different types of buildings to support more complete building LCAs from the building elements perspective in the application of the 2025 limit value[41].

41. Malmqvist, T., Borgström, S., Brismark, J., Erlandsson, M. (2023). *Referensvärden för klimatpåverkan vid uppförande av byggnader.* Version 3. KTH Skolan för Arkitektur och Samhällsbyggnad. ISBN: 978-91-8040-754-0

Table 9 Whole building assessment scope (as of January 2024).

Included building parts		Denmark	Estonia	Finland	Iceland	Norway	Sweden		Europe
		BR18	Climate declaration (proposal)	Climate declaration (proposal)	Climate declaration (proposal)	TEK17	Climate declaration 2022	Limit values 2025 Climate declaration 2027 (proposal)	LEVEL(s)
Site preparation		-	-	soil stabilisation and site reinforcement elements*	-	-	-	soil stabilisation and site reinforcement elements, reported from 2027	?
Substructure	Foundations	√	√	√*	√	√	√	√	√
	Piling	√**	√	√*	√	√	-	reported from 2027	?
	Basement walls	√	√	√	√	√	√	√	√
	Ground floor structure	√	√	√	√	√	√	√	√
Superstructure (external elements)	Frame (columns, beams)	√	√	√	√	√	√	√	√
	External walls, façade	√	√	√	√	√	√	√	√
	External doors, windows	√	√	√	√	√	√	√	√
	Balconies	√	√	√	√	-	√	√	√
	Roof structures	√	√	√	√	√	√	√	√
Superstructure (internal elements)	Internal walls, load- and non- load bearing	√	√	√	√	√	√	√	√
	Floor slabs	√	√	√	√	√	√	√	√
	Internal doors	√	√	√	√	√	√	√	√
	Stairs and ramps	√	√	√	√	-	√	√	√
Internal finishes	Wall and ceiling interior finishes and coverings	√	√	√	√	√	-	√	√
	Flooring materials	√	√	√	√	√	-	√	√
	Suspended ceilings	√	√	√	√	√	√	√	√
Building services	Lifts and escalators	√	√	√	√	-	-	only for building types in Group 1	√
	Electricity system	-	√	-	√	-	-	only for building types in Group 1	√
	HVAC system	√	√	√	√	-	-	only for building types in Group 1	√
	Renewable energy systems	√	√	√	√	-	only building integrated solar panels	All panels for all building groups, in 2025	√
	Water system	√	√	√	√	-	-	only for building types in Group 1	√
	Sewage system	√	√	√	√	-	-	-	√
	Other systems (e.g. firefighting)	-	√	√	√	-	-	only for building types in Group 1	√

External works		only if included in the area definition	-	only external structures on yard*	-	-	-	-	√
Furnishing	Fixed furniture	-	-	√	-	-	-	only for building types in Group 1	√
	User furniture	-	-	-	-	-	-	-	-

limit values scope	√= included, (√) = likely included
climate declaration scope	
proposed limit value scope	
proposed climate declaration scope	

*The new proposal (January 2024) states that LCA calculation should be done only for the buildings that are in the scope of limiting value. This could be interpreted that the building site elements will not be included in the calculation. This is still open to be decided after a commenting period: see, https://www.lausuntopalvelu.fi/FI/Proposal/Participation?proposalId=65211281-8a8f-4eb3-9465-ff3246a312c0

** Allowance for exclusion as a special condition of the building resulting from its location

Table 10 Standard values for building elements (as of January 2024).

Standard values		Site preparation	Building services	Fixed furniture and interior finishes
Denmark	BR18	No	Yes, ranges from 33-62 $kgCO_2e/m^2$ (A1-3, C3-4) detailed values are provided per module differentiated per building type[1].	No for interior finishes, N/A for fixed furniture
Estonia	Climate Declaration (proposal)	N/A	Yes, same as Finland	No
Finland	Climate Declaration (proposal)	No	Yes[2], ranges from 33-62 $kgCO_2e/m^2$ (A1-3), and 10-96 $kgCO_2e/m^2$ (B4), depending on the building type; Standard values for fire extinguishing system and cooling system are provided separately	No
Iceland	Climate Declaration (proposal)	N/A	No	No
Norway	TEK17	N/A	N/A	No
Sweden	Climate Declaration 2022	N/A	N/A	N/A
	Climate Declaration 2027	development of standard values for earthworks and foundation reinforcements under investigation	Yes, ranges from 12-60 $kgCO_2e/m^2$ (A1-5), depending on the building type; detailed values are provided both per module and A1-5 as a sum differentiated per building type[3]	Yes, ranges from 22-53 $kgCO_2e/m^2$ (A1-5), depending on the building type; detailed values are provided both per module and A1-5 as a sum differentiated per building type[3]

[1]Teknologisk Institut & SWECO. (2022). *Oplæg til defaultværdier for installationer - enfamiliehuse, rækkehuse*. Teknologisk Institut & SWECO.

[2]Source: https://co2data.fi/rakentaminen/

[3]Report: "Referensvärden för klimatpåverkanvid uppförande av byggnader. Version 3, 2023" Appendix 4

A requirement to reduce the climate impact of certain elements may increase the incentives to implement reduction measures in this part of construction. If only included in the climate declaration separately, it increases knowledge in the field and initiates discussions on potential improvements. The latter is the case for the climate impact of groundworks and ground improvements[42] (as part of site preparation) which is becoming more widely discussed in Finland and Sweden and intended to be included in the future climate declarations as a separate item first. The rationale is that comprehensive overviews of the

42. In Sweden, the term "groundworks and ground improvement" refers to soil stabilisation measures, capillary breaking layers and drainage on the site where the building is to be erected up to insulation under the foundation, including measures two metres outside the façade of a building. Activities that may be performed during groundworks and ground improvements are: basic excavation, subgrade preparation with crushed rock, piling, soil stabilisation, sheet piling, remediation measures and removal of contaminated soil (not off-site remediation), grading, paved surfaces, blasting and felling of trees (Boverket, 2023).

climate impact associated with different land measures or ground conditions currently is lacking. The Swedish Geotechnical Institute is carrying out work within the framework of the project entitled "Klimatdata för grundläggningsmetoder", which will run until 2023. The project has produced no useful public figures to date, but it is widely acknowledged that ground improvements come at a high cost in terms of carbon emissions. There was a case study as part of a project entitled "Klimatdata för grundläggningsmetoder" that showed that the climate impact of driven concrete piles and tubular steel piles in a 36-storey office building in Gothenburg was approximately 90 kg CO_2e per m^2 GFA. Boverket proposes their inclusion from 2027 to lay the foundation for a potential future value. This proposal has been judged as reasonable from the industry with the precondition that the use of standard values for groundworks is allowable in an initial phase only, and eventually project-specific values are requested. One of the reasons for this is to provide the necessary time to land contractors, as a new group that will be affected by the legislation, to be trained through specialised programmes.

Denmark includes special allowances for components, which have a high climate impact to justifiable function demands. This includes deep foundation for sites with weak soil and particular purposes such as laboratories, security facilities or industry[43].

2.4 Energy Consumption Calculation

From a methodological perspective, the relative importance of the carbon emissions associated with operational energy consumption in the operation of a building does not only depend on the scope of consumptions covered under B6 module (B6.1 “Regulated operational energy”, B6.2 “Unregulated building-related operational energy” and/or B6.3 “Unregulated user-related operational energy” in the EN 15643 nomenclature). It also depends on the impact intensity of the energy sources used. That is why the choice of the energy supply model to be applied in LCA requirements and limit values is considered very important. One of the most essential modelling choices is the choice between present mixes and future mixes that account for future developments in the energy production for electricity, district heating and gas[44]. Another

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43. Tozan, B., Birgisdottir, H., Hoxha, E., Nielsen, L.H. (2023) Regulation on carbon emissions for buildings with special conditions: analysis, calculation model and stakeholder perspectives. J. Phys.: Conf. Ser. 2600 152011. doi.org/10.1088/1742-6596/2600/15/152011
44. Zhang, X. (2023) *Basics and recommendations on influence of future electricity supplies on LCA-based building assessments - A Contribution to IEA EBC Annex 72*. In: IEA EBC Annex 72 - Background information - Assessing life cycle related environmental impacts caused by buildings. Available at https://annex72.iea-ebc.org/publications

important choice is whether to allow the use of provider-specific (i.e. market-based) emission factors when provided in EPDs or other verified sources or to strictly apply a generic mix for all buildings[45]. An overview of these choices for the Nordic countries is given in Table 11.

For the introduction of the limit values in Denmark in 2023, the emission factors used for electricity, district heating and gas were calculated in 2020 and include future decarbonisation scenarios. However, recent developments in energy production with an intensive increase in renewable energy sources have led to the development of updated emission factors in 2023, which is meant to reflect the current and future energy system better[46]. The updated emission factors for electricity, district heating, and gas can be used exclusively in module B6 in building LCA. The factors are reduced by nearly 40%, 80% and 45% for electricity, district heating and gas, respectively, compared to the factors developed in 2020 and used in the 2023 limit values[47]. These reductions are due to consideration of the newer 2022-2050 projections by the Danish Energy Agency (DEA), which also incorporate political objectives and not just approved investments (frozen policy). Since the Danish limit values are planned to be updated every two years, it is recommended that the emission factors also be updated every two years, or any time there are major changes in energy projections. Updated decarbonised emission factors have also been published for Estonia and Finland in 2023, with small adjustments still pending. In Sweden, Boverket also suggests that scenario-based emission factors data be developed for electricity and district heating specifically for the proposed 2027 climate declaration (however, it is made clear that how the energy requirements will look like in 2027 depends on the upcoming changes in EPBD). Therefore, a certain consensus can be observed regarding the inclusion of future scenarios for the energy supply.

At the EU level, the Level(s) framework similarly suggests the use of the PRIMES (Price-Induced Market Equilibrium System) model to establish future emission factors for the electricity grid. PRIMES has been used by the European Commission and Directorate-General for Energy (DG Energy) to draw the EU Reference Scenario 2020. PRIMES handles multiple objectives such as GHG emission reductions, energy efficiency and renewable energy targets, and associated constraints.

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45. Peuportier, B., Frischknecht, R., Szalay, Z., Birgisdottir, H., Bohne, R.A., Lasvaux, S., Padey, P., Francart, N. (2023) *Basics and recommendations on electricity mix models and their application in buildings LCA - A Contribution to IEA EBC Annex 72.* In: IEA EBC Annex 72 - Background information - Assessing life cycle related environmental impacts caused by buildings. Available at https://annex72.iea-ebc.org/publications
46. See: https://sbst.dk/udgivelser/2023/emissionsfaktorer-for-el-fjernvarme-og-ledningsgas-2025-2075
47. Sørensen, M. N., Høibye, L., & Enersen Maagaard, S. (2023). *Emissionsfaktorer for el, fjernvarme og ledningsgas for 2025-2075*. Artelia A/S.

Table 11 Details behind B6 calculation in Nordic countries, in addition to the B6 scope shown in Table 7 (as of January 2024).

Operational energy consumption calculation (B6)		Calculation method	Energy decarbonisation scenario	Method for decarbonisation scenario	Expected revision and timeline	Possibility to use market-based GWP-values for energy[2]	Allocation method for CHP fuels[3]
Denmark	BR18	As for building permission (BR18)	**Yes**	Danish national policy scenario (COWI 2020)	Update in 2023, new factors will apply for 2025 limit values	No	Heat efficiency of 125% has been used as the allocation key
Estonia	Climate Declaration (proposal)	Based on energy performance minimum requirement method	**Yes**	Ministry of Environment 2023, Estonian Environmental Research Centre (Keskkonna Uuringute Keskus, KUK)	The scenario was recently developed by Ministry of Environment; it might be adjusted as various roadmaps are not yet published	Under investigation	Unknown
Finland	Climate Declaration (proposal)	As for building permission (YMa1010/2017)	**Yes**	Finnish national policy scenario (2019)	Update coming in 2023	Currently No	Benefit-sharing method
Iceland	Climate Declaration (proposal)	As for building permission	Iceland already has 99% renewables and district heating, therefore there will be no future scenarios.	N/A	Due to EU and voluntary scheme requirements, updates to energy framework are underway	No	Unknown
Norway	TEK17	N/A[1]	N/A[1]	N/A[1]	N/A	N/A	N/A
Sweden	Climate Declaration 2022	N/A	N/A	N/A	N/A	N/A	N/A
	Climate Declaration 2027 (proposal)	Not yet decided, but suggested as the energy rules in BBR	Boverket suggests that they develop scenario-based climate emission factors for electricity and district heating specifically for 2027 climate declarations	Not specified (likely based on the scenarios for the electricity consumption till year 2050 developed by Swedish Energy Agency)	Unknown	No	Unknown
Europe	Level(s)	National, as for building permission	**Yes**	EU PRIMES model (EU Reference Scenario 2016)	Latest EU Reference Scenario is from 2020	Not specified	Not specified

[1] there is a separate energy requirement calculated according to NS 3031 or measured consumption; expected decarbonisation is considered as such: NOR and EU scenarios, decarbonise linearly by 2050; Market-based values are not permitted to be used.

[2] i.e. GWP values from specific energy suppliers

[3] sharing between heat and electricity-associated emissions

Regarding the issue of allowance to use a specific electricity or district heating provider mix, Denmark provides generic emission factors for electricity, district heating, and gas, and Boverket proposes a similar approach for Sweden and 2027 requirements. Methods can however include specific rules for cases where the building occupant is known or if a long-term contract exists with an energy provider. For example, one of the Swiss methods (2,000-Watt society) considers the specific mix of a known provider but only for 50% of the total consumption in order to account for the risk that this situation may change during the actual building use. The inclusion of such rules is under investigation in Estonia.

2.5 Exported Energy Calculation

With the promotion of on-sites renewables through the "solar mandate" under REPowerEU (Member States must ensure the deployment of suitable solar panel installations on new buildings), the importance of appropriate rules to account for the benefits of exported energy increases. According to the EPBD's definition, 'exported energy' means the proportion of the renewable energy generated on the building site that is exported to the energy grid instead of being used on-site for self-use or for other on-site uses (such as electric vehicle charging points). Rules for how renewable energy generated on-site is calculated and allocated to different uses are expected to be an important part of the revision of the EPBD. Member States should take necessary measures so that the benefits of maximising the use of renewable energy on-site, for the building and for other uses, are acknowledged and accounted for in the calculation methodology, taking into account current and future grid capacity.

Treatment of exported energy does not only involve decisions on how savings are allocated but also the supply chain impacts, which are the embodied impacts of the renewable energy systems. The revision of EN 15978, which is in progress, is expected to influence how the countries will adapt their approaches. EN 15978 contains proposals for how the export of energy generated on your own property can be reported in what is known as module D2. That is to say, the societal benefit generated by any net export from a building can be provided as separate information in module D. One argument in favour of including the reporting of exports of locally produced electricity is that this then provides a complete picture of the climate impact from the entire life cycle A–D. Broadly, there are currently three approaches (EBC Annex 72 report[48]):

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48. See: https://annex72.iea-ebc.org/Data/publications/B_Luetzkendorf%20et%20al%202022_Assessment%20Methods%20for%20Buildings_v2.pdf

- A share of the life cycle-based climate impact of on-site electricity production corresponding to the proportion of self-consumed electricity is accounted for in the building LCA. The rest of the impacts, corresponding to exported electricity, is accounted for in the electricity mix of the buyer of the electricity. This represents the "Step A" approach according to ISO 52'000-1 (clause 9.6.6) and is identical to approach B of the draft version of the revised EN 15978 standard.
- The total life cycle-based climate impact of the on-site renewable energy generating system is allocated to the building. The building LCA also includes the potentially avoided impacts from exporting electricity to the national grid (or e.g. future European mix). In the grid mix of the one purchasing the exported electricity, the exported electricity bears the environmental impacts of the national grid (or future European mix). This corresponds to Step B" approach according to ISO 52000-1 (clause 9.6.6) [49].
- The total life cycle-based climate impact of the on-site renewable energy generating system is allocated to the building, and potentially avoided impacts from electricity export are reported as additional information in module D2, which is outside of the building LCA boundaries and therefore not accounted for in the building LCA result contrarily to Approach 2. This is identical to Approach A of the draft version of the revised EN 15978 standard.

Level(s) in its current version supports the third approach where energy that is exported is reported under Module D. It also stated that the scenario for module B6 shall specify, on a per energy carrier basis, both the imported energy used to satisfy the specified demand and the energy that is exported. The scenario shall specify how the imported and exported energy flows are quantified (e.g. the energy generation estimates for the renewable energy technology, including the amount of energy produced on site and how much of this is exported).

In Denmark, the building regulation makes no distinction between self-consumed renewable energy and exported renewable energy. A limited amount of electricity production from renewable energy installations such as solar cells and wind turbines can be included under module B6, corresponding to a

49. It is important to stress that in this approach, the avoided impacts have to be evaluated according to an electricity mix which can either correspond to attributional LCA (average mix) or consequential LCA (marginal mix), using hourly, seasonal or annual time step, recent past or future mix etc.

reduction in the need for supplied energy of maximum 25 kWh/m²year. Finland declares exported energy as part of its carbon handprint (module D3).

In Sweden, Boverket's latest proposal suggests excluding the carbon emissions of the production of solar cells in the 2025 limit value, and only reporting them separately in the climate declarations from 2025 (see Table 9). This exclusion is motivated by the fact that the proposed limit values exclude operational energy, and therefore the benefits of on-site renewable electricity production would not be visible. Earlier, a requirement to report net exports of locally produced electricity had been introduced. However, it is no longer considered important, and Boverket has suggested cancelling it. The reasons mentioned are a desire to keep the climate declaration simple, and the fact that these export values would have to be based on assumptions and standard values rather than verifiable measurements, since the climate declaration must be submitted before the building is in operation.

2.6 Biogenic Carbon

The different perspectives on biogenic carbon consideration in LCA in the various countries can highly influence the climate impact outcome of building cases and the decisions and actions of some stakeholders. These implications are important since the competition between biogenic construction products and mineral products affects powerful industrial and economic actors (e.g. the forestry sector and the concrete industry) and potentially has profound implications for greenhouse gas emissions at the national level. Three distinct approaches are currently applied in European regulations: the 0/0 approach, the -1/+1 approach and the time-dependent approach[50]. The 0/0 approach considers a value of 0 for biogenic carbon in both modules A and C. The -1/+1 approach considers an uptake of carbon in module A (negative emissions, corresponding to plant growth) and a corresponding emission in module C (carbon leaving the building life cycle for being released to the atmosphere through waste process or transfer to next life cycle). The time-dependent approach accounts for the benefits of temporary or semi-permanent carbon storage in biogenic products. The first two approaches are applied in the Nordic countries, favouring one over another depending on the scope covered in the declaration and/or limit values (as seen in Table 12).

In Denmark, the already introduced building regulation applies the -1/+1 approach as part of the GWP-total indicator since the Danish industry climate

50. Ouellet-Plamondon, C. M., Ramseier, L., Balouktsi, M., Delem, L., Foliente, G., Francart, N., Garcia-Martinez, A., Hoxha, E., Lützkendorf, T., Nygaard Rasmussen, F., Peuportier, B., Butler, J., Birgisdottir, H., Dowdell, D., Dixit, M. K., Gomes, V., Gomes da Silva, M., Gómez de Cózar, J. C., Kjendseth Wiik, M., … Frischknecht, R. (2023). Carbon footprint assessment of a wood multi-residential building considering biogenic carbon. *Journal of Cleaner Production*, 404, 136834. https://doi.org/10.1016/j.jclepro.2023.136834

emission factors for biogenic products are still compliant with EN 15804 version A1, where only this GWP indicator is provided. GWP-total covers climate impact from land use (GWP-luluc), fossil fuels (GWP-fossil) and biogenic sources (GWP-bio). Data includes CO_2 removal in modules A1–A3 and emissions releases in modules C3-4 without separating between fossil and biogenic shares. Finland follows a similar approach with the difference that it additionally requires the reporting of the biogenic carbon as part of the carbon handprint (D4 Carbon storage effect). The Finnish legislation recommends using the national emission factors database CO2data.fi, which currently provides conservative and typical values for GWP-fossil and GWP-biogenic values separately. With the shift to EN 15804 version A2, Denmark is planning to provide separate values for biogenic carbon in its generic data to make their reporting possible.

On the other hand, Sweden, Norway and Estonia follow the 0/0 approach and consider neither fixation nor releases of biogenic carbon in any of the modules. Sweden and Norway require using the indicator GWP-GHG which accounts for emissions from land-use and fossil fuels, while Estonia proposes using GWP-GHG or GWP-fossil (which only includes emissions from fossil fuels). For the first two countries, the rationale is that they do not yet include end-of-life modules C3-4 in their scopes. The 0/0 approach is also adopted in the soon to be released science-based target (SBT) guidance for buildings as only upfront embodied carbon is covered[51]. In this approach, the challenge lies in the use of product-specific data sources pursuant to EN 15804 version A1. Although it is no longer possible to create new EPDs pursuant to EN 15804:A1 after late 2022, EPDs are generally valid for five years, therefore EN 15804:A1 EPDs will still be in the market until 2027. For Swedish and Norwegian legislations, it therefore is important for the GWP indicator to be reported in the data sources in a way that the exclusion of biogenic carbon from the construction product is possible.

51. See: https://sciencebasedtargets.org/resources/files/DRAFT_SBTI_Buildings_Guidance.pdf

Table 12 Handling of biogenic carbon in the Nordic countries (as of January 2024).

	Denmark BR18	**Estonia** Proposed climate declaration	**Finland** Proposed climate declaration	**Iceland** Proposal under development (2023)	Norway TEK17	**Sweden** Climate declaration 2022	**Sweden** Climate declaration 2027 (pro-posal)
How is biogenic carbon handled?	**-1/+1 method. GWP-total values are required by legislation.**	**0/0 method. GWP-fossil or GWP-GHG values will be required by legislation**	**-1/+1 method. GWP-total values are required by legislation. Biogenic carbon is included separately (as GWPbio indicator and in category D4 of carbon handprint)**	**-1/+1 method. GWP-total values will be required by legislation. Biogenic carbon to be included separately (as GWPbio indicator)**	**0/0 method. GWP-GHG values are required by legislation**	**0/0 method. GWP-GHG values are required by legislation**	**To align with upcoming EPBD provisions**
GWP-bio reported separately	Not yet, but soon (shift to EN 15804+A2)	No	**Yes (see above)**	**Yes (see above)**	No	No	No
GWP-luluc reported separately	Not yet, but soon (shift to EN 15804+A2)	No	**Yes**	**Yes**	No	No	No

The accounting method for biogenic carbon used in France is notably quite different. In France, the use of a simplified dynamic approach to climate impact calculation leads to negative whole life GWP values for a lot of biogenic materials. The dynamic approach applies weighting factors depending on when the impact will occur and hence puts a lower weight on impact generated in the future versus those created now, thereby considering the benefits of temporarily storing carbon in buildings. The coefficient varies from 1 (year 0) to 0.58 (year 50) for all types of products except for the coefficient for cooling agents released from technical systems (presents a lower variation from 1-0.88). For products for which the greater share of carbon emissions is taking place during the product stage (A1-3) such as concrete and steel, the choice between a static and a dynamic approach does not lead to great variations. Conversely, the dynamic approach significantly benefits biogenic products such as timber that have a low impact today due to sequestrated biogenic carbon and a (potentially) heavier impact in the future, if these products are incinerated.

The actual benefits of biogenic carbon storage are highly dependent on assumptions about the end of life of biogenic materials, as well as assumptions about the sustainability of forestry practices. The choice of accounting method for biogenic carbon, and in particular whether or not to consider the benefits of temporary or semi-permanent carbon storage in biogenic products, is in part a political decision.

2.7 Other Methodological Features

The expected change of carbon intensity of electricity, district heating and gas supplies will not only affect the carbon emissions associated with the operational energy consumption of a building but also the embodied emissions of future construction products and direct emissions from transport services and construction activities. Currently, climate declarations mostly focus on the influence of future energy supply on the impact of operational energy, but not on the other aspects. In addition to the energy sector, the construction product manufacturing industry is also anticipated to become cleaner, e.g. through change from fossil fuels to biogas or hydrogen, process optimisation and implementation of mitigation measures such as carbon capture and storage for process-related emissions. Furthermore, improvements in recycling rates of future construction products are also anticipated. Considering that replacements (B4) of some building products take place in 20-40 years from the moment a new building is constructed, adapted inventories for different time periods become relevant for some construction products[52].

These considerations are currently debated in Finland without a definitive decision yet. The FutureBuilt Zero voluntary method in Norway does consider these effects (Resch et al. 2022[53]). Particularly, this method follows a simplified approach, where: (a) a technology factor of 0.33 is assumed for the production of PV systems in year 30 (i.e. 2/3 reduction over 30 years); (b) for other material-related processes (production, transport and waste incineration) an 1% annual technology development is used, which is based on historical development in Norwegian industry. Therefore, the same development is assumed for all building materials, except for energy-producing equipment (solar cell systems) where the reduction can be assumed to be greater.

There is an ongoing discussion in society about carbon offsetting and removal measures and what could be part of a net zero building, especially when looking at balancing the whole life cycle emissions. At the moment, it is difficult to determine the type of allowable measures for this owed to the lack of consensus. Thus no Nordic country has established any rules for this aspect yet. With the proposed EU-wide framework to certify carbon removals generated in Europe[54], this discussion is expected to be intensified also in the Nordic countries.

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52. Alig, M., Frischknecht, R., Krebs, L., Ramseier, L., & Stolz, P. (2020). *LCA of climate friendly construction materials.* https://treeze.ch/fileadmin/user_upload/downloads/Publications/Case_Studies/Building_and_Construction/670_LCA_constructionMaterials_1.5C_v1.4.pdf
53. Resch, E., Wiik, M. K., Tellnes, L. G., Andresen, I., Selvig, E., & Stoknes, S. (2022, September). *FutureBuilt Zero-A simplified dynamic LCA method with requirements for low carbon emissions from buildings.* In IOP Conference Series: Earth and Environmental Science (Vol. 1078, No. 1, p. 012047). IOP Publishing.
54. https://climate.ec.europa.eu/eu-action/sustainable-carbon-cycles/carbon-removal-certification_en

3 Preconditions for Setting & Controlling Limit Values

This section provides more qualitative insights into the processes that lead to the adoption of LCA-based limit values in the Nordic countries, including the roles played by various stakeholder groups, pre-existing frameworks, supporting resources, as well as available tools and data to carry out the assessments. While parts of this section are supported by references, many of these insights are based on the experience of co-authors who have been involved in the reported activities processes, as well as input from experts from the Nordic countries.

3.1 Stakeholders Affected by Limit Values

Introducing the type of novel carbon regulation in question entails considerable challenges in the construction sector on many levels. Conventional construction activities with high carbon emissions are confronted with a new challenging performance indicator. This implies changes in building design, procurement, product development, marketing, collaboration, among many others. Before implementing new legislation, policymakers need to ensure that stakeholders are prepared and willing to follow the proposed path. This section provides an overview of the main actors concerned by the introduction of limit values, as well as important assets enabling LCA regulations, which are developed further in the rest of the chapter.

Stakeholders are affected differently depending on their engagement in buildings. Construction actors involved in the production of buildings on all levels manoeuvre in a regime where buildings are viewed as investment assets traded on a market. They are most likely to support decarbonisation policies when opportunities for decarbonisation are viewed greater than the related risks. Regarding the ongoing development of mandatory European climate declarations, supporting branch actors expect to benefit from a market advantage as frontrunners, especially for attracting international investment and delivering services abroad. For these actors, a harmonised method is crucial for achieving a market with fair competition about the most efficient low carbon solutions.

Developers are responsible for directing resources to different building projects. In recent years and with support from the EU Taxonomy, investors have started requiring a high environmental performance from projects in which they invest. Here, harmonised national requirements support common quality standards and allow transparent decision-making.

A third group of actors are clients. In the Nordic countries, they are mostly represented by branch organisations, social housing associations and public institutions. Public procurement often entails more ambitious requirements than the regular market. According to the revised EPBD proposal, only public buildings must be zero emission by 2027. Also, many state or municipal clients already set local sustainability requirements[55]. Some of these clients are interested in cultivating an image as green frontrunners for different reasons. Green public procurement is challenged by a lack of harmonised assessment methods and performance. Novel carbon regulations would likely lead to an escalation of public client requirements beyond the mandatory legal level. All EU and EFTA states have undergone a development of tightening energy efficiency requirements towards nearly zero energy by 2020 according to the EPBD. Public buildings had to achieve this level already by 2018. This has created a policy precedence for life cycle decarbonisation pathways.

In Denmark, a cost impact analysis has been performed in 2022 prior to the introduction of limit values in January 2023. The subsequent cost calculation for the 2025 revision has been published in the current limit values report[56]. Here, only cost related to consultancy is included, since the impact of the generous limit values on the construction cost is assumed insignificant. A detailed time consumption table for different building uses and scales has been developed for the first seven years after implementation, applying progression of competences and routines after higher initial cost. In year two, a cost increase between 0.2 and 1.7% of total cost is expected, dependent on building scale.

3.2 Acceptance, Readiness and Active Support from Stakeholders

Readiness and acceptance depend on each other, and on the relation between the current state of the national industry and the targeted ambition level of regulation. Regarding the acceptance of limit values by the industry, commercial actors thrive in fair market competition based on transparent and

55. Francart, N., Larsson, M., Malmqvist, T., Erlandsson, M., & Florell, J. (2019). Requirements set by Swedish municipalities to promote construction with low climate change impact. *Journal of Cleaner Production*, 208, 117–131. https://doi.org/10.1016/J.JCLEPRO.2018.10.053
Häkkinen, T. (2016). The role of municipalities in sustainable building – the Finnish experience.
56. Torzan et al. (2023). *Klimapåvirkning fra nybyggeri: Analytisk grundlag til fastlæggelse af ny LCA baseret grænseværdi for bygningers klimapåvirkning fra 2025.* BUILD Rapport 2023:21

harmonised rules for all. However, harmonisation by a trustworthy independent third party or legislation provides clear performance criteria for clients, which supports the possibility of demanding low carbon industry services, especially for investors and public clients. Harmonisation entails agreement by stakeholders on the calculation method, which includes questions about environmental data, tools and reporting format. The greatest stakeholder acceptance is achieved when all elements are covered by harmonisation. The foundation for this complex endeavour is often seen laid by voluntary schemes. The ideal last step towards legally binding requirements is an independent, critical evaluation of practical experiences of the voluntary scheme, where arguments for and against methodological decisions and expected impacts are made accessible to public debate for informing political decisions.

Readiness, in turn, is dependent on the level of required resources and competences. In a regime with simplified and harmonised LCA methods, available and verified tools and data, the required level of competence is rather low compared with a more open situation, in which many risky decisions have to be made and resources have to be selected and acquired. In Denmark, Finland, Sweden and Norway, a harmonised LCA method and national environmental data or EPDs were accessible early in the process. Building LCA tools have also become available in these countries, through different approaches. The basic preconditions for minimising the readiness threshold follow a similar track as earlier measures dealing with operational energy efficiency.

However, readiness can be improved further, and acceptance increased by providing active capacity building in the industry in terms of education and competences. For instance, Sweden, Norway and Denmark have organisations specialised in capacity building in the building sector. Some of these organisations overlap with national authorities. In all countries, a Green Building Council hosts green certification schemes and provides learning material and training courses. The availability of appropriate assessment tools and data, voluntary sustainability schemes and supporting resources for capacity building is therefore essential to ensure both readiness and acceptance. These aspects are considered further in the rest of this chapter.

Beyond acceptance and readiness, building industry actors with a high level of LCA competence have sometimes actively supported the introduction of mandatory LCA declarations and limit values, through direct advocacy and/or the use of LCA in flagship sustainable projects. While this driving role of industry actors is sometimes difficult to demonstrate, it can be seen more explicitly through a few examples. The Swedish Construction Federation and the Swedish Construction Industry's R&D fund (SBUF) supported and funded a particularly influential study on embodied carbon in buildings, which received considerable attention from public authorities and industry actors, and it contributed to a paradigm shift in the adoption of building LCA[57]. Support from SBUF enabled a much more direct knowledge transfer between academic experts and a network of industry actors, compared to previous academic projects[58]. Later, when the Swedish mandatory declaration was introduced, and Boverket proposed to introduce limit values in 2027, some industry professionals commented that limit values should be introduced earlier. In Denmark, a foundation linked with a construction product manufacturer provided Aalborg University's BUILD department with funding to develop the first public set of voluntary sustainability requirements in 2017. These voluntary requirements became the Danish voluntary sustainability class, which was funded by public authorities to prepare the introduction of mandatory LCA requirements. The preparation of the Danish mandatory declaration was therefore kick-started by an industry actor, funding an academic project, whose results were taken up and built upon by public authorities. Additionally, a public-private panel called "Climate Partnership" developed recommendations for the government in light of the new Climate Act in 2020. Both the voluntary sustainability class and the Climate Partnership contributed to the carbon regulation, and two new public-private partnerships are now supporting future revisions. In both the Swedish and Danish cases, considerable progress happened when industry and political interests aligned.

In Denmark, prior to the introduction of the voluntary sustainability class, representatives from the construction industry have published a proposal for voluntary requirements in the building regulation[59]. The proposal was meant to fill the gap of sustainability requirements, including carbon declarations, in the current regulation. A specific demand was to achieve more simple, focused and public requirements than available in voluntary certification schemes of private organisations. A precondition for the acceptance of LCA-based requirements is that such calculations should be so simple that it can be effectively used as a design driver in project development. Inappropriately high extra administrative burdens shall be avoided.

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57. IVA 2014 Klimatpåverkan från byggprocessen (Stockholm: IVA and Sveriges Byggindustrier)
58. Moncaster, A. M., & Malmqvist, T. (2020). *Reducing embodied impacts of buildings – insights from a social power analysis of the UK and Sweden.* IOP Conference Series: Earth and Environmental Science, 588, 032047. https://doi.org/10.1088/1755-1315/588/3/032047
59. InnoByg (2018). Frivillig Bæredygtighedsklasse i Bygningsreglementet – Oplæg fra Byggebranchen. See: https://www.innobyg.dk/om-innobyg/publikationer/frivillig-baeredygtighedsklasse-i-bygningsreglementet/

3.3 Supporting Resources for Competence Building

Before introducing regulation, it must be ensured that resources are available to actively support the capacity building of the industry in terms of voluntary sustainability schemes, free online resources and databases, as well as that compliant tools are in place (Table 13).

The existence of voluntary sustainability schemes including LCA is often a way to build up LCA competence in the building industry before the introduction of a mandatory declaration. Such voluntary schemes are sometimes explicitly introduced to prepare for an upcoming regulation. This is for instance the case of the voluntary sustainability class introduced in Denmark in 2020 (and e.g. the E+C- label in France). The voluntary sustainability class, an initiative of the construction industry, which was officially introduced by the Danish Traffic, Building and Housing Authority, was used between May 2020 and November 2023 in order to gather experience and prepare the introduction of mandatory LCA regulations. The scope of the voluntary sustainability class was very much debated, and some organisations were concerned about additional consulting cost for reporting. The final scope, which was more comprehensive than the DGNB standard at the time, was only made possible due to the existence of the freely available LCAbyg tool.

In other cases, pre-existing certifications played an important role in paving the way for the introduction of a mandatory declaration. This is for instance the case of the DGNB certification, which pioneered LCA in the Danish building sector in 2012, and the BREEAM certification used in Norway, Sweden (nationally adapted versions) and Iceland (international version). The most common green building certification in Sweden is Miljöbyggnad. Miljöbyggnad was introduced in 2011 by the Swedish GBC[60] and did not initially include criteria related to climate impact. However, after its 2017 update, a criterion related to embodied climate impacts became part of it. These voluntary schemes allow practitioners to get familiar with LCA concepts, methodologies, tools and data. In turn, this allows for a smoother implementation of mandatory declarations and limit values later on.

The development of LCA competence in the industry is also supported by free resources developed by public authorities or industry actors. In Denmark, the Knowledge Centre for Building Climate Impacts[61] provides tutorials and

60. Miljöbyggnad is based on the system "Miljöklassad byggnad" which was introduced earlier than 2011. The system changed its name after being handed over to SGBC
61. See: https://byggeriogklima.dk/

information on the LCA regulation and available tools, as well as webinars and a library of LCA case studies. The Knowledge Centre was founded by the Danish Authority of Social Services and Housing. It is driven by a consortium of private-sector actors and by BUILD, a department at Aalborg University, which has provided background analyses and policy advice for many decades. The Norwegian Green Building Alliance is operating a similar Knowledge Centre with guides, case studies and events[62] (the focus is broadly on sustainable buildings, including e.g. the EU Taxonomy, the BREEAM certification, etc.). FutureBuilt[63], and the research centres Zero Emission Neighborhoods (ZEN)[64] and Zero Emission Buildings (ZEB)[65] have also contributed to bringing forth new knowledge on what is needed in terms of emission reductions. Furthermore, Enova, owned by the Ministry of Climate and the Environment, provides economic support for climate mitigation initiatives, including in construction[66], while Miljødirektoratet also provides economic support to municipalities[67]. In Sweden, Boverket provides simple, short guides on LCA[68] and sustainable construction. Boverket also provides a handbook on climate declarations[69] for guidance about the regulation on climate declaration for buildings. The handbook consists of information on LCA calculations, e-learning, e-service to register a climate declaration, tutorials, e-service for supervision, news and the national climate emission factors database. Similarly, the Finnish Ministry of the Environment provides a number of guides and information pages on sustainable construction[70]. A collaboration between actors of the concrete industry, the building industry and researchers also developed a classification of "low-carbon concrete"[71].

62. See: https://byggalliansen.no/kunnskapssenter/publikasjoner/
63. See: https://www.futurebuilt.no/
64. See: https://fmezen.no/
65. See: http://www.zeb.no/index.php/no/
66. See: https://www.enova.no/om-enova/
67. See: https://www.miljodirektoratet.no/klimasats
68. See: https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/livscykelanalys/miljocertifieringssystem-och-lca/
69. See: https://www.boverket.se/klimatdeklaration
70. See: https://ym.fi/vahahiilinen-rakentaminen
71. See: https://ym.fi/vahahiilinen-rakentaminen

Table 13 Timeline of supporting resources for the limit values (non-exhaustive examples).

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Denmark		GBC		DGNB Denmark								Voluntary Sustainability Class		Knowledge Center	
Finland		GBC											Climate database		
Norway	FutureBuilt; FME ZEB	GBC		BREEAM-NOR				FME ZEN; Klimasats							
Sweden	GBC				BREEAM-SE				Miljöbyggnad (LCA inclusion)			NollCO2		Climate database	
Estonia				GBC										Climate database	
Iceland		GBC													

Supporting organization or programme (GBC = Green Building Council)
Voluntary certification
Online resource or database

In all Nordic countries, the national Green Building Councils pioneered LCA in the building sector and have been providing resources, education and certification services. The Councils in Sweden, Denmark, Iceland, Norway and Finland were all founded around 2009-2010, while the Estonian Green Building Council was founded in 2012 (but is currently on standby).

As importantly, the development of LCA competence also is supported by the introduction of university education of building LCA in most Nordic countries in recent years (for example, since 2018 in Finland).

3.4 Data on Buildings, Components and Climate Impact

An important precondition for the introduction of limit values is the availability of data to carry out the assessment. In particular, practitioners need access to environmental product declarations (EPDs) or generic environmental data for all building products. Table 14 provides an overview of the generic and EPD data availability in each Nordic country as of second half of 2023.

Most Nordic countries are in the process of establishing or building up a national database of generic emission factors to use alongside the climate declaration. Publishing national average database can act as a lever for building product manufacturers to publish their EPDs.

In Denmark, the German Ökobaudat database has historically played an important role as it constitutes the base for most of the generic environmental data used in Denmark. This was not the case in other Nordic countries.

However, Denmark recently developed its own generic emission factors for the most used 20-25 standard construction products in Danish new construction [72] to be integrated into an updated set of generic data in 2024. The provision of generic data is supported by a significant number of the currently available EPDs in Denmark that are digitalised for use in the LCA tool LCAbyg and are available in the XML-based ILCD+EPD format.

Sweden and Finland developed their generic emission factors databases jointly. In Sweden, IVL, an independent non-profit research centre focusing on environmental issues, was one of the first actors to develop an internal environmental database for construction products. IVL's data is based on an analysis of existing EPDs on the Swedish market. This became the basis for most of the environmental data in the national database hosted by Boverket since 2022. IVL is also the parent organisation for EPD International, who administers and operates the international EPD system. While Norway, Denmark and Finland all have dedicated website reporting EPDs in the country, Swedish EPDs are usually reported on the international EPD website, or on other Nordic EPD websites.

The Finnish background environmental database was published in March 2021. The emission factors are based primarily on a review of EPDs from Finland, as well as other Nordic countries and Germany (including Ökobaudat data). All environmental data is digitalised and can be linked to common programmes used in the building sector. Predominantly using the Finnish generic data as a base, and in combination with the OneClickLCA localisation methodology, Estonia has developed a first version of generic data in 2022 and is now being updated so that a new version is provided as a package with the official climate declaration method in late 2023/early 2024.

72. Kragh, J., & Birgisdottir, H. (2023). *Udvikling af dansk generisk LCA-data.* (1 udg.). BUILD Report 2023:16

Table 14 Climate emission factors data availability in the Nordic countries (as of January 2024).

		Denmark	Estonia	Finland	Iceland	Norway	Sweden
National generic data	**Availability/ name(s)**	**√ generic data (Table 7 in Appendix 2 of BR18)**	**(√)** generic national data published but not yet officially approved; updated version will accompany the national method	**√ CO2data.fi**	no national generic database for building products or other life cycle phases – under investigation	no national generic database for building products[1]	**√ Boverkets klimatdatabas**
	Date of release	Current database: December 2022 Updated database valid from 2025: December 2023	February 2022, update expected end of 2023/early 2024	March 2021, updated many times	2024/25	N/A	January 2022, updated in May 2022 and January 2023
	Accessibility	Open	Open	Open	Open	N/A	Open
	Conservative emission factors	Newdata: 75% percentile of values found in an EPD sample	20%	20%	25%	25% added only if not already included	25%, but not for energy and fuels
	Background data (for products)	Current generic data is based on Ökobaudat 2021 version and Danish branch EPD. National generic data is under development (on top of branch EPDs)	currently predominantly based on the Finnish national database (CO2data.fi) using OneClickLCA localisation methodology for Estonia; it will be updated and improved within the LifeIP project BuildEST.	predominantly based on databases such as RTS EPD, EPD Norge, Environdec, ÖkobauDat, IBU and ICE	under investigation	unknown if a generic database will be developed	based on studies from IVL Svenska miljöinstitutet (Swedish Environmental Research Institute). Values were derived by calculating mean values from existing EPDs on the Swedish market.
National EPD data	**Registered number**	≈400 EPDs, a tenfold increase since 2019	≈ 50 EPDs	≈ 350 EPDs	>5 EPDs and more underway	≈ 2,600 EPDs from over 350 companies	There is no national EPD database for Sweden. EPD's for Swedish products and suppliers are registered in different databases, such as EPD Norway or EPD International; a number cannot be defined.
	Availability of EN15804+A2 data	≈170	unknown, since there is no national EPD system in place; estimate: around 85% of EPDs by various manufacturers.	yes, some	yes, some	≈140	unknown, since there is no national EPD system in place
	Degree of digitalisation	Most EPDs in the Danish database are digitalised for use in the calculation programme LCAbyg. ≈ 140 Danish EPDs are available in Ecoplatform.	not yet, but planned	Everything is digitalised, and it is possible to link it to other programmes like Tekla. ≈ 160 Finnish EPDs are available in Ecoplatform	EPDs of Icelandic products thus far published at EPD Norge or The International EPD System, thus available in Ecoplatform	≈ 1020 Norwegian EPDs are available in Ecoplatform	≈ 387 Swedish EPDs are available in Ecoplatform

Norway currently has no national database of generic emission factors for construction in place. The climate declaration is supported by the great number of digitalised Norwegian EPDs available. To assist early design stages, the closest to a national generic database is the maximum recommended values for GHG emissions for generic products by the Norwegian GBC as part of a series of guidelines for selecting materials.

It is common practice to include conservative values in the database. This is for instance a way to incentivise the use of specific data rather than generic data. For instance, Swedish values for materials represent an average of EPDs found on the Swedish market for each type of product, plus a conservative factor of 25%. Finland and Estonia use a similar approach but with a 20% conservative factor. Conversely, the Danish environmental database under development is based on the 75% percentile of values found in an EPD sample, rather than a corrected average[73]. Although Norway has no national generic database, it applies a 25% factor when generic data from other countries are used not already being conservative. It is important to ensure the development and availability of EPDs, to create a real incentive to use EPDs rather than generic environmental data. If the limit value is too easy to reach even when using only conservative generic data, there will be no incentive for the development of EPDs. Alternatively, if EPDs lack for some types of products, and all practitioners are forced to use conservative generic data, this risks artificially inflating all LCA results. This could give the impression that the limit value is harder to reach than it actually is, thereby slowing down efforts to tighten it. As EPDs become broadly available, limit values should therefore be set based on the assumption that practitioners will be using EPDs rather than conservative generic data.

Similarly, assumptions about the service lives of building components play an important role in climate declarations, but a systematic comparison of these assumptions between countries is difficult. Different countries have different ways of describing and **classifying building components** and different ways of attributing service lives. Sweden assigns a single technical service life for each product in the generic environmental database. The values are simple approximations (e.g. "> 50 years", "< 40 years", etc.), but it should be noted that service life values are not needed for the current climate declaration since replacement is not included. Boverket has suggested to expand the climate emission factors database with more information on maintenance and replacement, if the climate declaration is to be expanded to include these

73. Kragh, J., & Birgisdottir, H. (2023). *Udvikling af dansk generisk LCA-data.* (1 udg.). BUILD Report

processes in 2027[74]. Finland provides a short and normal service life value for various building parts, along with cases in which the short value should be used. For example, all floors and ceiling surfaces have a normal service life of 30 and 50 years, respectively, but in non-residential buildings, they should use short service lives of 20 and 30 years respectively[75]. This is meant to account for a higher wear-and-tear in e.g. shopping malls, schools, etc. Even more granular, Denmark assigns service life values depending on where the product is located in the building: a service life is determined by cross-referencing a material type (e.g. timber, stone, concrete, etc.) with the type of building part or element in which it is used (e.g. internal walls, external walls, stairs, etc.)[76]. Finally, in Norway, the Building Authority's guidance document suggests several sources for product service lives[77]. However, based on the findings from a report commissioned by the Norwegian Building Authority[78] that suggests that the use of varied sources for service lives for building products causes variations in climate impact results, the committee responsible for revising the Norwegian national standard for greenhouse calculations for buildings (NS 3720:2018) has initiated work to publish harmonised reference service life values among other revisions by summer 2024. It should be noted that the EU framework Level(s) also includes a table of suggested service life values. It is possible that service life values and the way they are described (e.g. per material, product or building part) will become more harmonised at the EU level.

3.5 Availability of Assessment Tools

Besides background environmental databases, the development of national building LCA tools has been critical to the adoption of LCA in the industry. In the Nordic countries, with regulation already in place, like Denmark, Norway and Sweden, any tool can be used to perform the LCA declaration as long as the calculations are carried out with climate emission factors compliant with the rules in the climate declaration and as long as all requested information is included in the declaration. In Denmark, the most commonly used tool so far has been LCAbyg, a freely available tool developed by Aalborg University's Department of the Built Environment (BUILD) since 2015. LCAbyg is, by design,

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74. Boverket (2023). Limit values for climate impact from buildings and an expanded climate declaration. REPORT 2023:24. Swedish National Board of Housing, Building and Planning
75. See: https://co2data.fi/rakentaminen/
76. See: https://build.dk/Pages/BUILD-levetidstabel.aspx
77. See pg 49: https://www.dibk.no/byggtekniske-omrader/veileder-om-klimagassregnskap/Veileder%20for%20utarbeidelse%20av%20klimagassregnskap_august%202023.pdf
78. See: https://www.dibk.no/verktoy-og-veivisere/rapporter-og-publikasjoner/klimagassutslipp-fra-byggematerialer/Klimagassutslipp%20fra%20byggematerialer_Multiconsult_2023.pdf

compliant with the national LCA regulation (the research group behind LCAbyg is also providing recommendations for the national LCA declaration and limit values). LCAbyg has been a pivotal asset enabling the adoption of building LCA through a harmonised package of a calculation tool, generic data, calculation and reporting methods, and trainings for professionals. Other new tools have entered the market in 2023 following the introduction of the mandatory declaration and limit values. An overview of available tools in Denmark is provided by the knowledge centre[79]. At the moment, there is no official verification procedure. In 2024, an official calculation specification will be provided, to which the tool developers will have to commit.

In Sweden, IVL has developed a tool called Byggsektorns miljöberäkningsverktyg (BM – Building Sector Environmental Calculation Tool), which is compliant with the Swedish declaration. The tool is free, with paid licenses for advanced functionalities.

In Finland, the tool OneClickLCA has been very influential in the development and adoption of building LCA – both as a tool and as a private consulting company. OneClickLCA has been commissioned by the Finnish Ministry of the Environment to write reports e.g. on reference and limit values for building LCA. OneClickLCA is also very active in other countries, especially Nordic countries. For instance, OneClick LCA is one of the four tools mainly used in Norway[80]. The other options available in Norway include Reduzer (a tool developed at the Norwegian University of Science and Technology, NTNU), Holte SmartKalk Miljø and ISY Calcus (two calculation tools developed by private companies). Most mainstream building LCA tools available in Norway require paid licenses, except for LCAbyg Norway, the Norwegian version of the Danish tool LCAbyg.

Overall, it is interesting to note that some viable building LCA tools have been developed in academia and publicly funded (LCAbyg, Reduzer), others in public-private partnerships (BM, developed by IVL, which is owned by a foundation jointly established by the Swedish Government and Swedish industry), and yet others by private, for-profit companies (OneClickLCA, Holte, ISY). Some of these private companies, in particular OneClickLCA, have been influential in shaping building LCA practice and policies in the Nordic countries.

79. See: https://byggeriogklima.dk/viden/lca-vaerktoejer/
80. See: https://pub.norden.org/us2023-463/appendix-building-lca-and-bim-practices-in-norway.html

About this Publication

Harmonised Carbon Limit Values for Buildings in Nordic Countries: Analysis of the Different Regulatory Needs

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