Nordic Innovation

Decarbonisation of the building stock

Contents

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Preface

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

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

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

- Work package 1 – Nordic Harmonisation of Life Cycle Assessment
- Work package 2 – Circular Business Models and Procurement
- Work package 3 – Sustainable Construction Materials and Architecture
- Work package 4 – Emission-free Construction Sites
- Work package 5 – Programme Secretariat and Capacity-Building Activities for Increased Reuse of Construction Materials

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The work has been carried out by SWECO, BUILD – AALBORG UNIVERSITY, LCA Support, and EFLA. And with inputs from a large group of experts from the Nordic countries and Estonia.

All views, interpretations, and recommendations are made by the authors and represent no official statements.

Nordic Sustainable Construction

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

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Summary

Policy initiatives to decarbonise the European building sector are gaining momentum. The Regulations for Construction Products (CPR) and Ecodesign for Sustainable Products (ESPR) regulate product-level environmental information, and the Taxonomy for Sustainable Investments provides criteria to classify assets as "sustainable". Simultaneously, the revised Energy Performance of Building Directive (EPBD) includes mandatory climate impact declarations for buildings greater than 1,000 m^2 in 2028, and all buildings in 2030. By 2027, 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. Within Europe, the Nordic region has long been a pioneer for building climate impact assessment and mitigation. A legal framework for disclosing life-cycle greenhouse gases (GHG) emissions, with or without limit values, is planned to be introduced in all Nordic countries by 2026. This means that all Nordic countries will likely have had at least two years of experience with mandatory national life-cycle regulation before the expected implementation of the revised EPBD. With Denmark issuing the earliest limit values in 2023, Sweden and Finland with plans to follow by 2026 and Iceland in 2028, all Nordic countries are proactively implementing policies to regulate buildings' climate impact and decarbonise the building stock. By analysing and comparing their respective approaches, this report draws from the Nordic countries' experience to provide recommendations for the harmonisation of decarbonisation policies, and the implementation of such policies in other countries.

The ability to monitor and understand building stock carbon emissions is an essential prerequisite for effective decarbonisation policies. At national and sectoral level, input-output analyses and the System of Environmental-Economic Accounting (SEEA) provide insights into overall emission trends and a comprehensive account of all emissions happening today, albeit with a low level of detail. Such accounts are essential for formulating national reduction strategies and targets, allocating resources to high-priority policy areas, evaluating the effectiveness of policy interventions, and monitoring

progress towards environmental objectives. While accounting per economic sector does not typically allow for an easy monitoring of the building stock, Sweden has implemented a model accounting for emissions in the construction and real estate sector with a life cycle perspective that cover the entire building stock. At the building level, the life-cycle assessment (LCA) offers granular insights into emission hotspots in the building's entire upstream and downstream value chain, to inform targeted design interventions and set building-level performance targets. Two approaches can be used to aggregate building-level LCA results and provide macro-level insights for the entire stock. The archetype approach uses a small number of representative buildings, based on theoretical models or real cases, and is useful with insufficient real-case data. Conversely, the sampling approach relies on the statistical analysis of a sample of building LCA case studies, which requires a sufficiently large representative sample. Both approaches can provide a broad understanding of building climate impacts, but aggregating their results may not match national and sectoral accounts due to truncation gaps. Eventually, efficient building stock monitoring will require setting up a digital infrastructure to gather and analyse carbon declarations for new buildings. Sweden is currently the only Nordic country that has established a mandatory digital data reporting format and a database infrastructure for handling the data from carbon declarations. There are multiple registries and databases in the Nordic countries that provide relevant building information, but their content varies significantly. Available information on the building stock is not harmonised between countries and requires drawing from multiple different databases within each country. These differences complicate comparisons and modelling across countries.

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The strategies adopted by Nordic countries in the implementation of limit values differ in several respects. Regarding the coverage of carbon limit values, particular building types or sizes might be excluded, and different building types may have different limit values. The pace of the respective decarbonisation strategies (initial limit value and trajectory for its future revision) also differs. Denmark at first introduced a single limit value for all buildings exceeding 1,000 m^2, with an easily achievable initial level, followed by a planned biennial revision. Based on the experiences gained from this initial limit value introduction, updated limit values, differentiated by building type and covering 85% of new construction in terms of building types and sizes, will be valid from July 2025. Sweden initially introduced a mandatory declaration without a limit value, which will be followed from July 2025 with ambitious limit values differentiated by building type, updated every five years.

Multiple differences are also apparent in the life cycle assessment (LCA) methods used in each country. As a result, comparing assessments becomes more challenging, but there are numerous opportunities for harmonisation. The most important methodological differences relate to:

- **Covered assessment scope:** the required scope for a declaration and a limit value may differ as a declaration can drive learning and include a more extended scope, while a strict limit value requires higher assessment quality and precision to ensure robust compliance with the regulation. Regarding building parts, the inclusion or exclusion of deep foundations, soil stabilisation, external works, internal finishes, fixed furniture and building services causes considerable variability. According to the revised EPBD, Level(s), which is currently undergoing some updates, will set the minimum requirements for the building model scope at least for the mandatory climate declarations from 2028, which might be further specified in a Delegated Act. It is unclear whether the binding carbon limits should be subject to the same minimum scope as declarations when they are introduced on an EU level in 2030. The definition and inclusion or exclusion or elements in the limit value scope may have an impact on the localisation of a new build. Thus, we find that particularly deep foundations and external works are aspects that warrant consideration with more detailed clauses in further updates of Level(s). In relation to the covered life cycle modules, most current declarations and limit values exclude some modules of the life cycle. A striking example is the Swedish declaration, which explicitly focuses on upfront embodied carbon (module A) in its first implementation. However, some countries have already planned to expand this scope, which also aligns with EPBD's requirement for a full life cycle scope disclosure from 2028.
- **Building floor area definition:** national floor area definitions differ in whether they include basements, balconies, circulation areas and external wall thickness. The EPBD and Level(s) framework use the notion of "useful floor area", not yet used in any Nordic national framework.
- **Treatment of exported energy:** The allocation of impacts and benefits from exported onsite energy production is expected to have two options according to the EN 15978 revision. The Nordics and Estonia can achieve harmonisation by choosing a common option.
- **Biogenic carbon reporting:** Among the countries with a carbon declaration already in place, Sweden and Norway explicitly exclude biogenic emissions from the scope of the declaration, as they do not include C modules (end-of-life stage), while Denmark includes them (showing a negative value in module A and a corresponding positive value in module C). This is primarily a matter of transparency, as the total life cycle impact is similar (in the absence of discounting factors). However, it is unclear whether the Nordic countries will decide to introduce biogenic carbon reporting as separate information in future revisions of declaration methods, and whether this will be an aspect also addressed in the Delegated Act expected by mid of 2025. The revised EPBD text state that information on carbon removals associated with the

temporary storage of carbon in or on buildings along the life cycle global warming potential (GWP) indicator may be declared in the energy efficiency certificate (see EPBD, Annex V).

- **Which future scenario(s) are considered for modules B and C:** it is common to include a decarbonisation scenario for the energy mix in module B6, but assumptions taken as part of this scenario can affect the assessment results considerably. No Nordic national method considers future scenarios for the embodied part of B and C stages, but these have been considered in other initiatives. Relatedly, discounting factors can also be used to give a higher weight to emissions the earlier they happen, which considerably favours temporary biogenic carbon storage. Although this approach is not used in the Nordics, the French national method implements it.
- **Definition of conservative standard values for building systems and generic values for products:** considerable differences are found between the various Nordic databases of generic product emission factors. Some of these differences can reflect actual differences in the supply chains of products used in each national market, but differences can partly be explained by how conservative generic factors are defined. For instance, Estonia and Finland use the average of a product sample plus 20%, Norway and Sweden use a 25% factor, and Denmark uses the upper quartile of an EPD sample instead.

As for bottom-up building stock monitoring, the level of national limit values for buildings' GWP can be derived from LCA cases using an archetype approach or a sampling approach. It is particularly important to use a building sample that is representative of new construction to be able to draw reliable conclusions. Limit values can be defined as the X% percentile of the sample results, thus defining a certain share of current projects which would have to alter their design or material choice to meet the target. This is the rationale followed in Denmark, where the initial limit value was set as the 90th percentile of a building sample (i.e., 1/10 buildings must perform better), and the updated value for 2025 corresponds to the 15th percentile of an updated representative sample (i.e. 17/20 buildings must perform better). Considering that the recently established limits for 2025 are already within the range of current good practices, the latest agreement suggests that the limits for 2027 and 2029 will be lowered by approximately 10% compared to the previous limits, until more data is available regarding the impact of regulation.

The introduction and tightening of carbon limit values may have various complex economic, social and environmental consequences that require careful consideration. One direct consequence is the change in design and material choices in building projects. As limit values become stricter, optimised versions of conventional products will need to be developed, such as using alternative binders in concrete and changing production processes. However, if limit values are set too low to be achieved with optimised products, designers will have to alter the building designs. This can entail avoiding balconies or making changes to interior layouts. Importantly, there may be a shift towards using alternative materials, particularly bio-based materials, and an increase in timber construction if mineral materials cannot be sufficiently decarbonised. This has potential consequences for architectural identity, as well as for environmental indicators other than climate change, although data quality was found to be too low to draw robust conclusions for other impact categories. Importantly, to address the increased demand for wood products complementary policies and incentives are needed to mitigate potential adverse effects on land use, biodiversity and forest carbon storage. Efficient use of wood in construction would entail a cascading use of wood products, prioritising the use of timber in high-value engineered products and ensuring the possibility of future reuse and recycling by using reversible joints and non-chemical connections. Incineration should only be considered as a last resort. This should be combined with sufficiency measures on the demand side in order to avoid unnecessary material use. Finally, such changes also carry socio-economic implications, including potential cost increases in development projects and fluctuations in economic activity for construction material suppliers. For example, in Denmark, it is estimated that the construction cost for reducing the climate impacts of typical buildings to comply with the tighter limit values to be in effect in 2025 will lead to an increase of DKK 220/m^2 (i.e. EUR 30/m^2). The socio-economic consequences of such policy proposals must therefore be assessed on a case-by-case basis, and complementary measures to secure stakeholder support might play an important role when developing decarbonisation policies.

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Recommendations

The recommendations are divided into two parts:

(A) Preparing and harmonising carbon limit regulations: The introduction of carbon limits for new construction is a key strategy to decarbonise the building stock. The recommendations in Part A address the content of such regulations and the process of setting them, based on experience gained from the Nordic countries with carbon limit values. It is also acknowledged that differences in methodological approaches between carbon declarations and limit values may significantly affect results and reduce comparability. Learning from the existing Nordic methods, there are aspects that offer opportunities for harmonisation, and are addressed in Part A recommendations.

(B) Monitoring building stock carbon: Monitoring the carbon emissions related to the developing building stock is instrumental in decarbonising the building stock. A harmonised Nordic approach to monitoring would allow for comparison of decarbonisation trajectory. This can facilitate knowledge-sharing and cross-country collaboration for reducing emissions from the building stock.

(A) Preparing and harmonising carbon limit regulations

Variable	Findings	Recommendation	Stakeholder
Subject of the recommendation	**Description of the findings that lead to an actionable recommendation**	**The recommendation described**	**Stakeholder to act and affected stakeholders**
Capacity development	Academic and professional education as well as voluntary declaration schemes help building competences throughout the value chain. There are several national and international examples [1] (European Commission, 2023) and (Skills4Reuse, n.d.).	Existing and emerging international learning resources must be adapted to national contexts. Frontrunner competition must be fostered through certification schemes.	**Acting**: Academia, Industry
Stakeholder engagement	The Nordic Sustainable Construction Platform provides an overview of Nordic initiatives in this area (see also Table 5)	Consultation groups and public-private partnerships between must be formed for co-developing roadmaps, balancing current readiness with future innovation requirements and for monitoring and revisiting regulation.	**Acting**: Authorities, Policymakers, Industry Affected: All
Generic data	**Generic impact data for products and processes:** The CPR is making environmental product declarations mandatory for an increasing number of product groups in the future. However, EPDs are currently lacking for numerous construction products. In the meanwhile, generic data with conservative factors is being provided for ensuring design-stage decision support, compliant as-built assessments, while maintaining incentives for an increase in developing voluntary EPDs. Most Nordic countries have developed such national generic data (Section 4.2, Table 14). Variation in current national generic emission factors affect results considerably (Figure 14). Some of the differences between generic emission factors rely on actual product differences in national markets and eventually from import. Remaining differences must root in varying assumptions and methods.	Generic impact data for products and processes must be provided for filling data gaps allowing modelling complete inventories independently of the availability of EPDs. These data must not be allowed for use in as-built declarations, when specific data will be available for the respective product groups. In the meantime, and until sufficient specific data is in place for all product groups, a gradual phasing out of the conservativity factor in generic data should be strived for to reduce the risk of not following the real performance of the building stock. The structure and content of national generic emission factor databases can be aligned, including which product categories are used, and how conservative factors are defined. More recommendations are provided in the Nordic report on data needs and scenarios-setting by (Erlandsson, et al., 2024)	**Acting:** Authorities, Academia, industry Affected: Consultants, Designers
	Generic impact data for modules: Finland and **Iceland** provide generic impact data for life cycle modules, such as A4, A5, C1 and C2, for bridging the current lack of specific data. Iceland also allows the use of average data on energy demand in module B6 (Section 4.2, Table 14).	Generic impact data for certain modules would remove the effort and uncertainty for the industry to provide whole life assessments. However, carbon limits must only include specifically reported modules to ensure the decarbonisation steering effect.	
	Generic product service lives: The Nordics apply varying degrees of differentiation of table values from uniform to a differentiation after exposure, quality, or location in the building. There is the possibility of a potential EU harmonisation (Section 4.2).	National service life tables should apply a harmonised structure and evaluation criteria, securing adaptation to regional conditions such as climate. Developing common standards, which remove differences in the status of building products in varying regulation regimes increases consistency and improves fair competition. As for common service lives standards this is also a good preparation towards including maintenance in the scope.	

1. National examples are Denmark's Knowledge Centre for Building Climate Impacts (Videnscenter om Bygningers Klimapåvirkning, n.d.), the new portal by Iceland's Housing and Infrastructure Agency (Húsnæðis- og mannvirkjastofnun, n.d.), the Finnish Ministry of the Environment's information pages on sustainable construction, as well as Boverket's information pages and guides in Sweden. See more information in the report: (Balouktsi, Francart, & Kanafani, 2024)

	Generic inventory data for components: Most Nordic countries provide conservative inventory data for building components and systems to support the implementation of carbon assessments and early design decisions. An example is building services (**Section 4.2**, **Table 14**). Authority or other actors can provide standard values and built-ups, however, the issue is what standard solutions can be used directly in carbon declarations, and what deviations are allowed between standard and as-built solutions. (**Section 4.2**).	Generic components should be provided at the introduction of carbon limits when the industry is still lacking template data. It must be defined whether generic components may be used for as-built reporting.	
EPD availability & accessibility	The currently high costs for developing EPDs are a barrier for small suppliers and for covering a larger range of product variation. Industry associations like Swedish Concrete, Swedish Wood and Danish Concrete provide EPD generators for all branch members (**Section 4.4.6**, **Table 15**).	EPD data must be accessible in a digital, structured and exchangeable format for improving feasibility. This is in line with the requirement that product information must be transmitted digitally by means of a Digital Product Passport (DPP) under both CPR and ESPR legislations. Subsidies or automated tools designed to generate EPDs can help support small enterprises.	**Acting:** Authorities, EPD Programme Operators Affected: Product Manufacturers
Carbon limit structure	There is not a standardised approach for selecting and analysing reference data for deriving carbon limits. Limit values are based on a building stock analysis by either using a larger representative building case sample or by breaking down the building stock into few representative archetype models. Archetypes require a certain case sample as well and are also useful for simulating the carbon reduction potential (**Section 4.3.5**).	Limit values must be derived from a large statistical sample of building cases, which represent the building stock in relation to the limit values for certain building types. The statistical approach is useful for introducing limit values in a feasible manner. Alternatively, limit values can be derived from distinct archetype models, which represent the building stock. Archetypes are useful for understanding the variation in carbon impacts and the thresholds for reducing them. Archetypes are useful for more advanced studies of carbon mitigation and the efforts required to achieve certain limit levels.	**Acting:** Academia, authorities
	The EPBD requires limit value roadmaps differentiated for building type and climate zone. All Nordic countries apply building use or function for differentiating limit values, even though many other parameters can cause variation in building carbon impacts, including location, building geometry or construction method. In Denmark, some of the justified variation is being balanced by providing an allowance for components with extraordinarily high climate impacts (**Section 2.4.2**). Also, the construction process (modules A4, A5), as a location-sensitive parameter, has been agreed to be regulated with an individual limit value from 2025	Systematic variation in building properties can be addressed by differentiated limit values, while unavoidable variation can be balanced through exemption criteria. Due to the complex nature of construction, the steering effect of limit value differentiation must be considered carefully and monitored over time.	

	Due to the delay in necessary carbon reductions globally, upfront carbon reductions provide more immediate effects than long-term processes. Upfront carbon (modules A1-5) is both significantly high and provides the largest mitigation potential throughout the life cycle in energy efficient buildings. Three strategies for promoting upfront carbon mitigation are observed: 1. Initial focus exclusively on A1-5 (Sweden) or 2. Dynamic accounting of emissions over time, where today's emissions are assigned a higher weight than emissions in the future. 3. Dynamic emission factors for future process scenarios (i.e., operational energy, replacements or waste treatment) The Danish regulation includes dynamic emissions for energy supply, rendering their contribution to the overall impacts relatively small. On the contrary, only voluntary schemes are using dynamic emissions for other processes such as future product manufacturing. In general, the choice between static and dynamic factors influences the steering effect of regulation and should be considered carefully (**Section 4.3**).	Possible options to highlight upfront carbon reduction should be considered entailing the different influences on the steering effect of carbon limits: **An initial focus exclusively on A1-5** is an option for countries looking to quickly establish requirements in those phases where the market is more mature. The risk lies in that buildings may not be fully optimised if this is not accompanied by a clear indication of a long-term strategy considering the full life cycle. **A dual approach** with separate carbon limits for upfront modules and the whole life cycle increases immediate carbon reductions while also controlling long-term impacts. However, this added complexity may result in increased bureaucracy and challenges in effectively communicating the results. **Application of dynamic emission** factors for future scenarios leads to a significant decrease in the relevance of post-handover modules, which thus highlights upfront carbon. However, care should be taken to avoid applying overly optimistic scenarios that suggest minimal action is needed to lower the impact from the use stage poses. Additionally, applying such factors to future climate impacts from products with inherent carbon (biogenic and fossil) entails preparing GWP data for relevant disaggregation and increases calculation error risk. **Application of dynamic accounting over time** has the effect of increasing the influence of current emissions over future emissions. This approach results in negative impact values for wood products due to the lacking biogenic carbon neutrality (-1/ + <1), and provides incentives for using large amounts of wood, thus compromising an efficient use of renewable resources.	**Acting:** Policymakers Authorities Academia **Affected:** Consultants Designers Clients
Determination of method and limit value level	Introducing novel carbon regulations entail potentially far-reaching consequences. The construction sector has to adapt to the new regime implying new practices for planners, designers and contractors, but also for material suppliers and the rest of the supply chain (**Section 4.4**).	For allowing capacity building and increasing preparedness, carbon regulation methods and limit value levels should be implemented incrementally, and the steps be laid out on a long-term roadmap. A gradual expansion of life cycle scope and affected projects can be supported by stakeholder involvement and impact assessments.	**Acting:** Authorities, policymakers, industry Affected: All
	Currently the Nordics and Estonia employ different definitions of Global Warming Potential, where biogenic carbon is only included where end-of-life stage forms part of the scope. Harmonisation is expected to be achieved in the mid-term, as compliance with EPBD requires expanding to full life cycle scope. However, a module-by-module comparison will still not be feasible without the introduction of a separate biogenic carbon declaration. While the declaration of information on carbon removal associated with the temporary storage of carbon is only a suggestion in EPBD, at least the reporting of GWP-biogenic, and to the extent possible of the capability of products to temporarily store carbon, are essential requirements according to the CPR recast (**Section 4.2**).	Separate reporting of the amount of biogenic carbon stored in the building is advisable as it: - reflects the reality better and is crucial to understanding and tracking the amount of carbon withheld from the atmosphere over the building's lifetime or longer. - allows quantifying potential future benefits, such as continued storage of biogenic carbon if a building's life is extended or wood products are reused. - increases mutual compatibility and preparation for an extended version of the EPC certificate in line with EPBD's suggestion. On the other hand, reporting of additional information may add substantial workload to the process for both administration (creation of relevant generic data) and the industry.	**Acting:** Authorities, academia Affected: All
Building model	The inclusion or exclusion of deep foundations, soil stabilisation, external works, internal finishes, fixed furniture and building services causes considerable variability (**Section 4.3.1**).	The structure and level of detail of building models should be harmonised, or a Nordic mapping table for national classifications systems should be developed to automatically convert building inventories across countries. Eventually, classification and completeness will have to comply with overall principles given in Level(s).	**Acting:** Authorities, academia, industry Affected: All

Building reference area	Reference area is the functional unit for carbon assessments. Its definition varies in the Nordic countries. The expected mandatory usable floor area (UFA) stipulated in the revised EPBD may offer an opportunity for harmonisation (**Section 4.2**). However, the level of definition in the expected EPBD Delegated Act is not known yet.	Comparability of carbon calculations may be achieved by either introducing a harmonised Nordic definition of the usable floor area or by providing conversion factors between national definitions.	**Acting:** Authorities, academia, industry Affected: All
	Differences in Nordic reference areas affect the inclusion of external walls, basements, stairs, corridors and common facilities, rooftop terraces, balconies, and other areas outside the building enclosure, see (**Section 4.3.2**).	The influence of secondary spaces including basement, attic, external stairs/ramps and balconies should be analysed and a common definition for the inclusion of their area be considered.	
	Although all limit value definitions are based on a reference area, there are other ways of normalising LCA results, which provide alternative steering opportunities for carbon emissions, as discussed in the Nordic countries (**Section 4.2**).	Supplementary carbon metrics based on occupancy or users should be considered in order to incentivise an efficient use of space and support a sufficiency perspective.	
Carbon regulation for renovation	In Nordic countries, there is growing interest in assessing the climate impact of deep renovations. Sweden plans to incorporate deep renovation projects into its carbon declaration by 2027, following Norway's existing requirement. In most countries, discussions are ongoing, on the one hand, with concerns about the workload of building supervision and permit processes if renovations are included, and on the other hand, about impeding low-carbon innovations for renovations when excluding them, affecting national and EU carbon neutrality goals (**Section 2.4.2**).	Carbon regulation for renovations must avoid creating burdens for renovations with environmental benefits such as energy retrofits, life-extending renovations or use adjustments. A harmonised approach for a carbon declaration method for renovations should be developed, starting with deep renovations and repurposing. More research is needed to identify the environmental value of renovation and proposing regulative measures for mitigating carbon impacts.	**Acting:** Authorities, academia, Industry Affected: policymakers
Knowledge sharing through cases	Variation in current national generic emission factors in the Nordics affect impact results considerably (**Figure 14**). Some of the differences between generic emission factors rely on actual product differences in national markets and eventually from import. The other part of the differences comes from different assumptions and methods behind generic data.	In order to ensure that comparisons of building case results in the suggested Nordic case data base (see Part B of recommendations) are based on different building systems, technologies, and designs rather than potential methodological variations or non-representative product data, a thorough study and analysis should be carried out to compare emissions factors for materials and products in the Nordic region, including EPDs (as they also form the basis for the generic impact data).	**Acting:** Authorities, academia, construction product manufacturers Affected: EPD programme operators, consultants designers

(B) Monitoring building stock carbon

Variable	Findings	Recommendation	Stakeholder
Subject of the recommendation	**Description of the findings that lead to an actionable recommendation**	**The recommendation described**	**Stakeholder to act and affected stakeholders**
Carbon monitoring approach	The current carbon monitoring approach in the Nordic countries is based on national environmental accounts. None of the sectors in the national accounts sufficiently describe the GWP related to buildings directly (**Section 3.2**).	Monitor carbon emissions, related to the developing building stock, with a dual-level monitoring system in place: sectoral accounts based on already established national environmental accounting and building-level accounts based on life cycle assessment. The Swedish model for sectoral accounting can be introduced in other Nordic countries for a harmonised detailed sectoral monitoring approach.	**Acting:** Authorities, academia
Data collection New buildings	All Nordic countries has soon implemented mandatory climate declarations for new buildings. By aggregating data, climate declarations can be used to monitor the climate impact related to new buildings in building stock scale. Only one Nordic country (Sweden) has introduced a mandatory reporting format for collecting data from climate declarations and method for utilising it for building stock monitoring (**Section 3.3.1**).	A building-level monitoring approach needs to be established, including approaches to collect and analyse carbon declarations from new buildings. Sweden has introduced a method for collecting carbon declarations and disclosing data for new buildings, which can serve as inspiration for the other Nordic countries' authorities. Iceland has introduced a simple online submission format for carbon declarations which can also serve as inspiration for the other Nordic countries' authorities.	**Acting:** Authorities
Data collection Buildings-in-use	There are currently no available databases in the Nordic countries containing information on emissions from buildings in use (**Section 3.3.1**).	For a cost-effective and harmonised approach to building-level monitoring of emissions related to operational energy use, data from the EU building stock observatory with relevant emission factors could be utilised.	**Acting:** Authorities
Data collection Renovations	No countries have yet introduced mandatory climate declarations for renovations, but some are planning to in the coming year (**Section 2.4.2**). No other databases are available in the Nordic countries containing information that can be utilised to monitor emissions related to renovations (**Section 3.4.2**).	As for new buildings, climate declaration for renovations could be introduced to monitor the environmental impact from renovations (potentially starting with larger renovations)	**Acting:** Policymakers, authorities
Data collection Demolishing of buildings	There are currently no system or databases in place in the Nordic countries to directly monitor the emissions related to the processes from demolishing a building or taking down parts of a building (**Section 3.4.2**).	For building-level monitoring of emissions related to the demolishing of buildings, the data collection on the amount of construction waste divided in fractions could be utilised with emission factors for waste management. The quality of construction waste data should be considered for this approach.	**Acting:** Authorities
Data collection Reporting format	Sweden (mandatory), Iceland and Denmark (voluntary) have introduced a reporting format developed for each country's specific method (scope, area, building part etc.) (**Section 3.3.1**).	For a robust and harmonised reporting format, make sure that the format aligns with the future guidelines according to EPBD by reporting according to Level(s) (whole life cycle, and reporting of useful floor area).	**Acting:** Authorities

Dynamic variables for projections	Dynamic variables represent specific variables that are altered within a model to explore alternative scenarios of an input. To implement decarbonisation efforts into projection models it is important to implement dynamic variables (**Section 3.5**).	For projections of carbon emissions related to the development of the building stock consider dynamic variables such as: • Development of emissions factors for energy use (electricity, heating, cooling and gas) • Development of emissions factors for production of construction materials • Development in use of recycled construction material • Renovation rates • Building stock growth based on population • Building typology requirement change • Dwelling size development • Materiality and building characteristics change	**Acting:** Authorities

Reading guide

This report is structured into four chapters, each focusing on a different aspect of decarbonisation in the building sector within the EU and specifically the Nordic countries. Here is a guide to navigating through these chapters:

Chapter 1: Introduction

- Start with the introduction to understand the report's context and the pivotal role of the built environment in shaping a sustainable future.

Chapter 2: Decarbonisation policies and current state of carbon declaration and limit values for buildings in EU and the Nordic countries

- Read this chapter to gain an understanding of the landscape of decarbonisation policies that are currently in effect across the EU and the Nordic region.
- Familiarise yourself with the existing frameworks for carbon declaration and the limit values for new buildings. This will provide a baseline for comparing the approaches of different countries.

Chapter 3: Monitoring building stock carbon emissions

- In this chapter, explore the methods and systems used to monitor the carbon emissions of the building stock.
- Understand the importance of data collection, data analysis and reporting in tracking the progress of decarbonisation efforts.
- Learn about the challenges and considerations in creating a harmonised process for monitoring carbon.

Chapter 4: Development of carbon limit values

- This chapter delves into the process of developing carbon limit values for new buildings.
- Discover the factors that influence the setting of these limits, such as national conditions, climate, geography and market considerations.
- Examine the potential impacts of these limits on the construction industry.

In each chapter blue boxes, like this, will guide the reader to understand key messages. The recommendations provided in this report are summarised at the beginning of the report.

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1. Introduction

The built environment stands as a cornerstone of modern society, shaping the spaces where we live, work and interact. However, it also represents a significant source of carbon emissions, contributing to the pressing challenges of climate change. In the Nordic countries, the decarbonisation of the building stock has emerged as a critical pathway towards achieving national and international climate goals. Besides the essential carbon mitigation in existing buildings, the continuously added new buildings also provide a chance for decarbonisation and will be the focus of this report.

Limiting whole-life carbon emissions of buildings is a demand-side policy instrument for mitigating the carbon intensity of buildings across the value chain. While located at project level, indirect mitigation effects are desired to take place in the supply of construction products, energy and transport among others.

Today, countries apply different pathways and methods for building carbon declarations and limit values. A harmonised approach will remove barriers and unleash the potential for achieving greater and more cost-effective decarbonisation in the Nordic region. Common standards for carbon declarations will not only redirect financial investments towards green construction. It will also create a greater international marketplace for providers of construction services and innovation in low-carbon solutions, being key for achieving the EU climate-neutrality goal by 2050.

The primary purpose of this report is to exhibit the experiences and insights gathered from the Nordic countries in their journey towards decarbonisation, with the intention of serving as a blueprint for other nations. This report serves to highlight the opportunities and challenges related to harmonisation of approaches across borders. The collected information exhibits examples of how Nordic countries have specified Life Cycle Assessment (LCA) methods, carbon declarations and limit values, and different approaches for monitoring decarbonisation of the building. These examples can serve as inspiration for other countries and regions when developing and defining how to conduct assessments of carbon emissions from buildings and the building stock.

We acknowledge that this is a moving target and that policies at national and international level can develop and change quickly. Thus, this report is based on the information gathered up until June 2024. Focus has solely been on the policy instrument of national whole-life carbon limits for new buildings. It is however critical to acknowledge that numerous instruments are necessary for cutting construction carbon emissions. These include strategies such as building less, utilising buildings better, increasing operational energy efficiency in the existing stock and decarbonising energy supply systems, among others.

The report mainly focuses on two key aspects. First, it provides key insights and experiences from the implementation process in the Nordic countries, which will be valuable when introducing limit values in other countries; and second, it recommends a harmonised Nordic approach to carbon limits. This includes a proposal for aligning LCA methods to create a unified framework for evaluating the environmental impact of buildings. Furthermore, the report proposes a harmonised process for monitoring the carbon intensity of the developing building stock, which is essential for adjusting carbon limits and measuring the effectiveness of decarbonisation efforts.

The work described here does not attempt to define specific carbon limit levels, since such values are dependent on regional conditions such as climate, geography and markets and, thus, must be defined locally. Instead, the report seeks to guide authorities and stakeholders toward a mutual understanding of the preconditions and regulatory steering effect associated with carbon limits. This guidance is informed by the collective experiences and practices developed within the Nordic region over the recent years, with the ultimate goal of supporting the transition to a built environment with less environmental impact through informed and collaborative actions. Both authorities and stakeholders in the construction industry support the harmonisation of Nordic LCA methods and legislation. By harmonising methods, the industry can offer services and solutions across borders, which again will result in better and more cost-effective buildings. Harmonisation also supports a more efficient knowledge sharing and problem-solving among authorities which contribute to faster development and smoother implementation of more robust methods and regulation.

It is a call to action for continued cooperation and commitment to a more sustainable future, where the decarbonisation of the building stock plays a pivotal role in preserving our planet for future generations.

Photo: Nordic Sustainable Construction

2. Decarbonisation policies and current state of carbon declaration and limit values for buildings in EU and the Nordic countries

2.1 Decarbonisation goals and policies

This chapter provides a summary of the national GHG reduction goals defined by the Nordic countries. The goals presented in the tables are carbon reduction in 2030 and carbon neutrality by 2050 or before. The table highlights the targets set by the Nordic countries, as they work toward meeting international binding agreements such as the Paris agreement.

2.1.1 Carbon neutrality goals

Most of the Nordic countries are part of EU's Nationally Determined Contributions (NDC) or have made commitments to follow the same targets as outlined in the EU's NDC to the UNFCCC. The Nordic countries have all set goals to become carbon neutral by 2050 or before, following EU regulations. The goals relate to territorial emissions occurring within the country.

Sweden, Finland, Norway, Denmark and Iceland have accelerated the deadline. Denmark (Danish Energy Agency, n.d.) and Sweden (Swedish Civil Contingencies Agency, 2023) aim to become carbon neutral by 2045. Iceland intends to achieve carbon neutrality by 2040 (Government of Iceland, n.d.). Finland (State Treasury Republic of Finland, 2024) has set its sights on 2035 for carbon neutrality. Norway's target is to become climate neutral by 2030 (Norwegian Ministry of Climate and Environment, 2021) and aspires to become a low-emissions society by 2050, which involves reducing carbon emissions by

90% to 95% (Ministry of Energy and Ministry of Climate and Environment, 2020) from 1990 levels. Estonia is aiming for carbon neutrality in 2050 (Republic of Estonia Ministry of Climate, 2023).

All the countries are defining carbon neutrality as a balance between carbon emissions and the absorption of carbon from the atmosphere to carbon sinks. To achieve this, the greenhouse gas emissions must be offset by carbon sequestration. It is important to note that the countries' carbon neutrality goals are based on different reductions achievement goals. Not all the countries disclose the reduction goal for achieving carbon neutrality and simply defines it as the net zero balance between emission and absorption. Sweden is defining the neutrality goal in 2045 with a goal of reducing 1990 levels to 85% lower. Denmark is presenting an ambition of 110% carbon reduction in 2050 compared to 1990 levels. The Finnish climate change act is outlining a goal of 90-95% reduction in 2050 compared to 1990 levels (see **Table 1**).

Table 1. *Carbon neutrality goals. Dark green = carbon neutral target, Light green = carbon reduction*

	2030	2035	2040	2045	2050
Denmark					*110%**
Estonia					
Finland					*90-95%***
Iceland					
Norway					*90-95%****
Sweden				*85%*****	
EU					

**Denmark has an additional goal of 110% reduction compared to 1990 levels in 2050*
***Finland's Climate Change Act outlining a reduction target of 90-95% in 2050 compared to 1990 levels*
****Norway's definition: "low-emissions society" is outlined as 90-95% reduction in 2050 compared to 1990 levels*
*****Sweden's Climate neutral goals are based on a carbon reduction of 85% reduction in 2045 compared to 1990 levels.*

2.1.2 Immediate carbon reduction goals (2030 goals)

In line with the European Green Deal, most of the Nordic countries have introduced a reduction goal for greenhouse gases (GHG) by 2030. The percentage value of the goal varies across the different countries, however, none of the countries have set a goal below 50% (see **Table 2**). Norway has a goal of 50-55% reduction of emissions by 2030 compared to 1990 (UNFCCC, 2020). Denmark has made the goal to reduce GHG emissions by 70% in 2030 compared to 1990 (Danish Energy Agency, n.d.). Finland aims to reduce GHG emissions by 60% compared to 1990 levels (State Treasury Republic of Finland, 2024). Iceland aims to reduce GHG emissions by 55% in 2030 relative to 1990 (Government of Iceland - Ministry for the Environment and Natural Resources, 2021). Sweden aims to reduce GHG emissions by 63% in 2030 and 75% in 2040 compared to 1990 levels (Swedish Civil Contingencies Agency, 2023). Estonia has no current target for 2030. However, the country has set a target to decrease emissions by 80% by 2035 (Republic of Estonia Ministry of Climate, 2023). Again, all goals relate to territorial emissions within national borders in accordance with IPCC's methodology for governments to estimate their GHG emissions and removals.

Table 2. *Immediate carbon emission reduction goals (2030-goals)*

	2030	2035	2040	2045	2050
Denmark	70%				
Estonia		80%*			
Finland	60%				
Iceland	55%				
Norway	50-55%				
Sweden	63%		*75%***		
EU	40%				

** Estonia's goal is in 2035 instead of 2030*

***In addition to the 2030 goal, Sweden have introduced a 2040 goal*

Photo: Nordic Sustainable Construction

2.1.3 Relation between national emissions reduction and carbon limit values for buildings

Introducing building-specific carbon limit values in regulations aligns with the national emission reduction goals by targeting emissions from the built environment, which accounts for a significant portion of total emissions in many countries. Building-level GHG accounting with LCA relies on fundamentally different accounting principles than national-level reporting based on Systems of Environmental-Economic Accounting (SEEA) (see illustrative example in Figure 1). LCA relies on material and energy flows while SEEA relies on economic data and national reduction goals and usually take a territorial perspective whereas LCA uses a consumption perspective. Therefore, building-level targets cannot easily be compared with national reduction goals. Still, LCA-based building-level targets create a direct push towards decarbonisation in the building sector, which ultimately contributes to fulfilling national reduction targets.

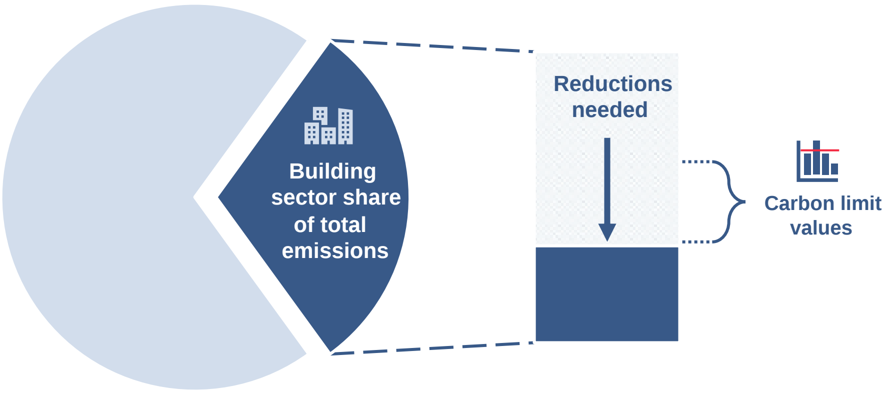


Figure 1. *Carbon accounting in building LCA and national reporting methods are two different frameworks whose accounting principles do not align. They are not comparable, but building-level carbon limit values act as a direct tool to ensure that the construction of new buildings is in line with overall decarbonisation efforts in national objectives.*

2.2 Dynamics of the building stock

Decarbonisation of the building stock refers to the systematic reduction of carbon emissions associated with buildings over time. To effectively address decarbonisation, it is essential to understand the elements in the development of the building stock over time, here referred to as the dynamic of the building stock. This includes the categories: new buildings, buildings in use and renovations and demolitions, that are presented in Figure 2.

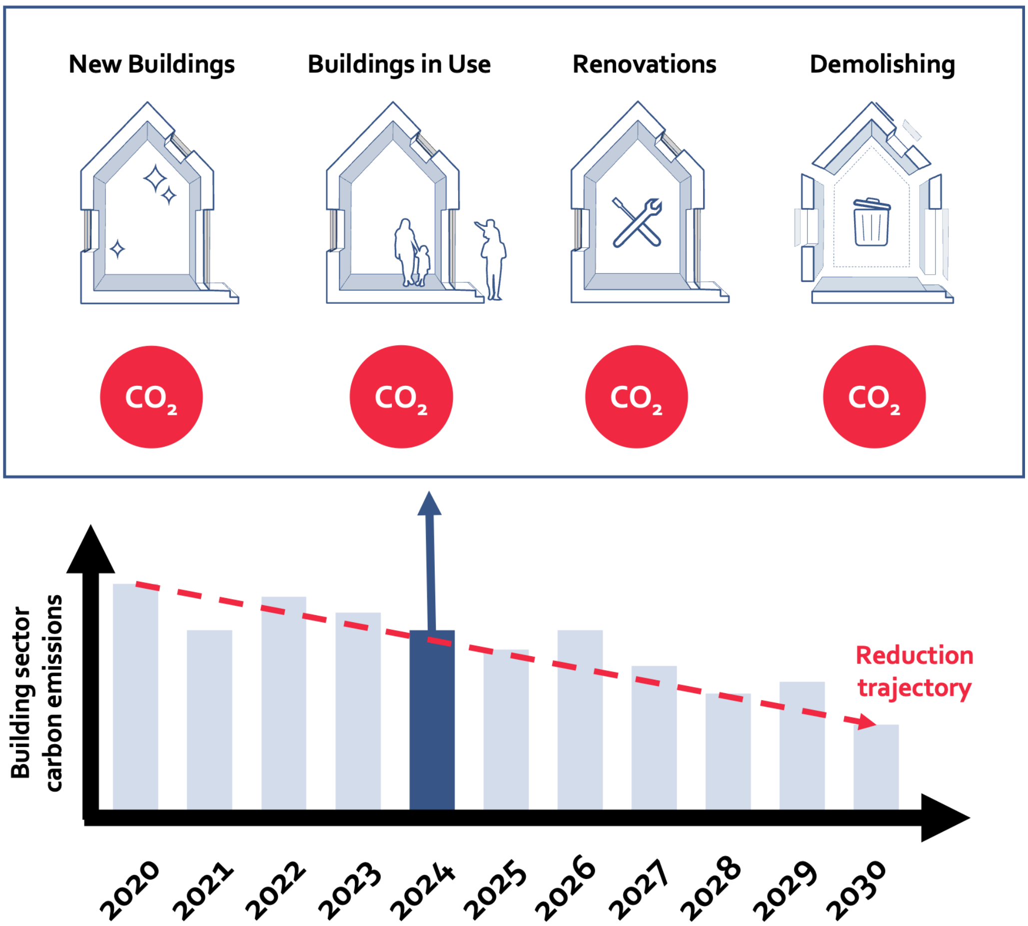
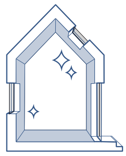


Figure 2. *Elements in the building stock dynamic affecting the carbon emissions associated with buildings over time. The figure is illustrative and does not reflect the actual carbon emission level.*

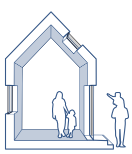


New buildings

The number of new buildings constructed and their design are key determining factors for the building sector's climate impact in the short and long term. It is essential to address new construction both from an efficiency and a sufficiency point of view. New construction should be carefully planned and monitored to ensure that it is carried out where it is truly necessary.

Immediate implications: The creation of new buildings involves the extraction, production and transportation of materials, which collectively contribute to the building's embodied carbon. Construction processes also generate emissions.

Long-term implications: Once constructed, new buildings determine the operational emissions for decades to come. Their energy consumption for heating, cooling, lighting and power is a critical aspect of the building stock's overall carbon footprint. Incorporating renewable energy sources, high-efficiency systems and smart building technologies can significantly reduce these operational emissions. Design for flexibility, adaptability and disassembly can help decrease future refurbishment needs. The building design and material selection will also lead to different future needs for repair and replacement of materials over the building's lifetime.

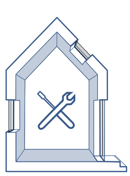


Buildings in use

The ongoing use of buildings is the most significant source of carbon emissions within the building stock, predominantly due to energy consumption for heating, cooling, lighting and electrical appliances.

Immediate implications: Operational emissions are directly influenced by the energy sources used, the efficiency of building systems and occupant behaviour.

Long-term implications: The continuous use and maintenance of buildings offer numerous opportunities for incremental improvements in energy efficiency and sustainability. Over time, these small changes can lead to substantial reductions in the overall emissions of the building stock.

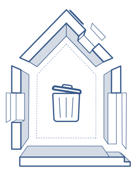


Renovations

Renovations and retrofits of existing buildings are crucial in reducing the carbon footprint of the built environment. Since a large portion of the building stock consists of older structures not originally designed for energy efficiency, renovations can significantly improve their performance.

Immediate implications: Renovation projects can involve updating or adding insulation, windows, heating, HVAC systems, lighting and other building components to reduce energy demand. While renovations may result in some emissions and waste, careful planning and material selection can minimise the impact.

Long-term implications: The improved energy efficiency resulting from renovations leads to reduced operational emissions over the building's remaining lifespan. Moreover, extending the life of a building through renovation avoids the emissions associated with demolition and new construction.



Demolition

Demolition of buildings plays a pivotal role in the dynamics of the building stock, particularly in relation to decarbonisation efforts. Demolition and waste treatment processes do cause some direct climate impacts (particularly for materials that are incinerated), but the most important consequence of demolition from a climate perspective is that it usually leads to new construction.

Immediate implications: Demolition activities generate considerable amounts of waste, which must be properly treated. While some materials are recycled (e.g., metals), many products end up landfilled or incinerated. Incineration can provide electricity and heat that can be used as energy supply, but the process will also lead to substantial GHG emissions. The demolition process itself also consumes energy and may result in additional emissions from the machinery used, although these are usually small compared to the rest of the building's life cycle. The deconstruction process can also vary. There is an increased focus on selective demolition where the building materials are recovered with the intention to re-use these in new constructions or recycle the materials to use these and, thus, avoid production of new materials from virgin resources.

Long-term implications: The removal of buildings from the stock creates a demand for new construction. While the newly constructed buildings might be more energy efficient, this will often be far outweighed by the considerable embodied emissions associated with new construction. Indeed, one of the main decarbonisation strategies for the building stock is to preserve and retrofit existing buildings as much as possible to limit new construction.

2.3 European initiatives

- Several new EU initiatives support national building carbon regulations. They include the Energy Performance of Buildings Directive (EPBD), the Regulations for Construction Products (CPR) and Ecodesign for Sustainable Products (ESPR) and the Taxonomy for Sustainable Investments Regulation. Secondary initiatives include the technical standards EN 15978 and 15804 as well as the Level(s) reporting framework for sustainable buildings.
- These initiatives will, in return, have a significant influence on how national carbon regulations for buildings can be shaped through harmonised limit values for buildings' climate impact. National carbon declarations and limits will have to operate within the framework given by the EPBD. This includes the full life cycle and building model scope (consistently with Level(s)) as well as definitions for environmental data, scenarios and calculation rules (EN15978, EN15804).
- The European Commission is developing a Whole Life Carbon Roadmap to reduce buildings' climate impact by 2050, which will contain whole life carbon milestones and targets.
- Two EU member states outside Nordics and Estonia have already introduced carbon limits using alternative approaches including dynamic emission factors (France) and using a single-score weighting of 19 environmental indicators (Netherlands).

National building carbon regulation will be affected by numerous EU regulations and initiatives, see **Figure 3**.

The revised EPBD (The European Parliament and The Council of The European Union, 2024) requires mandatory whole-life carbon declarations from 2028 for new buildings > 1,000 m^2 and in 2030 for all new buildings. National roadmaps for building carbon limits must already be defined by 2027. The declared results must be the total cumulative life-cycle global warming potential (GWP), differentiated in terms of climatic zones and building typologies. The assessment method will be based on the already established Level(s) scheme, which uses the ecosystem of technical buildings standards around EN 15978. 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 carbon declaration, e.g., in terms of which building elements and life cycle stages (i.e. assessment scope) are to be included in the declaration. The scope of included life cycle stages follows the Level(s) indicator 1.2, which are currently under revision. Furthermore, carbon removals associated to carbon storage in or on buildings must be addressed. The latter is expected to be methodologically supported by the quantifying rules for carbon removals currently under preparation within the EU-wide certification scheme for carbon removals.

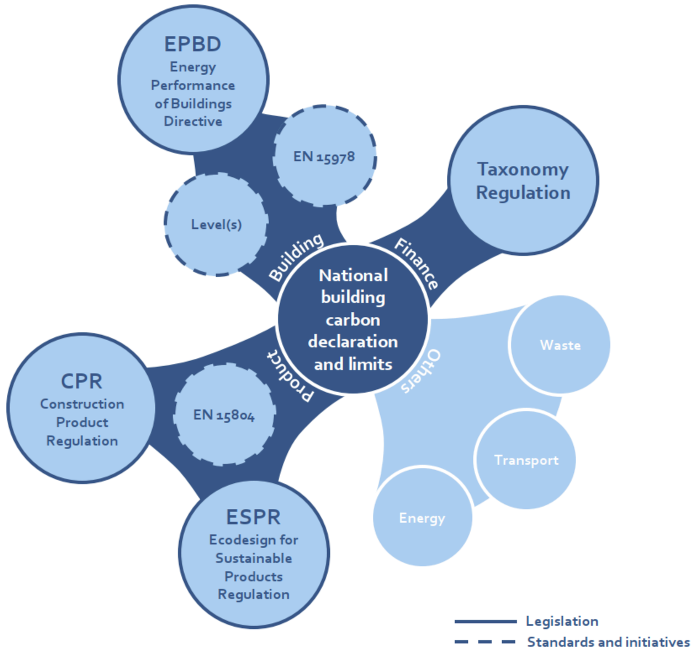


Figure 3. *Key EU regulatory initiatives that affect national building carbon limits. Other areas with indirect impact include energy, transport, waste and many more.*

The environmental performance of construction products is key for assessing and regulating building carbon emissions. The first step to improving products is a transparent declaration of the environmental performance. Environmental information on construction products is regulated by the CPR and ESPR, however environmental declaration is not yet mandatory for all construction products. This is why EN 15978 refers to the core product calculation rules in EN 15804 and related standards to fill this gap. Current gaps in product-level environmental information can be filled by national generic environmental data for construction products and voluntary Environmental Product Declarations (EPD) by the industry.

According to the European Green Deal, the EU aims at directing financial flows to sustainable activities, including investments in construction and renovation. The EU Taxonomy supports the transparent classification of activities as sustainable assets. In order to fit the Taxonomy's criteria, buildings erected after 2023 with a floor area of more than 5,000 m^2 must provide a calculation of GWP based on EN 15978 and Level(s). However, these methodologies, in their current version, give room for interpretation, which challenges financial institutions for qualifying green investments in a uniform manner and managing their portfolios efficiently. When mandatory national carbon declarations exist, they can be used instead, which provides more accurate results and use existing consultancy resources. However, a Nordic or international harmonised approach would smoothen financial investments even more.

The EU is developing (as of March 2024) a Whole Life Carbon Roadmap for reduction of buildings' climate impact by 2050. The roadmap will consist of a series of milestones and targets designed to guide the construction industry in achieving a net-zero carbon building stock. The roadmap will include specific targets for reducing the whole life carbon emissions of buildings, encompassing emissions caused by the operation of buildings and embodied emissions related to building production, construction, renovation and deconstruction. A related technical study (Le Den, et al., 2023) has been published providing information on mitigation strategies and technologies for achieving the necessary EU reduction targets. It shows how the European building sector pathways and strategies can be translated into building-level carbon limits using two reduction scenarios. The TECH-Build scenario assumes the state-of-the-art technological improvements for production processes, efficient design, reuse, recycling, increased use of bio-based materials, etc. The trajectory for building-level embodied carbon in the TECH-Build scenario is shown in **Table 3**. The LIFE-Build scenario adds additional lifestyle and sufficiency measures such as building less and utilising existing buildings more.

It is important to note that according to the most recent studies analysing samples of existing buildings in Sweden (Malmqvist, Borgström, Brismark, & Erlandsson, 2023) and Denmark (Tozan, et al., 2023), the average upfront embodied carbon values in **Table 3** are not representative of the Nordic region because they are very high compared to the average climate impact for new buildings. Considering this, it is necessary to use regional building stock modelling results with care and complement them with national studies of actual buildings.

Table 3. *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) . 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. Each archetype covers structural elements, foundations, internal and external walls, floors, stairs, roofs, openings as well as technical and electrical systems. The study applies a 0/0 approach to account for the biogenic carbon content of bio-based materials (no consideration of biogenic GHG uptake, storage and later release in those materials).*

	2020	2025	2030	2035	2040	2045	2050
Upfront embodied carbon (A1-A5) (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 (A1-A5, C1-C4) (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

Along with the ongoing development of the regulatory framework in Europe, wider private initiatives increasingly support a harmonised carbon reporting and assessment of buildings (**Table 4**).

Table 4. *Wider industry initiatives supporting harmonised measurements and assessments for buildings' carbon footprint.*

Industry initiatives
Science-Based Targets Initiative (SBTi): The SBTi developed a sector specific guidance for setting science-based targets (SBTs) for buildings, which is targeted towards companies involved with the building sector.
Carbon Risk Real Estate Monitor (CRREM): a tool developed to assess the carbon risk of real estate assets and portfolios by measuring the carbon intensity of their energy consumption and identifying the amount of carbon emissions associated with their current energy consumption.
The LCBI Initiative: pan-European low-carbon label measuring the carbon footprint of real estate based on a Life-Cycle Analysis, driven by major European real-estate stakeholders. For embodied carbon, the minimum requirement level to be granted the certification is set to 1,000 $kgCO_2e/m^2$ for a full-scope LCA, while for exemplary projects is set to 700 $kgCO_2e/m^2$. The certification also includes benchmarks for the biogenic carbon storage through using of bio-based materials.

In addition to EU-wide initiatives, individual countries have been pioneering LCA-based mandatory declarations and limit values for newly constructed buildings. The Netherlands 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 conducting an LCA consistent with EN 15804+A2, including 11 different impact categories. These 11 results are then converted into a single metric expressed in EUR/(m^2.year), using a set of standardised weighting factors. In 2018, the MPG limit value was set to EUR 1/(m^2.year) for all residential buildings and office buildings over 100 m^2. As of 1 July 2021, the limit value for residential buildings was lowered to EUR 0.8/(m^2.year). 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.

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

2.4 Nordic initiatives

- In all Nordic countries and Estonia, mandatory carbon declarations (with or without limit values) are planned to be introduced by the beginning of 2026. The beginning in mandating carbon declarations was made by Sweden in 2022, the first carbon limit for large buildings was placed by Denmark in 2023.
- The Nordic countries use a limited number of life cycle modules at first implementation to provide industry and investors with a manageable and agreeable method at an affordable cost while preparing them for the decarbonisation transition. However, the EPBD agreement on life cycle completeness according to the full scope of Level(s) requires EU countries to include all stages.
- Aligning with the EPBD implementation, most Nordic countries will need to extend their declaration requirements to all buildings by 2030.
- Some Nordic countries are eager to expand their regulatory requirements to renovations. It is proposed to be incorporated into Sweden's carbon declaration in 2027 while a stakeholder panel in Denmark recommends a carbon regulation pathway beginning in 2025. Norway already has such a requirement in place.
- Although Denmark initially introduced one limit value for all building types, accompanied by exception rules for specific conditions, differentiation has been adopted for the limit values valid from 2025, as the 40 percent average tightening may begin to put pressure on the way we build.
- Countries with existing carbon regulation require post-completion reporting for achieving a permit for operation, an approach that Finland will most probably follow for its regulation to be effective in 2026. Iceland's soon-to-be-effective regulation additionally requires carbon reporting at the building permit level, which must then be updated at operation permit level, a practice Estonia is also considering

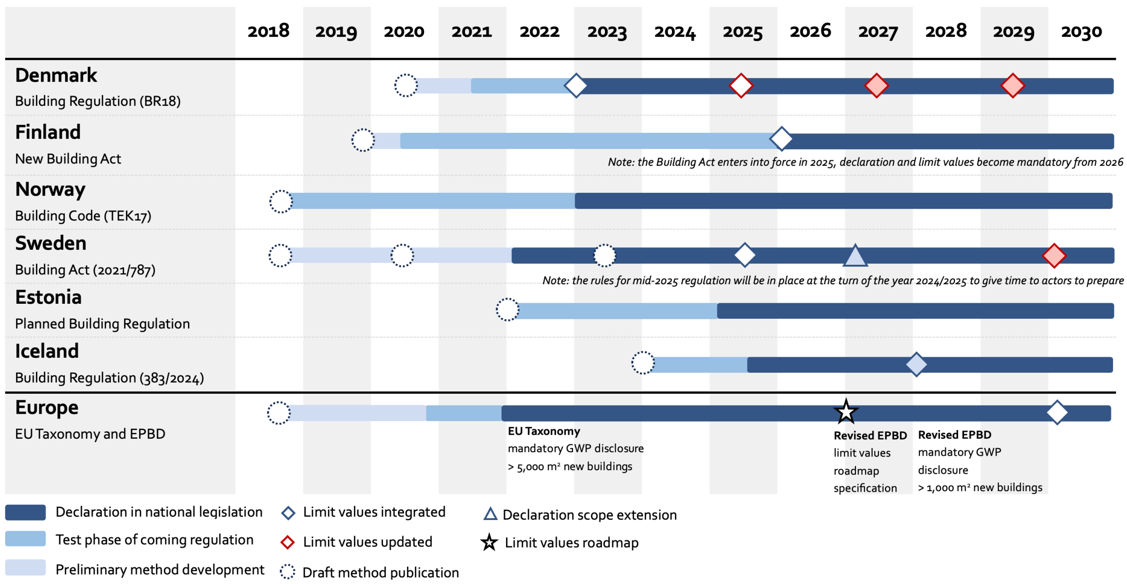
The Nordic countries and Estonia have initiated a range of governmental activities for planning and implementing carbon declarations and limits for buildings, while industry-led initiatives have helped strengthening the process and general awareness **(Table 5)**. Sweden started mandating carbon declarations in 2022, the first carbon limit for large buildings was introduced by Denmark in 2023, other countries will follow as shown in **Table 6**. In all Nordic countries and Estonia, mandatory carbon declarations (with or without limit values) are planned to be introduced primo 2026, four years after the pioneering regulation in Sweden. The countries have adopted different timelines for testing the method prior to implementation. The processes and experiences from early implementation of requirements in Nordic countries can provide learnings for other countries. Whole-life carbon limits for buildings are novel and complex and require some preparation of the building sector; a preparation which starts with whole-life carbon assessment competences and routines on the one hand, and cutting carbon emissions by adapting buildings and the construction value chain on the other. The main rationale for national pathways of progressively decreasing limit values is therefore to achieve actual decarbonisation of the building stock, while balancing societal and economic consequences The following chapters show the progress of how the different countries have planned to gradually expand the scope of assessment and the building types underlying carbon regulation.

Table 5. *Public policy and industry-driven initiatives related to carbon limits of buildings (as of June 2024)*

	Government-driven initiatives	Industry (private) initiatives
Denmark	National Strategy for Sustainable Construction (2021): Voluntary Sustainability Class for preparing mandatory requirements. Roadmap for carbon declarations and limits for new buildings with progressively decreasing carbon limits by 2023, 2025, 2027, 2029. Background analyses. Carbon regulation in the Danish Building Regulations, sections 297-298 (2023): Mandatory carbon declarations of buildings < 1,000 m^2 and carbon limits of buildings > 1,000 m^2	Reduction Roadmap 2.0 (2022)**:** CO_2 reduction roadmap for the Danish building sector, initiated by engineering and architectural firms, which aims to align the Paris agreement and the building regulation. Byggeriets Handletank (2024): Proposal for environmental regulation of the Danish construction industry including revised carbon limit values. Green Building Council Denmark's Certification Manual, 2025: New certification manual for "DGNB Renovation and new build" as a public hearing proposal and pilot project. It includes fewer, but stricter criteria, enhanced focus on performance and promoting renovations and aligning with EU taxonomy
Estonia	Long-term strategy for building renovation, 2020**:** strategic plan to renovate 22% of eligible buildings by 2030, 64% by 2040 and 100% by 2050.	Green Tiger Construction Roadmap 2040**:** construction roadmap that comply with **Estonia**'s climate goals and secure a stable supply within the construction sector, also suggesting the introduction of limit values in 2027
Finland	New Building Act (in force from 2025): to come into effect on 1 January 2025, including measures to streamline the construction process, promote a circular economy and digitalisation, improve the quality of construction and comprehensively address climate change through building legislation. It has been proposed that the carbon declarations and limit values will become mandatory from January 2026. Helsinki initiative: Helsinki municipality has placed a carbon footprint limit for new residential buildings at 16kgCO2e/m²/year) in a 50-year timeframe. The City of Turku has decided to follow Helsinki and will implement the same limit value starting from January 2025. The Circular Economy Green Deal: Government initiative, with Green Building Council **Finland** (FIGBC) facilitating construction and building sector and further supporting companies in actions taken. Particularly, it is a strategic commitment model, where operators voluntarily commit to goals and measures promoting reduction of natural resource and a carbon-neutral circular economy	
Åland	Strategy for Sustainable Construction - A sustainable and attractive Åland building stock with a healthy indoor environment (Expected in 2024)	Bärkraft (Åland) Network: network working towards a common goal of a viable and sustainable region, focusing on renovation, renewable materials, energy efficiency and waste reduction, among others.
Iceland	Icelandic Sustainable Constructions Roadmap to 2030 part III, 2023: a roadmap, which contains reduction targets within the building industry and 74 planned actions to reduce the carbon footprint. It requires a reduction from building materials by 55%, a reduction during the construction stage by 70%, a reduction during the use stage by 55% and a reduction in the end-of-life stage by 88% to 95%. Regulation on an amendment to the building regulations (2024): According to this amendment, as of September 1, 2025, it will be mandatory to carry out life cycle analyses for new buildings in scope categories 2 and 3.	

	Government-driven initiatives	Industry (private) initiatives
Norway	**Byggteknisk forskrift, TEK17, §17 (2022):** describes the regulations on technical requirements for buildings in **Norway** and includes a chapter (i.e., 17) with the LCA requirements for buildings. It also forbids use of fossil energy in new buildings. **Regulations prohibiting the use of mineral oil for heating buildings:** In 2020 it was forbidden to use fossil oil in existing buildings. In 2022 it was forbidden to use fossil oil to temporally heat buildings under constructions. **Climate partnership, 2023**: a climate partnership with stakeholders from the construction sector to develop a knowledge base through workshops. In 2024 Norway started to evaluate if regulatory measures to reduce climate footprint, including limit values should be implemented	**FutureBuilt:** innovation programme intended to showcase the most ambitious projects that can push the sector to get aligned with the Paris agreement carbon targets. It includes a defined criteria set for buildings with specific whole life cycle limit values and that are dynamic with ever more stringent limits depending on construction year. The programme has several large municipalities and various authorities as partners but is also widely used by private real estate actors. **DFØ's reference buildings**: The public procurement authority (DFØ) has compiled a set of reference buildings of standard construction methods. These buildings are used to calculate reference limit values that are widely used in the sector (BREEAM NOR among others).
Sweden	**Act on Climate Declarations for Buildings (2021)**: it came into effect on 1 January 2022. The Act applies to new buildings for which planning permission is sought from that date onwards. **Boverket limit values**: the national board of housing, building and planning (Boverket) proposes a GHG limit value for carbon declarations on new buildings in the construction sector for the earliest by July 2025. As of June 2024, the Swedish Housing Authority agreed that the new rules will come into force on 1 July 2025, with a transition period until mid-2026 when one could choose between applying all new regulations or older regulations. The specific rules will be in place at the turn of the year 2024/2025 in order to give the actors the opportunity to prepare.	**Fossilfritt Sverige (Fossil Free Sweden):** Collaborative effort among companies, municipalities, regions and organisations to accelerating the pace of the climate transition. 22 different business sectors have developed roadmaps for fossil-free competitiveness. The construction and civil engineering sector strives for a 50% reduction of GHG emissions until 2030. **National Procurement Authority**: this Authority has criteria for procurement on lowering the climate impact from buildings. For example, the climate impact from each project must be at least 40% lower than the calculated baseline solution for the project or not exceed 235 Kg CO_2e per m^2 of gross floor area.

__Table 6.__ Timeline of carbon declaration and limit values integration (as of June 2024). The existing and proposed limit values follow different methodologies. More details can be found in __Table 15__. The symbols filled with colours indicate that the exact date of introduction of the indicated activities is still open and subject to political negotiations



2.4.1 Trajectory to full life cycle scope

Two distinct strategies are observed in order to facilitate the adoption of carbon declarations and limit values at the time of their introduction. (a) First introducing a declaration without limit value, and then introducing a fairly ambitious limit value after some years of evaluation (i.e. Swedish approach), or (b) introducing a limit value early in the process, but ensuring that the first-generation limit value can most often be met by conventional building solutions without adaptation efforts; limit values will then have to be reduced over time (i.e. Danish approach) – see Table 7.

Table 7 *Detailed planned integration of carbon declaration and limit values for the two Nordic countries (Denmark and Sweden) with concrete suggestions in place (status as of June 2024). For each country, the top layer shows an overview of the limit value(s)-related plans, while the bottom layer provides the planned activities for declarations. Most decisions from 2025 are still open to political negotiations.*

Denmark		Year		Sweden
		2022		**All new buildings** A1-A5
1/10 buildings to perform better **New buildings > 1,000 m²** **12 $kgCO_2e/(m^2$ yr.)** A1-A3, B4, B6, C3-C4 **All new buildings** A1-A3, B4, B6, C3-C4 + D		2023		
		2024		
17/20 buildings to perform better **New buildings/Extensions > 50 m²** **Extensions for small houses > 250 m²** **4-8 $kgCO_2e/(m^2$ yr.), building type dependent** Average: 7.1 kgCO2e/(m² yr.) A1-A3, B4, B6, C3-C4 **Construction process: 1.5 $kgCO_2e/(m^2$ yr.)** A4, A5	*	2025	**	**1/2 buildings to perform better** **New buildings > 100 m²** **180 $kgCO_2e/m^2$, 1-or 2-family houses,** A1-A5, *~3,6 $kgCO_2e/(m^2$ yr.) for 50 years RSP* **330-460 $kgCO_2e/m^2$, building type dependent,** A1-A5, *~6,6-9,2 $kgCO_2e/(m^2$ yr.)*
		2026		
~ 10% ↓ *Likely inclusion of outdoor areas*** *Potential extension to further life cycle modules (B1, B2, C1, C2) following European developments***	**	2027	**	**New buildings and deep renovations** A1-A5, B2, B4, B6, C1-C4
		2028		
~ 10% ↓	**	2029		
		2030	**	**15% ↓ 1-or 2-family houses** **25% ↓ other building types**

limit value — carbon declaration

* Initially planned tightening to "1/3 buildings to perform better"
**still open to political negotiations

Unlike the Netherlands and France, which already have undergone a preparatory and evaluation process, 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. Denmark already announced the consideration of two additional modules (A4 and A5) in the 2025 assessment scope (new rules to come into force on 1 July 2025), and Sweden plans to extend the current system boundary with more life cycle modules towards a more complete life cycle scope in the future (new rules to be in place at the turn of the year 2024/2025 and come into force on 1 July 2025), while Finland and Iceland are planning to include the most relevant modules from the beginning. The EPBD agreement refers to the total life cycle, Annex III (The European Parliament and The Council of The European Union, 2024), which is likely the prospect for the member state implementation, at least regarding carbon declarations. A more detailed view on this aspect is provided in the method-focused Section 4.2.

2.4.2 Trajectory to full coverage of building types

In the Nordic countries, most new buildings are being built for residential purposes, however, offices, institutions and other uses also have a considerable share of new construction and may therefore have significant climate impacts. While building typology, construction method and subsequent climate impacts are varying considerably within the individual use categories of i.e., schools or apartment blocks, building use, meaning the delivered function, is applied as the categorisation factor for carbon regulation in the Nordic countries. The remaining justified variation within each use category (i.e., urban area versus country-side school) should be considered by other means, for instance through an allowance for components with extraordinary high climate impacts, as in the case of the Danish Building Regulations.

Currently, Denmark includes all at least partially heated building uses except for agriculture. However, carbon limits only apply for buildings above 1,000 m^2 in the initial implementation phase. According to the new agreement (effective May 2024) for 2025 limit values, all types of new buildings are covered, whether heated or unheated, with the exception of socially critical buildings and unheated buildings under 50 m^2. Norway excludes detached homes and other small homes like semi-detached houses, town houses and small terraced houses. Finland excludes single family homes in the beginning. Sweden has detailed rules excluding industrial and agricultural buildings, buildings constructed by private individuals without business purposes, as well as buildings necessary for safety and defence. In Iceland, all new buildings are subject to the new requirements, except for small new constructions such as storage facilities, summerhouses, cabins, detached garages and guesthouses.

The latest limit value studies in Sweden (Boverket, 2023) and Denmark (Tozan, et al., 2023) demonstrate a significant difference in climate impact level dependent on building use, which suggests individual limit values for building uses (see **Table 8**). A differentiation would secure an appropriate balance between reduction goals and decarbonisation potential in each use category. Accordingly, Denmark introduced differentiated limit values for building types from 2025 to ensure that buildings with a lower climate impact are as motivated to reduce emissions as those with a higher climate impact. This aligns with the current EPBD proposal, which specifically includes all energy-consuming buildings and requires carbon limit roadmaps separated into different building uses.

Table 8*. Building uses and sizes covered by the current and proposed requirements (as of June 2024). Note: Iceland plans to include limit values in its regulation by 2028, however it has not been determined whether these will initially focus on a limited number of building types and sizes. Therefore, the table only provides information about the upcoming carbon declarations in this case.*

Building TYPE	Denmark	Estonia	Finland	Iceland[9]	Norway	Sweden	Europe (EPBD)
Single-family home	✓			✓		✓[1,2]	✓
Other residential building	✓	O	O	✓	✓	✓[1,2]	✓
Office	✓	O	O	✓	✓	✓[1,2]	✓
Retail and restaurant	✓	O	O	✓	✓	✓[1,2]	✓
School and daycare	✓	O	O	✓	✓	✓[1,2]	✓
Laboratory	✓	O	O	✓	✓	✓[1,2]	✓
Hospital and health	✓	O	O	✓	✓	✓[1,2]	✓
Sports facilities	✓	O	O	✓	✓	✓[1,2]	✓
Cultural and other public	✓	O	O	✓	✓	✓[1,2,8]	✓[6]
Religious	✓			✓	✓	✓[1,2]	
Industrial	✓			✓	✓		✓[6]
HOLIDAY cottages[5]	**from 2025**				✓[4]	✓[1,2]	✓
Other	✓[7]	O		✓	✓	✓[1,2]	✓[6]
Renovation projects				✓	✓	O[3]	

Size of buildings	**2023-2025:** > 1,000 m^2 **From 2025:** > 50 m^2 for unheated buildings; > 250 m^2 for extensions of single family, terraced and holiday houses	unspecified	no size requirement, except for warehouses, transport and communications buildings, indoor swimming pools and indoor ice rinks (> 1,000 m^2)	unspecified, buildings under scope classes 2 and 3 in Building Regulation	no size requirement, just building type	> 100 m^2	**2028:** > 1,000 m^2 **From 2030:** > 50 m^2

✓ = included in limit value(s), ✓ = included in declaration, O = suggested or planned inclusion in future limit value(s), O = suggested or planned inclusion in future declaration

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.
2. it can be assumed that the same building types included in the 2022 climate declaration will also be subject to the limit values proposed for July 2025.
3. when a building permit is needed according to a building regulation definition (and according to further exemption rules in Sweden)
4. included when they are in blocks.
5. called “leisure homes” in Norway.
6. Member states may decide not to set or apply the requirements to buildings owned by the armed forces or related government buildings, as well as temporary and agricultural building.
7. Socially critical buildings are exempted from the 2025 limit value, but not from the carbon declaration requirements.
8. Some public authorities are exempted.
9. it can be assumed that the same building types included in the 2025 carbon declaration will also be subject to the limit values proposed to be introduced by 2028

limit value carbon declaration

A great interest in learning more about the climate impact of deep renovations is observed in Nordic countries, with Boverket proposing to include deep renovation projects such as building remodelling or repurposing in the carbon declaration in Sweden from 2027, a requirement already in place in Norway. A stakeholder panel in Denmark has recommended a pathway for carbon regulation starting with carbon declarations of large 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. The rationale for excluding deep renovations in the initial stages of regulation implementation is based on simplifying the workload of building supervision and streamlining the permit process. However, excluding renovation construction from carbon assessments could undermine the environmental impact of the renovation construction market and impede the development of new low-carbon innovations. Consequently, this could have a significant impact on the achievement of carbon neutrality goals set at both national and EU levels.

2.4.3 Compliance control regime

The envisioned decarbonisation goals for construction can only be achieved when minimum carbon limits are met. Thus, an appropriate compliance control regime is a must when planning carbon regulation. The need for verification and sanctions for infringement depends on the specific regulation approach including the required reporting stage (building permit or use permit), the detail of reporting requirements and who is authorised to check them. Key reporting elements include the building component inventory, operational energy calculations, scenarios, environmental data and the calculation procedure.

In order to avoid the risk of infringement, both sides of the compliance regime, the construction value chain and the building authority, have to be considered for achieving an efficient procedure. This is achieved by balancing the reporting requirements with the expected stakeholder preparedness. A way of reducing reporting workload, the risk for error in reporting and the need for external verification is narrowing down the methodological choices to the necessary minimum. Professional tools can improve reporting feasibility and ensure quality in the assessment workflow. Here, a part of the quality management is delegated to the tool providers. Since the EPDs are only available for parts of the construction product supply, generic environmental data for building products can fill the data gap and simplify the modelling process. **Table 9** gives an overview on similarities and differences in control regimes for building carbon regulation in the Nordic countries.

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. Iceland's regulation, effective from September 2025, will require carbon reporting at the building permit stage, which will then need to be updated at the operation permit stage. Estonia is also considering a similar approach. No country requires the use of a specific official tool.

***Table 9**. Relevant factors for correct reporting and compliance control (in force or planned)*

	Denmark BR18	Estonia Proposed	Finland Proposed	Iceland Proposed	Norway TEK17	Sweden Boverket
Reporting stage	As-built	Building permit	As-built	Building permit + As-built	As-built	As-built
Technical compliance control	10% of cases checked	Not yet decided	Not yet decided	Random checks	Yes	10% of cases checked**
External verification	No	Not yet decided	Not yet decided (possibly BIM file)	LCA result is handed in an excel format to HMS*	No	No
Market-based tools allowed	Yes	Yes	Yes	Yes	Yes	Yes
Environmental product database	Yes	Yes	Yes	Yes	Yes	Yes

**Iceland's Housing and Infrastructure Agency*
*** Boverket proposes that 100% of carbon declarations are controlled when limit values are introduced (Boverket's report 2023: 24). This can be achieved by comparing the digitally registered climate impact with the reference value for the building type, i.e., comparing the calculation base submitted by the developer with the calculation base for the reference building, and then performing a reasonability assessment for the correct calculation.*

Being a keystone in carbon 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 being able to perform control and related delivery notes and other product documentation to the model.

Photo: Nordic Sustainable Construction

3. Monitoring building stock carbon emissions

3.1 Introduction

As the Nordic countries strive towards achieving their emission reduction targets, effective monitoring and evaluation of decarbonisation efforts become imperative. This chapter recommends strategies for monitoring the decarbonisation of the gradually growing share of new buildings in the building stock, highlighting key methodologies, data sources and dynamic variables essential for comprehensive assessment and future projections. The aim is to provide recommendations for monitoring approaches to support policymakers, and industry stakeholders in effectively tracking progress, identifying barriers and opportunities and accelerating the transition toward a low-carbon built environment in the Nordic region.

This report chapter provides insights into the following aspects:

- **Building stock climate impact modelling approaches**

  Efforts to decarbonise the building stock necessitate robust modelling approaches to understand emissions dynamics. Two primary methodologies are addressed:

  National/sector level: At this macroscopic level, modelling focuses on broad emission trends across economic sectors. Input-Output Analysis and the System of Environmental-Economic Accounting (SEEA, 2012) are commonly used. These methods provide valuable insights into overall emissions profiles and sectoral contributions, aiding in the formulation of national emission reduction strategies.

  Building level: Zooming in on individual buildings or building types, this approach employs Life Cycle Assessment (LCA) for emission accounting. Evaluating emissions on a building's level offers granular insights into specific emission sources and opportunities for mitigation. This micro-level perspective informs targeted interventions and allows setting and monitoring performance targets for individual buildings.

- **What building-related data is already being monitored and can it be utilised for carbon monitoring?**

  In the Nordic countries, significant efforts have been made to gather and monitor building-related data to support various aspects of urban planning, energy efficiency initiatives and environmental sustainability goals. This report section provides an in-depth exploration of the building-related databases currently in place, with a focus on their potential utility for monitoring the decarbonisation of the building stock. Mapping and analysing the existing building-related databases in the Nordic countries will provide valuable insight to the recommendations developed in the following section of this chapter.

- **Recommendations for monitoring decarbonisation of the building stock**

  Recommendations for monitoring the decarbonisation of the building stock will be based on the knowledge gained from the exploration of environmental building stock modelling approaches and the existing building-related data being monitored. By following the recommendations, policymakers and industry stakeholders can strengthen the monitoring infrastructure and enhance the capacity to track and evaluate progress toward decarbonising the building stock in the Nordic countries.

- **Recommendations for dynamic variables for projections**

  Drawing from an analysis of relevant literature and empirical studies, a set of recommendations for incorporating dynamic variables into projections of the building stock in the Nordic countries is proposed. By incorporating these dynamic variables into projections, policymakers and industry stakeholders can develop robust, adaptive and future-proof strategies for decarbonisation and sustainable development in the Nordic countries.

3.2 Environmental building stock modelling approaches

- Both national emission accounts and building-level emission accounts are important to understand the full scope of carbon emission related to the building stock.
- National emissions accounts are well established in all EU and EFTA countries through EU regulation and rely on acknowledged emission accounting methods from the SEEA framework. National emission accounts provide a macroscopic perspective and support policy formulation towards the national reduction goals.
- Sweden has developed a sophisticated sectoral accounts model with more detailed accounts for the building sector based on data from Swedish Statistics.
- Building-level emissions monitoring is important to understand the carbon footprint of individual buildings and for identifying specific emission sources, hotspots and mitigation opportunities. Monitoring building-level emissions accounts is also instrumental in informing the development of building-specific carbon limit values as a measure for decarbonising the building stock.

Photo: Nordic Sustainable Construction

Emission accounting is a critical aspect of monitoring the climate impact of the building stock, aiming to quantify and understand the sources of emissions, their trends and their impact on the environment. As outlined in the introduction to this chapter, two overall modelling approaches for defining climate impact from the building stock are explored. Both National Emissions Accounts and Building-Level Emissions Accounts play crucial roles in accounting for carbon, offering complementary perspectives and insights that are essential for comprehensive and effective emission accounting and monitoring. Below are key reasons why both methods are important in emission accounting:

Macroscopic and microscopic perspectives: National Emission Accounts provide a macroscopic view of emissions at the national or sectoral level, offering insights into broad emission trends, sectoral contributions, and overall environmental impact. On the other hand, Building-Level Emissions Accounts offer a microscopic perspective, focusing on individual buildings or building types to identify specific emission sources, hotspots, and mitigation opportunities. Integrating both perspectives allow for a more holistic understanding of emissions, encompassing both broad trends and detailed insights into specific sources and sectors.

Policy formulation and targeted interventions: National Emission Accounts inform the development of overarching environmental policies and regulations by identifying high-emission sectors, setting emission reduction targets, and allocating resources efficiently. These policies provide the framework for addressing emissions at national or sectoral level. Building-Level Emissions Accounts, on the other hand, support the implementation of these policies by providing detailed insights into building-specific emissions and mitigation opportunities. By targeting emissions at the building level, policymakers and stakeholders can implement tailored interventions, such as building codes, energy efficiency incentives and sustainable building practices, to achieve emission reduction goals effectively.

Monitoring and evaluation: Both National Emission Accounts and Building-Level Emissions Accounts play critical roles in monitoring and evaluating the effectiveness of emission reduction measures and environmental policies over time. National Emission Accounts provide indicators for tracking overall emission trends, assessing progress toward emission reduction targets, and evaluating the impact of policy interventions at a national or sectoral level. Building-level emissions Accounts enable stakeholders to monitor the performance of individual buildings or building portfolios, track changes in emissions over time, and assess the effectiveness of specific mitigation measures. This continuous feedback loop supports adaptive management and evidence-based decision-making, ensuring that emission reduction efforts remain effective and responsive to changing environmental conditions and priorities.

3.2.1 National/sectoral emission accounts

All European Union (EU) Member States and European Free Trade Association (EFTA) countries are legally required to provide data according to the European environmental accounts, established in Regulation (EU) 691/2011 (The European Parliament and The Council of The European Union, 2024). This regulation provides a legal framework for the harmonised collection of comparable data from all EU Member States and EFTA countries, ensuring consistency and reliability in environmental reporting across the region.

The European environmental accounts are aligned with the System of Environmental-Economic Accounting (SEEA) 2012 Central Framework (SEEA, 2012 C), which serves as an internationally recognised statistical standard for environmental accounting. SEEA 2012 C provides guidelines and principles for organising and presenting environmental information within an economic accounting framework, enabling systematic analysis of the interactions between the economy and the environment. Concretely, SEEA complements national economic input-output accounts (income, production, capital, and expenditure in various sectors) with environmentally relevant information such as flows of energy and materials (including pollutants emitted by various sectors), stocks of natural resources or ecosystem services, in a structure compatible with economic accounts. Key features of National/Sectoral Emissions Accounts include:

Comprehensive data collection: National/Sectoral Emissions Accounts collect data on a wide range of pollutants, including greenhouse gases (e.g., carbon dioxide, methane, nitrous oxide), air pollutants (e.g., sulphur dioxide, nitrogen oxides), and water pollutants (e.g., phosphorus, heavy metals). Data is collected from various sectors of the economy, including energy, industry, transportation, agriculture, and waste management.

Harmonised reporting: The European environmental accounts ensure harmonised reporting of emissions data across EU Member States and EFTA countries, facilitating comparisons and assessments of environmental performance at the regional and national levels. This harmonisation is essential for monitoring progress towards international agreements and targets, such as the Paris Agreement on climate change.

Time series analysis: National/Sectoral Emissions Accounts provide time series data, allowing for the analysis of emission trends over time. This longitudinal perspective enables policymakers, researchers and stakeholders to identify patterns, drivers and changes in emissions patterns, informing the development of targeted mitigation measures and policies.

Sectoral breakdown: Emissions data is disaggregated by economic sectors, allowing for the identification of sector-specific emission sources and trends. This sectoral breakdown is instrumental in understanding the contributions of different economic activities to overall emissions and prioritising sectors for emission reduction efforts. Although the sectoral breakdown is an important instrument in policy making, none of the sectors in the national accounts sufficiently describes the GWP related to buildings directly. GWP related to buildings typically falls under sectors such as: Industry, Household, Manufacturing and Transport.

To circumvent the inherited issue with the sectors represented in the national accounts, The Swedish National Board of Housing, Building and Planning (Boverket), in collaboration with Statistics Sweden (SCB) and The Royal Institute of Technology (KTH), has developed a model for estimating the environmental indicators of the construction and real estate sector (Boverket, 2024). The environmental indicators provide insights into the environmental impact of the construction and property sector, focusing on emissions to air, energy use, use of hazardous chemicals and waste generation. In the environmental indicators, the National Board of Housing, Building and Planning wants to capture all the environmental impact that occurs in:

- Construction of buildings (new construction)
- Renovation, rebuilding and extension
- Property Management
- Heating of buildings

These indicators support the national environmental quality target "Good built environment" and are used to monitor progress towards this target.

The model for the production of data for the environmental indicators is based on the Swedish Standard Industrial Classification (SNI) (Boverket, 2024). The SNI, is based on the industry standard classification system used by the European Union (Statistics Sweden, n.d.), NACE Rev.2, and is primarily an activity classification system. This is the same classification used to produce statistics in national and environmental accounts. In Boverket, SCB and KTH's model, specific SNI industries that fit the delimitation for the environmental indicators has been selected.

The analysis adopts a life cycle perspective, encompassing the environmental impact of all construction and property operations in Sweden, including supply chains. Data is updated annually to maintain comparability between years.

3.2.2 Building-level emission accounting

Building-level emission accounting is essential for understanding and managing the carbon footprint of individual buildings. The building level emissions accounts are essential for identifying specific emission sources, hotspots, and mitigation opportunities. Monitoring building-level emissions accounts is also instrumental in informing the development of carbon limit values for buildings as a measure for decarbonising the building stock.

A literature study (Röck, et al., 2021) on environmental modelling of building stock categorises four types of typical modelling approaches: Life cycle approach; Materials flow analysis; Energy simulation; and Cost-benefit analysis. The similarity in the different approaches presented in the study is the possibility of aggregating results to a stock level. The building specific carbon accounting method introduced in the Nordic countries' national legislation is based on Life Cycle Assessments (LCA). This approach will thus also be the focus for developing a recommendation for building level carbon accounting in this report.

With the ambition of monitoring carbon emissions related to building activity, the emissions could be categorised into the four elements of the building stock dynamic presented in Section 2.2:

- New buildings
- Buildings in use
- Renovations
- Demolishing

A yearly monitoring of emissions, similar to the national accounts, would require only monitoring emissions happening each year related to each activity (see **Figure 4**). Results from LCA can typically not be used directly for this purposed as it may contain emissions from more life-cycle stages depending on the national methodology (scope) for LCA calculations. If data from climate declarations (LCA) is reported in separate modules, a proposal for monitoring the yearly up-front emissions with life cycle modules defined in EN15978 and based on the four activities mentioned above could be:

- A1-A5 of LCA calculations for new buildings
- Yearly energy use data for heating, cooling, electricity, etc. (with emission factors) for buildings in use
- A1-A5 of LCA calculations for renovations
- Waste amount and waste management data (with emission factors)

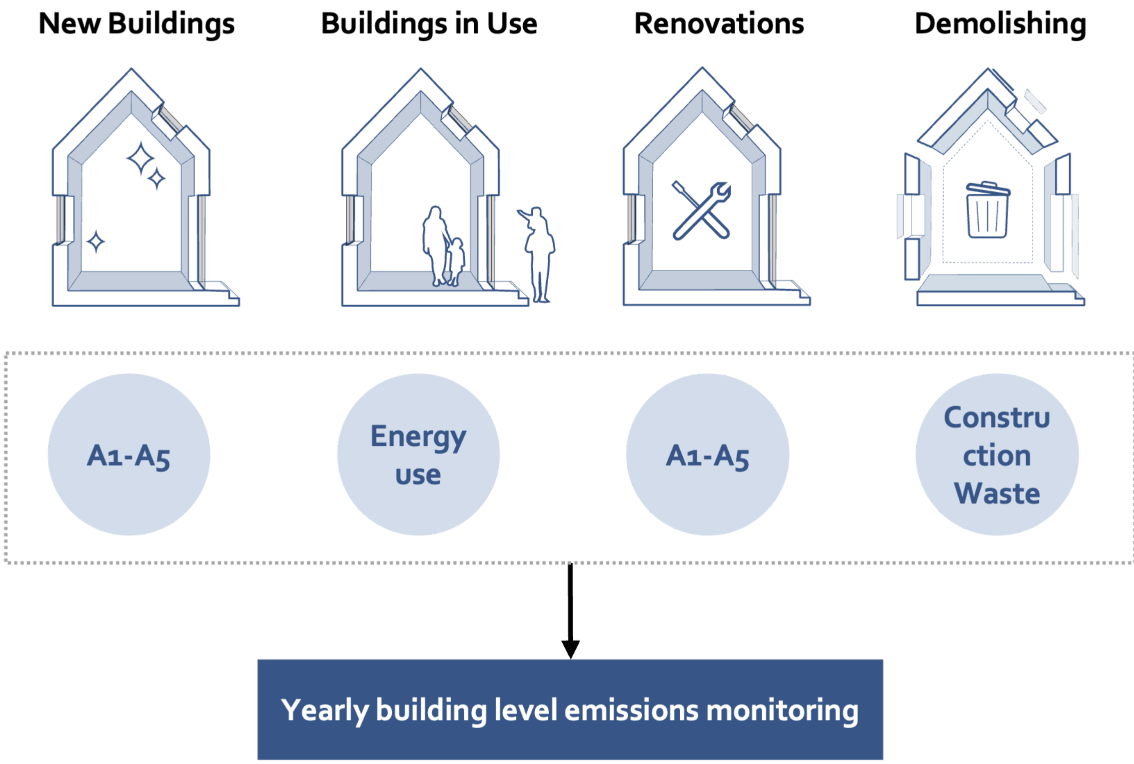


Figure 4. *Yearly building-level carbon emission accounting for the four elements in the building stock dynamic*

3.2.3 Building stock aggregation

To effectively monitor and manage decarbonisation efforts at the building stock level, it is necessary to aggregate building-level emission accounts. This aggregation will provide a macro-level view of the carbon footprint and the progress made toward reducing emissions across an entire national portfolio of buildings. Two principal methods for aggregating building-level data for decarbonisation monitoring are presented: the Archetype Approach and the Sampling Approach.

Archetype approach

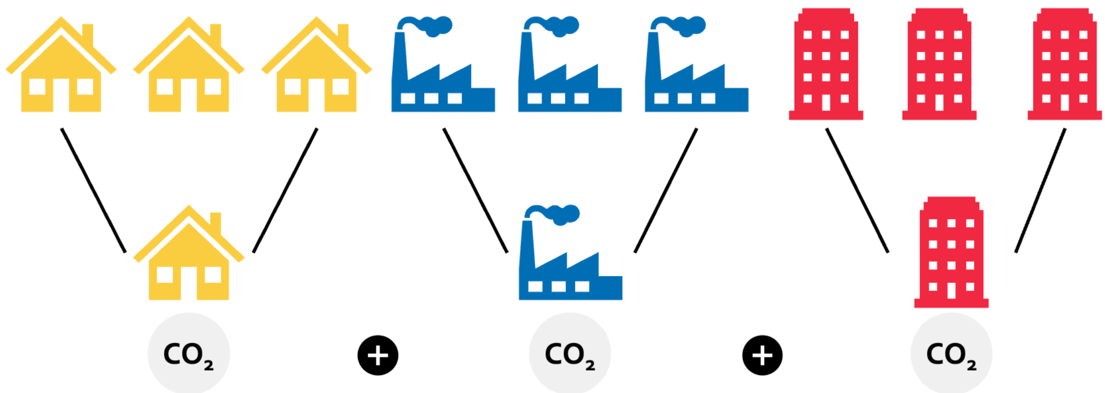


***Figure 5**. Building stock modelling of carbon emissions using archetypes based on building type*

Archetype-based modelling involves representing numerous buildings with a smaller number of representative building types or archetypes. Buildings are clustered based on common characteristics such as type, construction year, size, etc. These archetypes are then used to model the environmental impacts of the entire building stock (See Figure 5). There could be challenges with categorising hybrid buildings containing several functions. If building registration data would allow it, a hybrid building could be divided into functions with area data for each function.

Methodology:

- Archetypes are defined based on building typology and construction year.
- Emission factors for each archetype are developed for reporting emissions for the recommended scope.
- Archetypes emissions factor are updated regularly to reflect changes and follow decarbonisation trends.

Advantages:

- Provides a structured and simplified approach to modelling the diverse building stock.
- Allows for the representation of various building types and characteristics.
- Enables tracking of emission trends over time and across different building categories.

Sampling approach

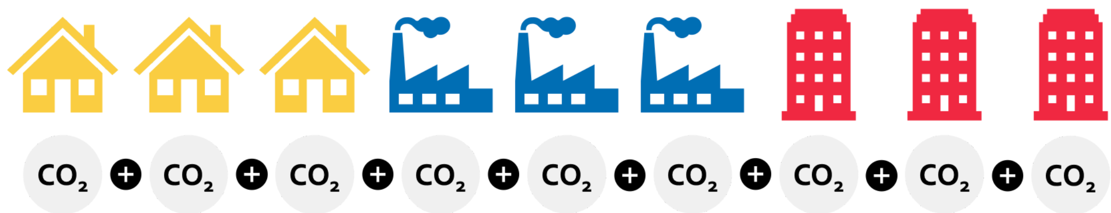


***Figure 6**. Sample modelling of carbon emissions*

The sampling approach involves collecting and analysing data from individual buildings. This method focuses on assessing environmental impacts on a building-by-building basis, leveraging data from e.g., carbon declarations and energy performance certificates (Figure 6). As this approach involves an individual emission factor (based on the LCA result) for each building, it is well suited for hybrid buildings containing more functions, as it would not have to fit a standardised emission factor based on specific building typology.

Methodology:

- Data derived from carbon declarations are used to assess environmental impacts.
- A digital infrastructure is established to manage and extract data efficiently.
- The approach facilitates a comprehensive assessment of environmental impacts for new buildings and potential renovations.
- It offers a granular understanding of emissions, materials, building parts, and types, enhancing accuracy and adaptability.

Advantages:

- Provides a more granular and accurate understanding of environmental impacts.
- Enhances efficiency through streamlined data extraction and management.
- Facilitates easy integration of data from new buildings and renovations.

3.3 Building related data

- A comprehensive and detailed mapping of all building-related data being recorded in each country is uncovered to understand the data landscape and the potential for utilising the data for monitoring carbon emissions on building-level.
- Key attributes potentially relevant for building-level emissions monitoring are identified and analysed concerning quality, accessibility and comparability.
- All Nordic countries have a large number of sources available for recorded building-level data for each key attribute.
- Data and data collection formats within each key attribute are not harmonised and can, in many cases, not be compared as it stands today.
- The current data recording landscape is not fit for direct or indirect comparable building-level emissions accounting.
- Sweden is the only Nordic country with an available database on carbon declaration from new buildings.
- There is a potential for creating harmonised archetypes based on the data available. This would require Nordic cooperation in defining archetypes, area definition and other characteristics

This chapter aims to offer a detailed overview of building-related data and other relevant information sources about buildings in the Nordic countries, that are being recorded today. The objective here is to gain a deep understanding of the building-related data at our disposal to determine whether the current data can be utilised for building-level carbon emission monitoring.

Table 10 lists the names of the sources for the building-related data used in the research is presented. Together with the country abbreviation, the numbers 1-8 create a unique identifier (e.g., DK1) for each database which will be used to refer to the databases going forward in the report.

Table 10. Databases and other relevant information sources containing data on building characteristics, operations, building materials and GHG emissions related to these, which are available in each nation.

Denmark	Estonia	Iceland	Finland	Norway	Sweden
Building and Housing Register (BBR)	Estonian Building Register (EBR)	Building register (Mannvirkjaskrá)	Generic climate impact data (Rakentamisen ja infrarakentamisen päästötietokannat, SYKE)	The land register (Kartverket)	Property register (Lantmäteriet)
DK1	*EST1*	*ICE1*	*FIN1*	*NOR1*	*SWE1*
Protected and listed buildings (FBB)	Land Register /Immovables Register	Property register (Fasteignaskrá)	Energy certificate database (Energiatodistusrekisteri)	Statistics Norway (Statistisk Sentralbyrå)	Building register (Bebyggelseregistret)
DK2	*EST2*	*ICE2*	*FIN2*	*NOR2*	*SWE2*
Waste database (ADS)	Statistic Estonia	Statistics Iceland	Registry of Finnish Heritage buildings (Museovirasto)	Cultural heritage search (Kulturminnesøk)	Generic climate impact database (Boverket)
DK3	*EST3*	*ICE3*	*FIN3*	*NOR3*	*SWE3*
Energy certificate (Energimærke)	Waste database (JATS)	Data library of The National Energy Authority (Orkustofnun)	Land, property, and ownership registry (Maanmittauslaitos)	Energy certificate (energimerke)	Energy certificate database (Boverket energideklaration)
DK4	*EST4*	*ICE4*	*FIN4*	*NOR4*	*SWE4*
Building archive (Byggesagsarkiv)	Planning database (PLANK)	Energy use (Veitur Utilities)	Statistical information on buildings, land, and everything (Tilastokeskus)	GeoNorway - Listed buildings (freda bygninger)	SCB - Statistics Sweden
DK5	*EST5*	*ICE5*	*FIN5*	*NOR5*	*SWE5*
Generic climate impact data (LCAbyg component library)	Emission factors for building materials (CO_2 calculator)	Waste statistics (Úrgangstölfræði)	Built environment information data (Suomen Ympäristökeskus, paikkatietoaineistot)	Case inspection (Saksinnsyn)	Energy statistics (Energiläget)
DK6	*EST6*	*ICE6*	*FIN6*	*NOR6*	*SWE6*
Generic climate impact data (Building regulation 2018 (BR18) Appendix 2 table 7)		Certified building register (GreenBookLive)		OneClickLCA	Climate declarations register (Boverkets Klimatdeklarationsregister)
DK7		*ICE7*		*NOR7*	*SWE7*
Danish statistics				DFØ limit values tool	Climate impact data (BM Tool)
DK8				*NOR8NOR8*	*SWE8*

A diverse array of attributes was identified in the reported databases and other sources of information. They were condensed to the following key attributes that were found relevant for aggregated building stock modelling:

- Building characteristic data
  - Construction year
  - Construction materials
  - Building type
  - Area

- Emission-related data
  - Emissions related to building materials.
  - Operational energy demand (operational emissions)
  - Carbon declarations

Figure 7 illustrates the key attributes in a hierarchical tree model, showcasing their interrelation with the overarching objective of monitoring the decarbonisation progress of the building stock. These attributes have been categorised into either "building stock" descriptors or "emission" descriptors.

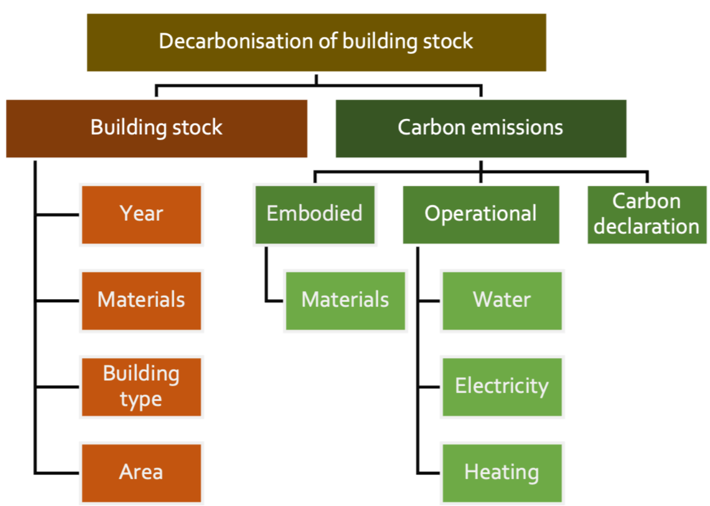


Figure 7*. Key attributes derived from the databases presented in a relational tree model.*

3.3.1 Analysis of key attributes

The databases listed in Table 10 have been organised based on whether they include information related to the important characteristics illustrated in Figure 7. This organisation is displayed in Table 11. To understand the IDs/abbreviations, please refer to Table 10.

Table 11. Building related databases in the Nordic countries mapped according to key attributes for building stock modelling.

		DENMARK (DK)	ICELAND (ICE)	ESTONIA (EST)	FINLAND (FIN)	NORWAY (NOR)	SWEDEN (SWE)
Building Characteristics	**Year**	DK1	ICE1	EST1	FIN2	NOR2	SWE1
		DK8	ICE2	EST3	FIN3	NOR3	SWE2
			ICE3		FIN4	NOR5	
					FIN5		
	Materials	DK1	ICE1	EST1	FIN4	NOR6	SWE2
		DK2	ICE2	EST4	FIN5		
		DK3			FIN1		
		DK5					
	Building type	DK1	ICE2	EST1	FIN4	NOR1	SWE1
		DK8	ICE3	EST3	FIN5	NOR2	SWE5
				EST5	FIN2	NOR3	
	Area	DK1	ICE1	EST1	FIN4	NOR1	SWE1
		DK2	ICE3	EST3	FIN6	NOR2	
		DK8			FIN5	NOR3	
Carbon Emissions	**Embodied (Data on construction products)**	DK7		EST6	FIN1	NOR7	SWE3
						NOR2	
	Operational	DK1	ICE3	EST1	FIN2	NOR2	SWE4
		DK2	ICE4	EST3	FIN5	NOR4	SWE5
		DK4	ICE5		FIN1		SWE6
		DK8	ICE7				
	Carbon declarations						SWE7

The following section is dedicated to an analysis of each of the key attributes, as well as the corresponding databases resulting from the mapping exercise. In this examination, we will delve into the specifics of data quality and database type to assess their potential in describing aggregated levels for use in environmental building stock modelling in Nordic countries.

The objective of this analysis is to define whether the attributes identified in the databases could provide a foundation for robust and reliable environmental building stock modelling in the Nordics.

Photo: Nordic Sustainable Construction

Building stock characteristics – construction year

To monitor emissions from new buildings and new material in renovations, a building's construction year will be important to record in order to capture the temporal aspect of the decarbonisation of the building stock. Construction year can also help determine the age of the building and identify construction methods and materials used. This information can potentially be used to estimate the building's carbon footprint and plan for future renovations or demolitions.

Most Nordic countries have multiple databases that contain information on building age. However, the information provided in these databases can vary. Some databases include construction year and not the year of renovation, resulting in slight discrepancies in the data that can complicate the process of combining information from different databases.

Building stock characteristics – material type and quantity

In most of the Nordic countries' databases, the material description is very limited and primarily focused on descriptions of roof and façade materials. Estonia's databases provide more detailed information on additional building elements like foundations and interior surface materials. In general, the quality of data on building materials is not found comprehensive enough to use directly or as an estimated inventory for LCA calculation.

Building stock characteristics – building type

Information on building type can be especially useful when using an archetype-based aggregation approach. This approach involves clustering buildings based on common characteristics such as building type and construction year. Utilising building typology data is commonly used in building stock modelling due to the large number of buildings involved and the limited availability of detailed building data.

There are multiple databases recording building typology available in each country. There are databases available for both individual buildings and building stock on a larger scale. This makes it easy to extract the required information and determine the total number of buildings in each typology.

Building stock characteristics – area

Information about the built area can be an important parameter to monitor the building stock. Each country has at least one, and often two or three databases that provide this information. The databases vary from individual building level to national statistics databases, which often have the average floor area for different types of buildings recorded. This makes the information easily extractable.

In Nordic countries, the building and property databases contain data on the gross floor area (GFA) of all buildings, while a subset of other buildings in the databases have additional information on other types of areas. The building and property registers define GFA in varying ways and incorporate different elements in the calculation of the floor area. Additionally, the definition of the area used for calculating carbon declarations in the Nordic countries varies (See chapter 4.3.2).

Emissions related to building materials

Most Nordic countries have been provided with a database or list, by their respected authority, which is often required to be followed when using generic environmental impact data for building materials in the national carbon declarations. The emission factor data in each database differs based on factors such as the energy mix, transportation distance, and original location of the products. The databases are tailored to each country and as a result, the embodied carbon emissions for the same type of materials vary for each country. Sweden's database only includes the product stage (A1-A3) and construction stage (A4 – A5). This variation in generic data makes it difficult to compare results from carbon declarations. This will be further unfolded in Chapter 4. Norway and Iceland do not have access to such databases or lists.

Emissions related to operations

Carbon emissions related to the operation of a building, such as water usage, heating and electricity consumption in buildings are not reported in any databases. Several databases are reporting on both labels (energy), actual usage (energy/heating/water), and supply type (energy/heating). There are databases available at the individual building level and on a larger scale for building stock. The larger-scale data sources are typically the national statistics banks.

If data from databases containing either information on labels or actual usage is to be utilised for monitoring emissions related to operations, emission factors can be used to calculate the carbon emissions related to the operations. Choosing correct emissions factors should be carefully considered, so it does not reflect the national production, but the actual use of energy including the trade between Nordic countries and rest of the Europe. To account for this and evaluate emissions with emissions factors, a Nordic electricity mix (including import and export) is recommended.

Energy label	Denmark	Estonia	Finland	Sweden*	Norway
	Limit value [kWh/m²]	*Limit value [kWh/m²]*	*Limit value [kWh/m²]*	*Limit value [Energy performance of a new building]*	*Limit value [kWh/m2]*
A++	27				
A+	< 30 + 1000/Area				
A	< 52,5 + 1650/Area	< 105	< 90	EP is ≤ 50%	85 + 600/Area
B	< 70,0 + 2.200/Area	< 171 - 200	< 91 - 155	EP is > 50 - ≤ 75%	95 + 1000/Area
C	< 110 + 3.200/Area	< 201 - 250	< 156 - 192	EP is > 75 - ≤ 100%	110 + 1500/Area
D	< 150 + 4.200/Area	< 251 - 300	< 193 - 272	EP is > 100 - ≤ 135%	135 + 2200/Area
E	< 190 + 5200/Area	< 301 - 350	< 273 - 402	EP is > 135 - ≤ 180%	160 + 3000/Area
F	< 240 + 6.500/Area	< 351 - 410	< 403 - 472	EP is > 180 - ≤ 235%	200 + 4000/Area
G	> 240 + 6.500/Area	< 411 - 470	< 473	EP is > 235%	> F
H		> 471			

Figure 8. *Energy label limit values for apartment buildings in the Nordic Countries. In some countries there are differentiated values for different building typologies. *The percentages constitute shares of the requirement for energy performance in the construction of new buildings.*

For all the Nordic countries except Iceland, there are energy certificate databases which contains labels for all new buildings. However, the value for each grade in the label (A, B, C, etc.) do not align across countries, making comparisons between countries difficult with the label alone. See **Figure 8** for an example with limit values for each grade for apartment buildings typologies). Additionally, the energy label in Estonia, Norway and Finland varies with the typology of the building. The energy labels are primarily updated when there is a transfer of ownership or tenant for the buildings.

Besides the national databases, the EU Building Stock Observatory (BSO), that was established in 2016 as part of the Clean Energy for All Europeans package, is also a key source for large-scale energy data from building. It aims to provide an understanding of the energy performance of the building sector through reliable, consistent, and comparable data. The background data for the operational energy use in BSO originates from Eurostat's energy statistics on household energy use, which means that the data is based on actual energy use.

Carbon declarations

A public register of building carbon assessments can provide very valuable data for monitoring carbon emissions from buildings and for the development of carbon limits. Sweden is currently the only Nordic country that has established a mandatory data reporting format and a database infrastructure for handling the data from carbon declarations that are being delivered to the authorities. It is available for researcher on request and is planned to be open when the quality is assured. Boverket is also providing summarised statistics (Boverket, 2024) on the climate impact derived from the data and presents the data on a dedicated website.

Iceland has also prepared a digital infrastructure (Húsnæðis- og mannvirkjastofnun, n.d.) for gathering climate declaration data for when the requirement in the building regulations is taken into force on 1 September 2025, but it is not yet mandatory to use. Denmark has created a voluntary reporting scheme in excel-format (BR18 - Bygningsreglementet, 2021), that can be used to hand in LCA results to the authorities.

The handling and availability of data collected from carbon declarations in the other Nordic countries remains undecided.

3.4 A harmonised approach for monitoring decarbonisation of the building stock

- Carbon emissions, related to the developing building stock, should be monitored with a dual-level monitoring system in place: National accounts (already established) and building-level accounts.
- The Swedish model for sectoral account developed by Boverket and Swedish Statistics can be introduced in the Nordic countries for a harmonised, detailed sectoral monitoring approach.
- A building-level monitoring approach needs to be established. For a harmonised Nordic approach to monitoring emissions related to new buildings, the Nordic countries can follow the Swedish method (Boverket) for disclosing data from all collected carbon declarations for new buildings.
- For building-level monitoring of emissions related to operational energy use, leverage data from the EU building stock observatory with Nordic emission factors.
- For building-level monitoring of emissions related to renovations introduce climate declaration on renovations (starting with larger renovations). Follow the recommendations on data collection and disclose data on A-modules (material production and construction site).
- For building-level monitoring of emissions related to building demolishing, strengthen the data collection on the amount of construction waste divided in fractions. Monitor the waste management of construction waste fractions.

It is recommended to monitor emissions on both sectoral level and building levels combined. This recommendation is based on the understanding that each approach offers unique insights and benefits that are crucial for a comprehensive assessment of the environmental impact of the building stock and for the effective implementation of decarbonisation strategies.

Sectoral emission accounts provide a macroscopic view of emissions. This perspective is essential for understanding the overall environmental impact and for relating emissions to national policies outlined in Chapter 2. Building-level emission accounts focus on individual buildings or types of buildings. This detailed perspective is necessary for identifying specific emission sources, hotspots and opportunities for mitigation at a more granular level, and allows building sector stakeholders to develop strategies on a building level.

This monitoring approach enables adaptive management and evidence-based decision-making. Policymakers and stakeholders can develop strategies that are both broad in scope and detailed in application, leading to more effective and sustainable outcomes in emission reduction and environmental protection.

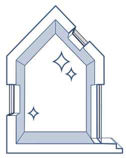
3.4.1 Sectoral level monitoring

The national level accounting covers the full scope of emissions related to the national economy, which is why it could be concluded that the full scope of emissions related to the elements in the building stock dynamics should be covered. The issue with the national accounting method is the level of detail. It does not match the life cycle modules of buildings and it is not possible to gain insight into emissions distributed into categories such as new building, renovations, buildings use and demolitions.

The Swedish model for sectoral emissions accounting (described in chapter 3.2.1) in the housing and real estate sector tackles this issue by distributing the emissions into the mentioned categories. As the calculation method is based on the industry standard classification system used by the European Union, it could be introduced in all Nordic countries, for a harmonised monitoring approach to a more granular sectoral-level monitoring. It would involve utilising the calculation methodology developed by Boverket in collaboration with SCB and KTH and is deemed to be relatively cost-effective, as the calculation methodology is already developed, and statistic data should be available in correct formats.

3.4.2 Building level monitoring

The primary limitation of the existing data landscape mapped out in the previous chapter is the inability to directly facilitate the monitoring of environmental impact from buildings. To address these limitations, a sampling methodology is recommended. This approach aligns with the introduction of carbon declarations in the Nordic countries in the forthcoming years. Furthermore, the EU Energy Performance of Building Directive (EPBD) Article 7 states that Member States must ensure that the life-cycle Global Warming Potential (GWP) is calculated in accordance with Annex III and disclosed through the energy performance certificate of the building. Establishing a digital infrastructure to manage data derived from carbon declarations and/or GWP disclosed in the energy performance certificates, can provide a more robust foundation for carbon emission modelling. In the following, recommendations for monitoring carbon emissions for each element in the building stock dynamic are presented.



New buildings

For new buildings, the recommendation is to use a sampling method when carbon declarations are in place. Carbon declarations can then be analysed, and data presented. This involves establishing a data-gathering infrastructure. Sweden has established a digital infrastructure and is already utilising the data for presenting carbon accounts. A screenshot from Boverket's website, with a presentation of median data for all carbon declarations delivered to the Swedish authorities in the period 2022-2023 is shown in **Figure 9**. It is highly recommended to follow Sweden's approach on the disclosure of data from carbon declarations. The approach leverages the data and provides a granular understanding of emissions, materials, building parts and types, enhancing comparability.

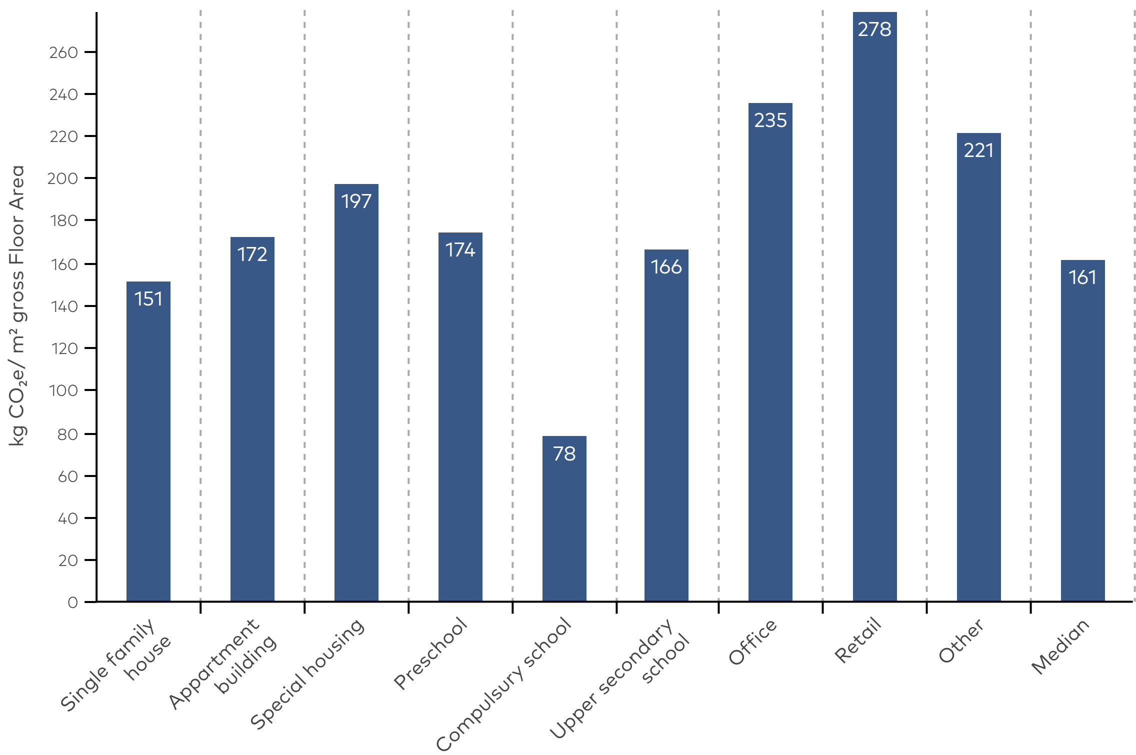
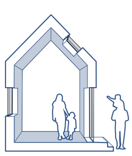


Figure 9. *Overview of climate impact from building types based on statistical data from building carbon declarations Figures modified from original figure from Boverket website (Boverket, 2024).*

Iceland has prepared a digital infrastructure for gathering climate declaration data for when requirements laid down in the building regulations enter into force on 1 September 2025. The results are submitted to an electronic LCA submission portal (Húsnæðis- og mannvirkjastofnun, n.d.). It is done by breaking down the results into each life cycle phase A1-A3, A4, A5, B4, B6, C1-C4 and D (see screenshot from submission portal in **Figure 10**). Stakeholders are encouraged to start using the submission portal before the requirement takes effect.

***Figure 10**. Iceland's LCA submission portal*

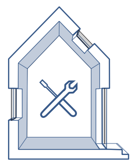


Buildings in use

Accounting for carbon emissions from energy use in buildings is a critical component in efforts to decarbonise the building stock. The accounting method should align with established practices and frameworks to ensure consistency and comparability of data. In the context of the European Union, the EU building stock observatory provides a model for accounting practices for energy use in the European building stock. It is recommended to apply the same method and potentially utilise the same data. Use emission factors that represent the amount of CO_2 emitted per unit of energy consumed for each energy source.

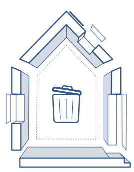
Renovations

Renovations play a significant role in reducing the overall environmental impact of the building stock, as they provide opportunities to implement



energy-efficient technologies and materials. However, current data monitoring for renovations is insufficient or non-existent.

While carbon declarations are not currently required for renovations, their introduction could significantly enhance data availability and accuracy. Carbon declarations for renovations would ensure that data on the environmental impact of renovation projects is systematically collected and reported. On the other hand, excessive reporting requirements might create a barrier to renovation, while renovation should instead be broadly encouraged as a strategy to preserve existing buildings and improve their viability and energy efficiency. A dedicated infrastructure for reporting data would serve as a central repository for data related to renovation activities.



Demolition

There are currently no system or databases in the Nordic countries to directly monitor emissions related to the demolition processes. For emissions related to demolitions or dismantling of buildings for renovations, the recommendation is to focus on utilising construction waste data. Construction waste is recorded in most Nordic countries and typically offers insight into waste fractions and waste amounts generated. This can be coupled with use of emission factors that represent the amount of CO_2 emitted per amount of each waste fraction treated. Such factors should be consistent with those used in the EU's environmental accounts and the System of Environmental-Economic Accounting (SEEA).

3.5 Modelling dynamic elements in future projections

- For projections of carbon emissions related to the development of the building stock consider dynamic variables such:
    - Development of emissions factors for energy use (electricity, heating, cooling and gas)
    - Development of emissions factors for production of construction materials
    - Development in use of recycled construction material
    - Renovation rates
    - Building stock growth based on population.
    - Building typology requirement change
    - Dwelling size development
    - Materiality and building characteristics change

Unlike static elements, which remain constant, dynamic elements can fluctuate over time. Dynamic scenario variables represent specific variables that are altered within a model to explore alternative scenarios.

To gain a comprehensive understanding of different approaches and methodologies used in modelling dynamic elements in monitoring environmental impact from the building stock, two research studies (Röck, et al., 2021; Ohms, et al., 2024) and two reports on decarbonisation initiatives (International Energy Agency, 2023; UK Green Building Council, 2021) have been analysed to provide valuable insights and examples of how dynamic elements can be effectively incorporated into future projections.

Table 12 presents the analysis by categorising the proposed dynamic elements found in the studies into three groups: emission factors, building stock, and building design. The emission factors category includes variables such as decarbonisation of the electricity grid and material production optimisations. These factors focus on reducing carbon emissions and improving materials. The building stock category captures the variations in the aggregate number of buildings, as affected by a range of dynamic factors. This category explores how factors such as population growth, changes in demographic and urbanisation impact the overall number of buildings. The building design category pertains to modifications in the building's specifications, including its shape, dimensions and type of construction materials.

By categorising the proposed dynamic elements into these three groups, Table 13 provides a structured overview of the different aspects that could be considered when modelling dynamic elements in future projections.

***Table 12**. Analysis of dynamic variables for building stock projections included in other relevant studies.*

	Emission factors (Energy supply, material production optimisation)	**Building stock** (More/less buildings, more/less of certain types)	**Building design** (Change in building design, change in material use)
Environmental modelling of building stocks – an integrated review of life cycle-based assessment models to support EU policy making	• Energy and material production efficiency • Change in heating, cooling and illumination. • Recycling and reuse of materials. • Energy consumption and future electricity mix changes	• Building stock size and renovation plan • Building stock growth based on population. • Building typology requirement change	• Dwelling size development • Building characteristics change due to climate. • Rate of timber and low impact concrete typologies
Dynamic environmental sustainability assessments of the built environment: Coupling material flow analysis. **(MFA) and LCA**	• Energy decarbonisation • Less carbon-intensive materials (Materials within Europe & less waste) • Reduced energy from construction site • Reduced heat and electricity requirement in buildings	• Growth in building stock based on students and faculty. • Model the lifetime of research and educational purposed buildings the same as residential.	• Increase in area-to-user ratio. • New construction with less carbon-intensive material for the load bearing structure
IEAs pathway to 1.5-degree	• Energy decarbonisation • Tripling renewable energy and other low emissions energy resources • Increase the amount of energy demand from the building sector.		
UKGBC's Whole Life Carbon Roadmap	• Decrease the operational carbon emissions. • Decrease in average energy usage. • Reuse materials for a reduction in virgin material demand • Reduction in embodied emissions	• Increase in building stock based on population. • Reduction in demand of office and residential buildings • Retrofit existing homes	• Reduction in material usage through design efficiency

After analysing the categorisation presented in **Table 12**, it is important to consider certain elements when modelling dynamic elements in future projections. Based on the analysis, the following recommendations can be made:

Integration of dynamic elements into models

Incorporate changes in building stock size and renovation plans, considering the growth in population and household composition based on demographic projections and the expected increase in retrofitting of existing buildings, as highlighted by the UKGBC's Whole Life Carbon Roadmap.

Model the impact of changes in building design and materiality, including the increase in built-up area per person, the adoption of low-emission materials like timber and low-impact concrete and the reduction in material usage through design efficiency.

Account for the evolution of energy consumption and the electricity mix, emphasising the shift towards renewable and low-emission energy sources, as well as the anticipated improvements in energy efficiency for heating, cooling, and lighting.

Scenario development

Develop scenarios that reflect different rates of decarbonisation of the energy supply, as suggested by the IEA's Pathway to 1.5-Degree report, and the optimisation of material production processes. Scenarios for decarbonisation of the energy supply cannot stand alone, as this would make the model incomplete. Decarbonisation scenarios should be made for all processes within the system boundary (transportation, construction site, material production, waste management etc.)

Create scenarios based on the anticipated reduction in operational carbon emissions and average energy usage in residential and commercial buildings, as outlined in the UKGBC's Whole Life Carbon Roadmap.

Consider scenarios that simulate the impact of climate change on building characteristics and the consequent changes in building typology requirements.

Policy and strategy alignment

Align the scenarios with existing national policies and strategies, such as the national decarbonisation strategies, renewable energy plans, carbon neutrality goals and national plans for renovation of the building stock.

Incorporate strategies for energy decarbonisation, including renewable energy and other low emissions energy resources, as well as the increase in energy demand from the building sector.

Photo: Nordic Sustainable Construction

4. Development of carbon limit values for buildings

4.1 Introduction

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. There is a great need for identifying harmonisation potential of limit value methods from Nordic countries and to influence upcoming common exchange standards resulted from various European initiatives.

This report section is a contribution towards harmonising the approach to national building carbon limits ('carbon´ is here used in line with common terminology and refers to GHG emissions) for creating a supportive environment for the large-scale decarbonisation of building stocks. The aim is to improve the understanding of the differences and synergies, harmonisation potential, as well as the expected changes, which different limit values scenarios are expected to cause or require, in terms of building design, other environmental impacts, society and economy.

The section provides the following insights:

- **Overview of the current state of building carbon declarations and limit values in the Nordic countries**

  This includes an overview of the differences and synergies in the methodological background of limit values and carbon declarations to evaluate the harmonisation potential.

- **The influence of most relevant variables on carbon limits**

  It provides an instrument for differentiating variables, which need to reflect regional differences on the one hand and others, which can and should be harmonised.

- **The further impact of introducing limit values**

  It explores the unintended consequences of gradually tightened carbon limits. The assessment considers the carbon limit level and pace of implementation using the quantitative case study and literature.

4.2 Nordic LCA definitions

- Building reference area as functional unit uses different definitions in the Nordics and Estonia. The expected mandatory usable floor area (UFA) mandated in the EPBD may offer an opportunity for harmonisation.
- Upfront carbon from modules A1-5 is both significant in magnitude of emissions, but also include the largest carbon mitigation potential with an immediate effect. Various strategies for promoting upfront carbon mitigation are observed: An initial focus exclusively on A1-A5 (Sweden), or a dynamic accounting of emissions over time, where today's emissions weigh higher than future ones (France), or dynamic emission factors for future process scenarios (in parts applied in Denmark). Alternatively, a dual approach with separate carbon limits for upfront modules and the whole life cycle can support immediate carbon reductions and keep future emissions on an acceptable level.
- Currently the Nordics and Estonia employ different definitions of Global Warming Potential, where biogenic carbon is only included where end-of-life stage forms part of the scope. Harmonisation is expected to be achieved in the mid-term as compliance with EPBD requires expanding to full life cycle scope, however, a module-by-module comparison will still not be feasible if not introducing a separate biogenic carbon declaration. While the latter is only a suggestion in EPBD, at least the reporting of GWP-biogenic, and to the extent possible of the capability of products to temporarily store carbon are essential requirements according to the CPR recast.
- Main differences in current definitions of included building parts root in earlier considerations about the life cycle scopes. The material inventory has a major influence on the comparability on results and has a good harmonisation potential.
- The allocation of impacts and benefits from exported onsite energy production is expected to have two options according to the EN 15978 revision. The Nordics and Estonia can achieve harmonisation by choosing a common option.
- Most Nordic countries and Estonia apply or prepare future decarbonisation scenarios for the energy supply in operational energy use (module B6). The choice of scenario can greatly influence assessment results. Since no decarbonisation scenarios are applied to other use-stage modules or end-of-life yet, harmonisation can be achieved by following a common approach.
- Conservative standard values for building systems, and generic values for construction products, can facilitate assessments and fill data gaps. Not all countries propose standard values for building service systems. All Nordic countries have developed conservative generic values for common products, but

they use different approaches for developing conservative emission levels. In future revisions, harmonisation in data sampling and definitions may be pursued.

- Different component service life approaches are used in the Nordics, applying varying approaches regarding standard tables or differentiation after exposure, quality, or location in the building. There is the possibility of a potential EU harmonisation.

This chapter provides a brief overview of current differences in Nordic and Estonian LCA methodology including definitions (**Table 13**), as well as the choice and availability of environmental data and scenarios (**Table 14**). This overview constitutes an updated summary of a detailed state-of-the-art mapping provided in the report "Harmonised Carbon Limit Values for Buildings in Nordic Countries" (Balouktsi, Francart, & Kanafani, 2024).

Building reference area: While Denmark, Norway and Sweden consider the gross floor area (GFA) as the reference area unit for carbon declarations, with differences in including shared and external spaces, Finland and Estonia are applying the heated floor area (HFA). Current EU policy, represented by Level(s) and EPBD though define the reference unit as useful floor area (UFA) per year. The Delegated Act, which is expected to be adopted by the European Commission by 2025, will clarify how the UFA will be defined and what flexibility the members states may have. In a scenario where the EU definition provides room for national differences, a harmonised Nordic UFA approach could be a vehicle for making assessments more comparable.

Life cycle system boundary: At the moment, Nordic countries use varying approaches for the life cycle system boundary. Sweden is the only country restricting the limit value scope to upfront carbon, but is considering to extend the boundary of the declaration to the remaining modules in 2027 in order to align with the revised EPBD proposal. Due to a focus on A1-A5, Sweden uses the GWP-GHG indicator which does not account for biogenic carbon uptake in the product or its packaging and emissions in the end of life. The rationale for special attention to upfront emissions is twofold. Firstly, today's emissions can be measured and verified at building hand-over and mitigation has an immediate effect. Secondly, the ongoing decarbonisation of energy systems and the constructions product supply chain is progressively decreasing the magnitude of future emissions of buildings built today. This gives upfront emissions in modules A1-5 the greatest potential for achieving significant and measurable fossil-based carbon emission reductions for new buildings.

This does not mean that the remaining life cycle stages, which are based on future scenarios, can be ignored. In fact, they are crucial to ensuring that today's decisions do not shift environmental burdens into the future. A part of this is already achieved through continuing the current regulation of building energy demand and supply according to the EPBD. However, this does not include the remaining modules in the Use and End-of-Life stages. A separation of carbon regulation into an indicator for upfront carbon and a second indicator for a holistic whole-life cycle perspective that includes scenario impacts could bridge the dilemma and allow more tailored carbon regulation for these different areas, thereby reducing today's emissions while avoiding trade-offs between upfront and lifecycle emissions.

Such separation mandates to exclude biogenic carbon from the calculation of upfront emissions in order to avoid misleading results. This adjustment will not change the incentive for or against using biomaterials, since biogenic carbon emissions are neutral and carbon storage may not be included in the calculation according to EN 15978. This manoeuvre requires data developed after the latest EPD standard (EN 15804:2012+A2:2019) that includes separate reporting of all parts of the GWP indicator (fossil, biogenic, LULUC) and will soon be the default for EPD's.

Photo: Nordic Sustainable Construction

Biogenic carbon: The Nordic countries currently use varying definitions of 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 an indicator called GWP-GHG. In the case of the two latter countries, where end-of-life carbon is not included, biogenic carbon cannot be included as it is based on the complementary modules A1-3 and C3 for the carbon calculation. Estonia will most likely require the reporting of both GWP-fossil and GWP-total in parallel. A separate upfront carbon declaration requires the use of the latest EN 15804:2012+A2:2019 EPD standard that includes separate reporting of all parts of the GWP indicator (fossil, biogenic, land use and land use change (LULUC)) and will soon be the default for EPDs. In EU-regulation, the new EPBD 'life cycle GWP' indicator corresponds to GWP total without subdivision. GWP total is equal to the GWP-GHG when reporting the full life cycle including stages A to C. However, they are not compatible when comparing module by module or assessing upfront carbon. This problem can be solved by reporting biogenic carbon separately, which will make the different GWP indicators compatible and comparable. The amount of biogenic carbon in products can be estimated from EPD data following the +A2 format in different ways. When biogenic carbon is provided in kgCO_2e/functional unit, it can be reported as unchanged. If it is given in kg C/functional unit, it needs to be converted to kgCO_2e by multiplying with 44/12. In cases where no specific value is provided, it can be estimated from the GWP-bio

values in the A (product) stage. Especially the latter practice aligns well with the so-called environmental essential requirements that are mandated to be declared in an EPD set in the CPR Acquis process as the GWP-bio indicator is part of this pre-determined list. The revised CPR also requires covering the capability to temporarily bind carbon and other carbon removals "to the extent possible", see ANNEX II: (European Parliament). The CPR Acquis process is ongoing, and binding interpretations are still missing. At the same time, the EPBD states that the life-cycle GWP indicator for building-level carbon declaration, in the energy efficiency certificate, may be complemented with "information on carbon removals associated with the temporary storage of carbon in or on buildings". Whether this information needs to be reported as elementary carbon or $kgCO_2e$. is not clarified.
Furthermore, EPBD implementation also necessitates the addressing of carbon removals associated with carbon storage in or on buildings, however without specifying a method yet. While this requirement assumingly refers to long-term removals that could mostly be considered relevant for the carbon permanently bonded in concrete and cementitious products, however, biobased materials and products in construction can also offer a potential long-term storage of carbon biogenic such as the use of biochar and/or the multiple reuses of timber and other biobased elements, if they can be legally guaranteed. Combining the currently used indicators GWP-total or GWP-GHG with information on biogenic carbon stored in buildings is an important first step in improving modular comparability and adapting to future European requirements.

Building parts included: The decision on what building parts should be included in carbon assessments is related to the chosen life cycle scope. For example, when a scope is limited to upfront emissions A1-A5, the structure tends to be more important, while including the use stage makes short-lived components more relevant. Main differences among Nordic countries and Estonia concern site preparation, building services, external works and furnishing. Finland and Denmark include most building services, while Boverket suggests excluding solar panel installations in the Swedish limit values in 2025.

Exported energy: Member States must ensure the installation of suitable solar panels on new buildings as a consequence of promoting on-site renewables in the REPowerEU plan. The increasing amount and relevance of on-site renewable energy production requires appropriate calculation rules to account for the benefits of exported energy. 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 ongoing revision of EN 15978 is expected to provide definitions for reporting exported energy in the new module D2 "Exported utilities". It allows two approaches for allocating building generated energy production. In Approach A all impacts of the energy generating equipment is allocated to the building life cycle. In Approach B, only the proportional amount of impacts of the equipment corresponding to the energy consumed in the building is allocated to the building life cycle). These two approaches can lead to considerably different results, if a large share of the energy generated on site is exported. For harmonising results and steering effects, the Nordic report on data (Erlandsson, et al., 2024) recommends Nordic countries to use Approach A.

Use of future decarbonisation scenarios: Scenarios for a gradual decarbonisation of energy supply are applied in the Danish 2023 carbon limit value, and are being prepared or updated for Estonia, Finland and Sweden. The purpose are future carbon declarations and limit values and implementing upcoming changes in the EPBD. The updated emission factors for the next generation of Danish limit values in 2025 show significantly lower impacts compared to current emission factors, resulting in lower relative impacts in module B6 compared to other parts of the life cycle (Tozan, et al., 2023) and indicating the need to consider major changes in energy projections when developing and revising limit values. However, assessments in Nordic countries and the EU can only be comparable when using a common base for deriving the decarbonisation scenarios. The European Commission has developed high resolution scenarios based on national information and political decisions, which can therefore be used throughout Europe as a common source of data. These scenarios are derived from the PRIMES (Price-Induced Market Equilibrium System) model which is also recommended by LEVEL(s) framework. This does not mean using the PRIMES-based scenarios in the regulation, if a national regularly updated energy scenario exists, created by the national regulators, as the incentives and regulation for the decarbonisation of the energy sector differ country by country. To maintain both comparability and the use of more specific national scenarios, the Nordic experts on data within the Nordic Harmonisation project (Erlandsson, et al., 2024) recommend a double reporting since the scenarios selected can make a remarkable difference in the results.

It is worth mentioning that the development of district heating decarbonisation scenarios is complex, especially when the use of local data is allowable. If the operator refuses to disclose information on future investments, it is impossible to make reliable predictions regarding the local grid's future decarbonisation. Aside from this complexity, the question of whether only national averages must be used, or the specific emissions of a local grid can be considered is also dependent on how much the location of buildings should be affected by carbon limit regulation.

Unlike energy supply in module B6, no Nordic country has considered mandatory decarbonisation scenarios for the remaining modules (B1, B2, B4, B5, C1-4) yet with the exception of voluntary frameworks like FutureBuilt and the 2025 DGNB Denmark pilot. The Nordic report on data[8] presents a simplified concept to include future decarbonisation scenarios in the assessment focusing on providing the best estimation possible to create a decision support given existing knowledge and uncertainty.

Conservative standard impact data 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 other actors (For instance, the standard component library in LCAbyg 2023 (Kanafani, Zimmermann, Stranddorf, & Garnow, 2023),the question is what standard solutions may be used directly in carbon declarations and what the allowed deviation between standard and the specific as-built solutions must 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 structure and supply of these standard solutions and their status in a regulation perspective.

Conservative generic impact data for construction products: Most Nordic countries have already developed a national database of generic emission factors, see **Table 14**. Generic data allows modelling complete inventories independently of the availability of EPD. This is especially important in early design stages, but also in as-built reporting, where specific data is currently lacking for numerous products. Conservative impact levels are key to encouraging building product manufacturers to publish EPDs and assessors to using specific rather than generic data. This incentive principle is important in the current regime, where the use of EPDs cannot be required by legislation due to EU market rules. Potential areas for harmonisation include areas that are not specified in the standardised calculation rules such as EN 15804, in particular 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 for developing generic data has considerable harmonisation potential. Instead of providing a single generic impact level, one option is to provide a lower and upper emission level of selected products. Another difference in current generic values is the definition of the conservative level. Estonia and Finland use the average value of a sample of products plus 20%, while Norway and Sweden use 25%. Denmark defines conservative values as the upper quartile of a given EPD sample and multiplies it by 1.1. Also, the level of detail in product variants differs such as the variety 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 and spruce.

Service lives of building components: Scenarios for B2 to B5 are often based on time intervals, dependent on on-site conditions or other parameters. However, information on interval definition is often hard to verify, so some countries require the use of default information. It is difficult, however, to conduct a systematic comparison of assumptions about the service lives of building components between countries when making carbon declarations, due to varying ways of describing and classifying building components and defining service lives. Finland provides both a short and normal component service life for relevant building parts to account for a higher wear-and-tear in certain highly frequented buildings such shopping malls and schools. Denmark uses an approach of assigning service life on the main material and the location of installation in the building. Norway recently acknowledged that the use of varied sources for service lives for building products causes variations in climate impact results, and in response, the committee responsible for revising the Norwegian national standard NS 3720:2018 has initiated work to publish harmonised reference service life values in 2024. The EU Level(s) framework also includes a table of suggested service life values, which indicates a potential upcoming EU harmonisation of component service life.

__Table 13__. Essential national methodological choices in terms of indicator, scope and accounting (as of June 2024).

Methodological choices in Nordic regulations		Denmark	Estonia	Finland	Iceland	Norway	Sweden		Europe
		2023/ 2025	**2022**	**2023**	**2025**	**2022**	**2022**	**2025**	**2024 (EPBD)**
General	**Reference unit definition**	**GFA** for embodied **HFA** for operational	**HFA**	**HFA**	**GFA**	**GFA**	**GFA**	**GFA**	**UFA**
	GWP indicator	**GWP-total**	**GWP-fossil** and **GWP-total** (most likely)	**GWP-total**	**GWP-total**	**GWP-GHG**	**GWP-GHG**	**GWP-GHG**	**GWP-total**[5]
	Handling of biogenic carbon	**-1/+1 method** not handled separately yet	**0/0 and -1/+1 methods** not handled separately yet	**-1/+1 method** also separately (GWPbio) and in carbon handprint (D4)	**-1/+1 method** also separately as per EN 15804+A2 (GWPbio)	**0/0 method** not handled separately yet	**0/0 method** not handled separately yet	**0/0 method** not handled separately yet	**-1/+1 method,** temporary carbon storage may be reported (Annex V)
Assessment scope	**Life cycle modules considered**	**2023: A1-3, B4, B6.1, C3-4**; D1 & D2 separate declaration **2025**: **A4-5** added individually	**A1-3, A4, A5, B4, B6.1, C3-4**; D1 & D2 separately	**A1-3, A4, A5, B4, B6.1, C1, C2, C3-4**; carbon handprint separately	**A1-3, A4, A5, B4, B6.1, B6.2, C1, C2, C3-4**; D1 separately	**A1-3, A4, A5** (only waste), **B2, B4**	**A1-3, A4, A5**	**A1-3, A4, A5** (planned to include B2, B4, C1-4 from 2027 in carbon declaration)	full life cycle scope; the Delegated Act will specify the minimum modules required
	Building model parts included	**Substructure** (piling: allowance for exclusion) **Superstructure** **Building services** (without electricity and firefighting systems) **External works** (partly)	**Substructure** **Superstructure** **Building services**	**Substructure** (foundations: only declaration or excluded[1]) **Superstructure** **Building services** **Furnishing** (only fixed)	**Substructure** **Superstructure** **Building services**	**Substructure** (only pile and shallow foundation) **Superstructure** (without stairs, ramps and balconies)	**Substructure** **Superstructure** **PV panels**	**Substructure** (piling: only declaration from 2027) **Superstructure** **Building services** (for some building types; PV panels: only declaration from 2025) **Furnishing** (only fixed, for some building types)	EPBD refers to LEVEL(s): **Substructure** **Superstructure** **Building services** **External works**[3] **Furnishing**

Methodological choices in Nordic regulations		Denmark	Estonia	Finland	Iceland	Norway	Sweden		Europe
		2023/ 2025	2022	2023	2025	2022	2022	2025	2024 (EPBD)
Other	Exported energy calculation	Inclusion of max. 25 kWh/m^2/year renewable energy (embodied + operation)[2]	To be clarified	Exported energy is part of D3	To be clarified	Not applicable	Not applicable	Exclusion of solar cells (embodied + operation) in the 2025 limit value, and only separate reporting	prEN 15978 proposes two approaches[4]; The Delegated Act may require a specific approach
	Handling of long-term carbon removals	Not yet specified	Not yet specified	Not yet specified	Not yet specified	Not yet specified	Not yet specified	Not yet specified	Must be addressed, no further specification of a method yet (Article 7)
	Template to use when reporting the LCA	Voluntary template to help more uniform submissions (the 2.0 Standard format for LCA delivery) (BR18 - Bygningsreglementet, 2021)	Not yet specified	Not yet specified	online reporting format	No specific format	mandatory data reporting format prepared by Boverket		requires a digital logbook (no specification yet)

1. together with the foundations, it is also investigated whether site preparation and external areas will be only declared or fully excluded.
2. no distinction between self-consumed and exported renewable energy.
3. While LEVEL(s) includes external works, EPBD directive only covers the building, it may be assumed that external works are excluded from the inventory scope of the EPBD carbon declaration.
4. Approach A where embodied impacts of energy-generating systems are fully allocated to the building (exported energy is shown in module D2 as emissions-free) and Approach B where a proportional allocation takes place.
5. Level(s) requests for detailed subdivision as per 15804+A2

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__Table 14__. National choices of critical scenarios, use of generic emission factors and standard values (as of June 2024).

Generic data and scenarios in Nordic regulations		Denmark	Estonia	Finland	Iceland	Norway	Sweden	Europe
		2023/ 2025	**2022**	**2023**	**2025**	**2022**	**2022/ 2025**	**2021/ 2024**
Decarboni-sation scenarios	**Energy decarbonisation scenario for B6 (operation)**	**Yes** 2023: Danish national policy scenario (2020) 2025: new national policy scenario[1]	**Yes** Estonian national policy scenario (2023)	**Yes** Finnish national policy scenario (to be updated 2024/Q3)	**No** Iceland already has 99% renewables and district heating	**Not relevant** B6 is excluded from the scope.	**Not relevant** B6 is excluded from the scope. May become relevant from 2027 where carbon declaration is planned to include B6.	**Yes** Level(s) chooses EU PRIMES model (EU Reference scenario)
	Decarbonisation scenarios for B/C modules (embodied) [2]	**No**	**No**	**No**	**No**	**No**	**No**	**No**
Generic emission factors	**Data source (base)**	Table 7 in Appendix 2 of BR18, §297	Approved national generic data expected in 2024	CO2data.fi	no national generic database for building products yet, EPDs or other generic databases are used	no national generic database for building products, EPDs are used	Boverket's climate database	No specific plans for development of a common European database
	Conservative emission factors	New generic data for specific product types are based on the 75% percentile of related EPD Danmark values[3]	1.2	1.2 but not for energy and fuels emission data	1.25 added only if not already included	1.25 added only if not already included	1.25 but not for energy and fuels emission data	No specific proposal

Generic data and scenarios in Nordic regulations		Denmark	Estonia	Finland	Iceland	Norway	Sweden	Europe
		2023/2025	2022	2023	2025	2022	2022 /2025	2021/2024
Standard values	**Building elements**[4] **($kgCO_2e/m^2$)**	**Building services** (for A1-3, C3-4: 33-62 $kgCO_2e/m^2$; range due to differences per building type)	**Building services** (for A1-3: 42-125 $kgCO_2e/m^2$; for B4: 6,1-141 kgCO2e/m^2; range due to differences per building type) As a rule, CO_2 data.fi also includes C3, D, but not for the broad standard values for building services available per type of building		**Building services** (for A1-3: 56-94 $kgCO_2e/m^2$; range due to differences per building type)	**Not relevant**	**2022: No** **2025:** **Building services** (for A1-5: 12-60 $kgCO_2e/m^2$) **Internal finishes and furnishing** (for A1-5: 22-53 $kgCO_2e/m^2$)	No specific proposal
	Life cycle modules[4]	**No**	Under investigation	**A4**, C2 (20,4 $kgCO_2e/m^2$) **A5** (43-59 $kgCO_2e/m^2$) **C1** (10 $kgCO_2e/m^2$)	**A4** (19.8 $kgCO_2e/m^2$) **A5** (42.5 $kgCO_2e/m^2$) **C1-C4** (43.75 $kgCO_2e/m^2$) **B6:** average data on energy consumption	**No**[5]	**Yes**, derived from a study, but only provided as a guide, project-specific values must be used.	No specific proposal

1. the new scenario reflects 2022-2050 projections by the Danish Energy Agency (DEA), which also incorporate political objectives and not just approved investments (frozen policies); this results in factors being reduced by nearly 40%, 80% and 45% for electricity, district heating and gas, respectively (Nilsson, Høibye, & Maagaard, 2023)
2. Although this aspect is not currently integrated into any of the mandatory methods in Nordic countries and Estonia, it is part of some national voluntary methods such as the FutureBuilt Zero method in Norway. 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; (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. Such considerations are also seen in the new draft DGNB method in Denmark which applies an 1% annual technological improvement factor (on top of a time factor), (Green Building Council Denmark, 2024)
3. see: Kragh, J., & Birgisdottir, H. (2023). Udvikling af dansk generisk LCA-data. (1 ed..). BUILD Report 2023:16
4. standard values for building elements are usually provided per building type and life cycle module. The sources of the provided values (building elements and life cycle modules) and other values from recent studies done in Sweden and Denmark can be found in Appendix B.
5. A5 can be given as a% of A1-4 and varies per material type. Standard values in terms of transport distance and other parameters can be used for A4.

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4.3 Influential variables for limit values

- Current approaches to carbon declarations and limit values vary in terms of included building parts and processes, especially deep foundations, external works, building services, interior finishes and refrigerants. Harmonisation should focus on deep foundations, external works and building services, as they represent the most significant variability.
- The question frequently is raised as to whether carbon limits should not influence the choice of location, which would potentially result in location-sensitive factors such as module A5, special types of foundation and soil stabilisation, as well as basement parking and outside areas being excluded from the assessment scope, or alternatively treated with separate limits and exemptions for extreme cases.
- All countries use different definitions for the building reference area and whether or not it includes basements, balconies, circulation areas and external walls. Further, basements and balconies may lead to higher or lower total impacts, depending on the overall carbon level. Harmonisation and improved comparability can be approached by developing a common definition for the "useful floor area" for preparing the implementation of EPBD and Level(s) that can be used in parallel with already well-established national definitions, or by providing conversion factors between national definitions.
- Expected future changes in module B and C scenarios or delayed emissions are approached differently in the Nordics. Despite the trend to apply a decarbonisation scenario for operational energy impacts in module B6, no national method in the Nordics have implemented dynamic scenarios for replacements and waste treatment. A harmonisation effort should be discussing how these approaches could be aligned and if the French method of discounting future emissions has the desired steering effect.
- Large differences are observed between generic emission factors found in Nordic national databases. This partly reflects actual differences between products found on each national market, but part of the difference also relates to differences in approaches to derive conservative generic emission factors.
- Finally, the building stock analyses for deriving carbon limits has a significant influence on the comparability of regulation. Harmonisation may lead to common criteria for defining building stock representativity, so that potential archetypes and building samples can be developed and selected on a common basis in order to limit cross-national differences to actual variation in the stock and not method.

Several features of the LCA method and the data used to set and assess limit values influence the level of these limit values and the possible outcomes of the assessment.

Data involves both the building cases (and their characteristics) used as a basis to derive the limit values, and the product-level data used for calculating the impact of the building cases. This section gives an overview of some of the most important methodological points that must be considered in the process of setting limit values. It builds on published analyses in Nordic countries as a primary focus, supplemented by illustrative calculations when necessary to further highlight the potential importance of certain variables.

4.3.1 Building and life cycle scope

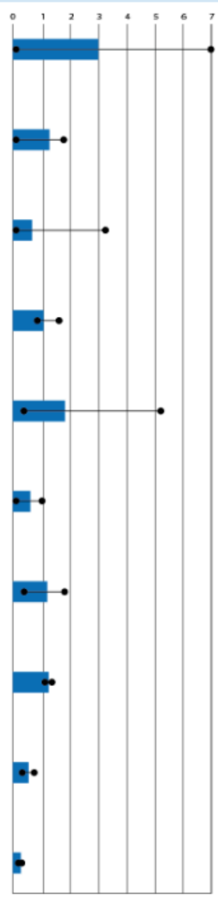
Table 13 – which presents an updated and summarised version of the comparative mapping of various aspects and details causing variation in Nordic methods provided in the report "Harmonised Carbon Limit Values for Buildings in Nordic Countries" (Balouktsi, Francart, & Kanafani, 2024) – shows that current Nordic climate regulations or proposals apply varying parts of the life cycle and differ in the building components included. It is important to understand the scale of limit value variation caused by the incompatibility of scopes. Furthermore, it is important to understand what it means for an initial limited limit value scope to expand with more modules and building parts in future revisions, considering that (a) in some Nordic countries this is already planned or investigated, as well as (b) the declaration of a whole life cycle scope and a minimum scope for building description for building carbon footprint will be requested by the revised EPBD from 2028. On the other hand, the scope of the initial and progressing limit values in the required national roadmaps according to EPBD by 2027 is still unclear. Often raised questions relating to scope include:

- **Site preparation, soil stabilisation, site reinforcement and special foundations:** Special foundations like piles are referred to as part of the minimum scope in Level(s) but are often omitted in Nordic carbon declarations and even more so in carbon limits. Depending on soil conditions, their impact can become a significant hotspot (Aspect 1, **Figure 11**). An exclusion would remove a relevant process from regulation, however their inclusion will create a steering effect towards building in locations with acceptable soil conditions and challenge the freedom of choosing land for development.
- **Parking basements:** When including both their relatively large floor area and minor material inventory, the relative contribution of parking basements will currently often lead to a lower climate impact per m^2. However, in a future low-carbon construction context, parking basements will no longer provide an easy way to meet limits, because they offer limited opportunities to reduce impacts (Aspect 2, **Figure 11**) A regulatory option would be including only a share of their floor area in the reference area, or reporting them separately with a different limit value than the rest of the building. Level(s) specifies that if parking basement accounts for more than 25% of the total useful floor area, the traffic area of the parking must be subtracted from the total useful floor area.
- **External works:** External works can make up a significant share of total impacts, depending on building type and the included elements such as infrastructure,

landscape or secondary constructions (Aspect 3, **Figure 11**). Their potentially large contribution and mentioning in Level(s) makes it important to define the exact scope of "external works". They generally cover any area outside the building footprint but within the site boundary and can include ground-level elements such as hard and soft landscaping, terraces and roofs as well as below ground items, such as irrigation tanks. External structures may use varying types of materials and require maintenance based on traffic. They may also include solar or geothermal energy generation as well as carbon sequestration by vegetation or carbon removal through concrete paving carbonation, affecting both B6 and B1 modules respectively.

- **Construction site impacts:** The impacts can be significant and can exceed module B6 in case of low-carbon energy supply (Aspect 4, **Figure 11**). Some Nordic countries already apply calculation rules for module A5, but use diverging scopes. All include energy and fuel consumption, except Norway, which only includes waste (while fuel consumption is regulated by not permitting the use of oil to heat on construction site). Sweden excludes ground works and therefore a considerable share of fuel associated with it. Differences in regulation approaches for module A5 reflect the fact that carbon emissions are strongly influenced by location, both regional and international, due to energy grids, material supply, geology and other factors. A regulation approach, which is willing to influence choice of site, module A5 may include site-sensitive processes based on energy and fuel consumption. When carbon limits should not interfere with the choice of location, A5 may have to be restricted to material wastage alone. A more universal alternative is developing a separate limit value for module A5 for avoiding interference with other modules, eventually differentiated by regional differences such as climate.
- **Building services:** Their impact can be significant in buildings such as institutions or offices, which is due to the use of metals and electronic components that need to be replaced during the building's service life. Considering the leakage of refrigerant fluids in the use stage can also influence the results, since these are potent greenhouse gases (Aspects 5 and 6, **Figure 11**). The new EU Regulation 2024/573 on fluorinated greenhouse gases will limit GWP to 750 kg CO_2e/kg from 1st January 2025 for new systems and maintenance of existing ones will reduce the significance of refrigerant impacts.
- **Internal finishes and fixed furniture:** Internal finishes (i.e., wall paints, flooring materials and suspended ceilings, among others) are expected to be included in the scope of all Nordic countries by 2026 (and are already included in Denmark and Norway), while fixed furniture has only been so far planned to be considered in Sweden and Finland. Like building services, the impact of finishes and fixed furniture can be significant primarily because of the need for replacement and maintenance in the Use stage (Aspect 7 and 8, **Figure 11**) Therefore, assumptions about replacement frequency considerably influence their calculated impact. Finland has notably introduced differentiated service lives for certain elements depending on the building type, where schools and offices will have a higher replacement frequency for partition walls and floor surfaces compared to housing.

- **Maintenance and other often neglected life cycle modules:** B2 typically has a low relative importance (Aspect 9, [Figure 11]), but is useful for demonstrating the advantages of low-maintenance buildings. It may also encourage producers to state this information in EPDs. Beyond climate impact, maintenance-intensive products can have a great effect on life cycle cost and other environmental and health-related indicators. C1 and C2 typically have low importance but are intended to be included in some assessment scopes for completeness (Aspect 10, [Figure 11]).



		LCA scope aspect (building part and/or LC process)	Absolute impact (kg $CO_2e/m^2/yr.$)	(Average) median	Notes
Context- and location-specific aspects	1	**Building part:** Deep foundations/ Soil stabilisation (A1-3)		2.90	based on a Finnish study by OneClick LCA Ltd (2021) and BUILD report 2020:04, with the latter not including soil
	2	**Building part:** Basement parking (A1-3, C3-4)		1.20	based on a Finnish study by OneClick LCA Ltd (2021) and three Danish cases with a basement parking (BUILD report 2023:21)
	3	**Building part:** External works/ Landscaping		0.50	the mean value is based on a Finnish study by OneClick LCA Ltd (2021) and the highest value on ZEN report 2020:24
	4	**LC process:** Construction site (A5)		1.00	based on a Danish study of 52 construction sites (BUILD 2023:21)
Other often missing aspects	5	**Building part:** Building services (A1-3, A4-5, B4, C3-4)		1.80	based on the standard values given in Denmark (A1-3, B4, C3-4), Finland (A1-3, B4), and Sweden (A1-5) per building type
	6	**LC process:** Refrigerants (B1)		0.58	based on a Danish study of 10 cases which assumes 2% annual leakage rate (BUILD 2023:23)
	7	**Building part:** Fixed furniture (A1-5, B4)		1.10	based on the A1-5 standard values given in Sweden per building type (Malmqvist et al. 2023) and an estimation for B4
	8	**Building part:** Internal finishes (A1-5, B4)		1.20	based on the A1-5 standard values given in Sweden per building type (Malmqvist et al. 2023) and an estimation for B4
	9	**LC process:** Maintenance (B2)		0.46	based on a Danish study of 10 cases (BUILD 2023:23). The median value is more than halved if glass replacement is in B4.
	10	**LC process:** Deconstruction and transport (C1, C2)		0.17	based on a Danish study of 10 cases (BUILD 2023:23) and the standard values considered in Finland

Figure 11 *Impact of excluding building parts and life cycle modules from the limit values scope, selected based on the countries' differences identified earlier. The studies used as a basis are presented in Appendix A. The values are indicative as the number of studies is low as well as the include various scopes and background data. If more than one study is used as a reference the average of the median values in the considered studies is taken into account.*

4.3.2 Building reference area

LCA methods used in the various Nordic countries use varying reference area definition to normalise the results per m^2, see the report "Harmonised Carbon Limit Values for Buildings in Nordic Countries" (Balouktsi, Francart, & Kanafani, 2024)[2] for details. Differences occur regarding the inclusion of

- External walls
- Basements
- Stairs, corridors and common facilities
- Rooftop terraces, balconies and other areas outside the building enclosure

The significant influence of area definition is illustrated in **Figure 12** for an apartment building calculated using different reference unit areas, while keeping all other parameters, especially different national inventory scope, constant. Area definition affects the influence of certain building design choices. In mid-carbon level buildings, basements will decrease emissions per area unit, unlike low-carbon buildings, where basement have the opposite effect. Currently, all Nordic countries include basements in their reference area, although Finland and Estonia only include heated or semi-heated ones. In the case for having balconies in Finland, Norway and Sweden, where balcony area is omitted from the reference area, the emissions per m^2 slightly increase. In Denmark, balcony area is included with only 25% in order to avoid disproportionate influences of balconies and other external areas on the overall building impacts, and therefore a smaller increase in normalised impacts is observed.

None of the Nordic countries currently applies the "useful floor area" definition from Level(s) framework. As the revised" - i.e. As the revised EPBD calls for more harmonisation of building LCA at the EU level, results should ideally be reported per useful floor area, at least in addition to the reference area used in each country. It remains to be seen whether the Delegated Act implementing the EPBD will call for a uniform use of useful floor area or allow for different national reference areas; the Nordics could work towards a common unit definition by 2025 along with continuing use the national one, to be ready for an implementation of the EPBD by 2028 or could examine possible conversion factors between national definitions.

2. Please note that for Finland, Table 6 of this report incorrectly includes balconies as part of the heated reference area.

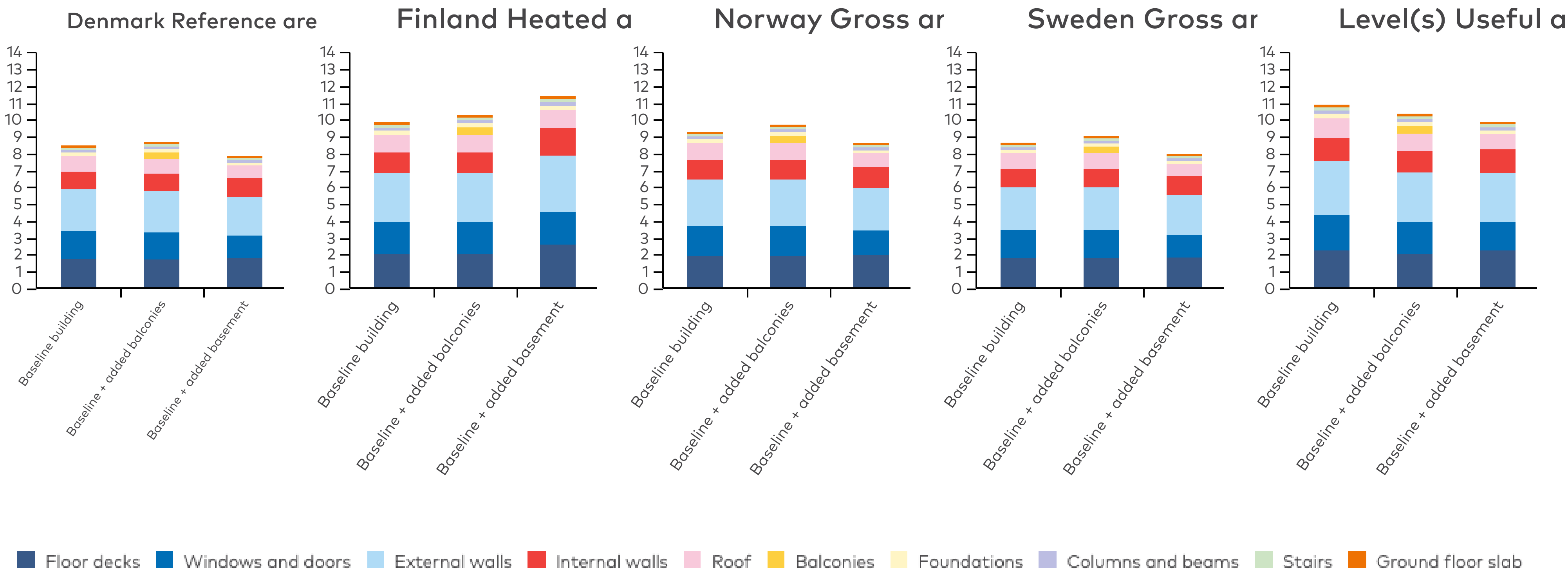


***Figure 12** LCA results for an apartment building (without basement or balconies), and for the same building with added unheated basement and added balconies, normalised using different definitions of reference area units from the Nordic countries and Level(s) (see Table 6 of report "Harmonised Carbon Limit Values for Buildings in Nordic Countries" (Balouktsi, Francart, & Kanafani, 2024)). Note: the scope of the life cycle inventory and the background impact factors are similar in all cases. Only, the reference area changes. Norway is the only country not including "Balconies" and "Stairs" in the method scope, but they are included here to focus on differences solely coming from the area definition.*

Because of many system boundary variations, employing a common useable floor area definition does not produce comparable carbon declarations; however, combining it with disaggregated reporting into life cycle stages and building elements provides a first good step towards this direction. Furthermore, differing secondary conditions connected with useable floor areas, such as temperature limits for heated areas and variances among countries, would also necessitate changes which is connected to additional challenges for the industry and the overall national statistics currently based on energy certification register.

Although all limit value definitions are based on a reference area, other complementary ways of normalising LCA results are being discussed in the Nordic countries. If suitable data are provided, this can easily be addressed digitally. In particular, normalising results per resident or building user could help account for how efficiently the space is used. Space sharing and compact housing strategies are seen as essential to deep decarbonising the building sector, whereas targets normalised per m^2 do not stimulate better space utilisation. Since area-based metrics are easily verifiable and appropriate to assess a building's technical properties, it can be appropriate to combine them with complementary use-based metrics.

4.3.3 Future scenarios in B and C modules

Assessing future life-cycle modules occurring after handover, involves making assumptions on component service lives and end-of-life processes including both the technological and regulative context, which may be outside the realm of building regulation. Unlike assuming current practice for scenarios, a recent trend includes making assumptions on the expected future development of boundary conditions. The decision for or against using dynamic scenarios reflecting technological progress in modules B and C, or applying discount factors for future emissions, substantially impacts the steering effect of carbon limits.

Discounting factors: The simplified dynamic approach in the French RE2020 regulation increases the influence of current emissions over future emissions. Essentially, one tonne of CO_2 emitted today is considered to have a larger climate impact than being emitted in 2050. The EN 15978 and Level(s) method under revision may allow national legislative approaches including dynamic scenarios, however no consensus exists on how discounting factors will be designed. Figure 13 (a) illustrates the significant influence of dynamic scenarios on results. Here, a typical Danish single-family house is calculated with the same data without discounting material impacts according to current legislation and with the French time-dependent factors applied. The main argument against the discounting approach is that it leads to negative impacts for wood products, because the biogenic carbon neutrality according to EN 15978 is lost (-1/ + <1). This leads to beneficial incentives for using large amounts of wood instead of using renewable resources more efficiently.

Technology improvement factors: Although no national carbon declaration method considers any future technical progress for post-handover modules other than B6, voluntary methods exist that address future developments in modules following simplified approaches (i.e., considering one or two variations of technology factors), such as the FutureBuilt method in Norway[3], the RICS method in the UK[4] and the upcoming DGNB method in Denmark[5]. The pros and cons in using decarbonisation scenarios for B and C modules are provided in the Nordic report on data (Erlandsson, et al., 2024). The main risk is applying too-good-to be true scenarios that imply that nothing or little needs to be done to lower the impact from the use stage. The approach proposed in this report is to apply a decarbonisation (scenario) factor for each year (i.e., multiply by the GWP indicator) that is representative for any resource used in the building sector today but without applying this factor to the calculated future climate impact from the use of products with inherent carbon (fossil as biogenic). This follows the rationale of the RICS approach.

Although the development in emission intensity from material production will depend on material types, simplified approaches are useful considering the high uncertainty of all the industry roadmaps and related scenarios. However, there are studies offering detailed analysis per material type, and therefore how the consideration of such issues in the emission factors of future construction products may look (Alig, Frischknecht, Krebs, Ramseier, & Stolz, 2021). According to a Swiss study creating future emission factors for several material types, a Swiss office building calculated dynamic effects in future replacements and End of Life (EoL) (B4, C3-4), has 20% lower impacts (See Figure 4.7 from the report: (Lützkendorf & Balouktsi, 2023)). When applying EU-wide decarbonisation scenarios for modules B and C to the present SFH case results in a decrease of 10-15% (**Figure 13b**). The significance of this effect raises the question, if a partial decarbonising factor for only one process such as B6 can be justified due to a potentially misleading incentive. Erlandsson, et al., (2024) recommends using one decarbonisation scenario for modules B1.2-B5, B7, and C1-C4 for simplicity, on the side of the typically used decarbonisation scenarios for B6. [6]

3. FutureBuilt Zero follows a simplified approach, where: (a) a technology factor of 0.33 is assumed for the production of PV systems in year 30; (b) for other material-related processes (production, transport and waste incineration) an 1% annual technology development is used 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 is assumed to be greater (Resch, et al., 2022).
4. The updated RICS method which forms the basis of future regulations in the UK proposes an additional reporting with a partial use of simplified decarbonisation scenarios, where for B1 associated with fugitive refrigerant emissions, B4, C1-2 and D1 a 0.5 decarbonisation factor is applied. No decarbonisation is considered for: (a) biogenic or LULUC carbon emissions at the end of life of biobased material, as well as fossil carbon emissions at end of life from incineration or energy recovery (for example from plastics), as they are a function of their carbon content, unless carbon capture, usage and storage (CCUS) is used (no rules in Europe about how to include CCUS scenarios as part of the calculation of impact so far are present); (b) removals by materials such as concrete in B1 as they are a function of the original materials installed and not subject to change over time. Refrigerant emissions are, however, assumed to decarbonise over time due to replacement with less harmful refrigerants.
5. DGNB intends to account for a dynamic effect of climate impact, including both a time aspect for where-when an emission takes place, as well as an estimate for the technological development of material production (assumed as 1%).
6. The suggested scenario to use for modules other than B6 is the EU Prime scenario called "Total GHG emissions, excl. international excl. LULUCF".

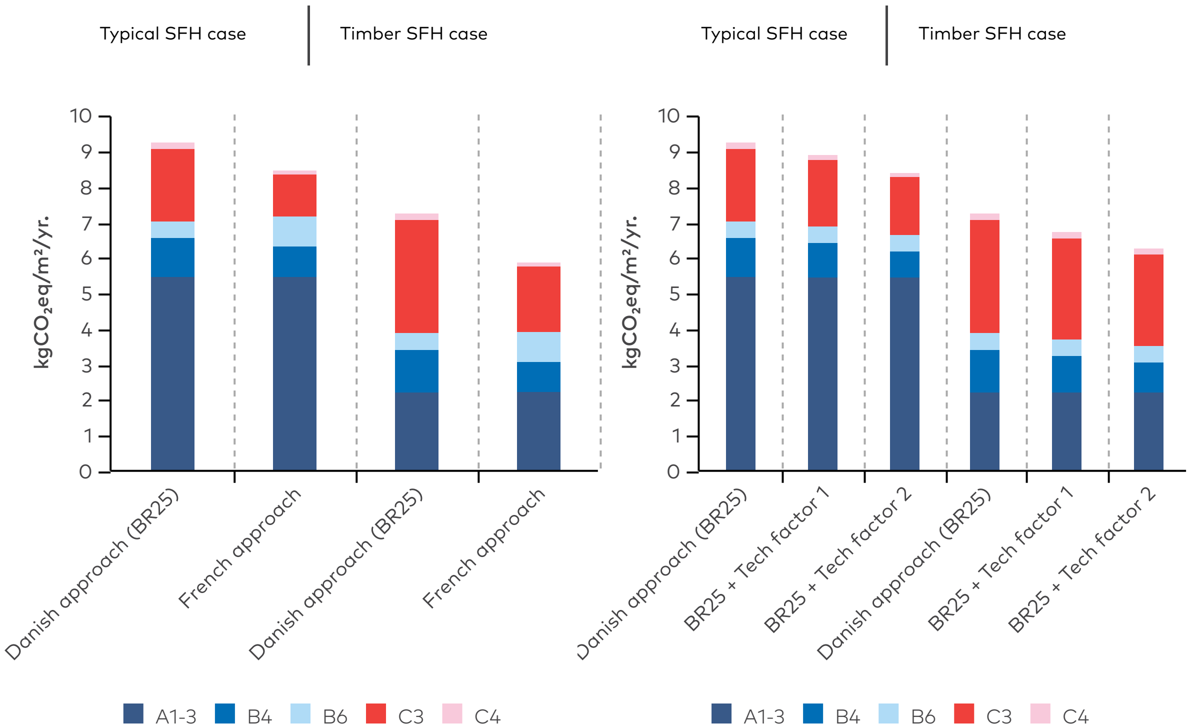


Figure 13 *(a) Effect of discounting future emissions according to the French approach for two different construction types of a single-family house (SFH), calculated with the updated Danish generic emission factors (to be in force for the 2025 building regulation/BR25) and scope; b) Effect of using simplified decarbonisation scenarios according to EU Calc Reference Scenario (Tech factors 1, corresponding to 1.20% annual improvement for the main products, i.e. minerals and metals) and EU Calc Tech scenario (Tech factors 2, corresponding to about 2.50% annual improvement) which provide the decarbonisation rates of energy in industry including steel, cement, lime, wood etc. The balance -1/+1 is preserved for wood in (b).*

4.3.4 Generic emission factors for construction products

Variation in current national generic emission factors affect impact results considerably. In the shown example (**Figure 14**), the largest deviation in results is 28% and occurs with data from Denmark and Sweden for modules A1-3.

Some of the differences between generic emission factors rely on actual product differences in national markets and eventually from import. The other part of the differences comes from different assumptions and methods behind generic data. Generic data is commonly set on conservative emission levels in order to maintain the incentive for developing product-specific data. Countries use different approaches to define this conservative margin as previously shown in **Table 14**, which have a major influence on limit values. These aspects are feasible to harmonise across countries (see the Nordic report on data (Erlandsson, et al., 2024) for more detailed recommendations):

- Collecting a sample of product EPD based on common selection criteria and data structure. This cross-national data foundation can then be adjusted for emission levels based on regional market characteristics to reflect national representativeness.
- Countries that are interested in developing a generic database for construction products in the Nordic region can join efforts and create a generic database for low-volume construction products that can be shared among several countries. One or more product EPDs can be selected as representative for the products consumed on the Nordic market.
- The level of conservative factors can be defined jointly. Although the use of conservative values is justified, it should be as small as possible. Conservative factors should be a temporary measure and phased out after the initial stage of carbon regulation in order not to overestimate building impacts. In the long run, voluntary EPDs will be replaced by a mandatory declaration according to EU product regulation (CPR), removing the demand for conservative factors and improving the possibility of assessing and monitoring the real impact levels.

Regarding the latter, significantly tighter limit values encourage the use of product-specific EPDs in the meantime, because they enhance the chances of meeting the requirements. The calculation for Denmark, shown in **Figure 14**, has been based on the updated Danish impact data for energy supply services and construction products, which will be effective from 2025. However, the overall performance does not align with the newly established value of 6.7 $kgCO_2e/m^2$/year for single-family houses as of 2025. To ensure compliance, it will be necessary to utilise product-specific data and make better design choices.

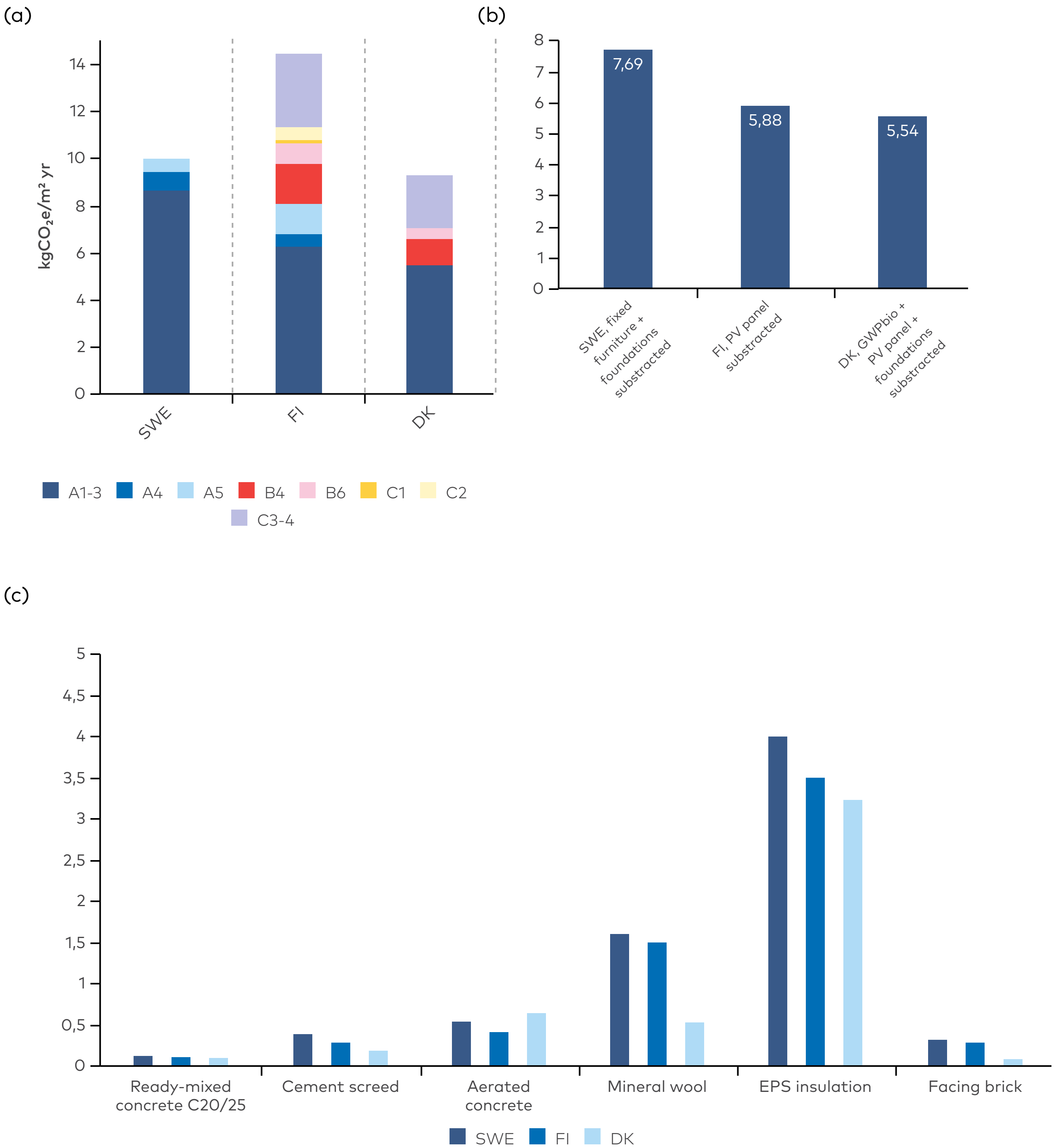


Figure 14. *LCA results for a single-family house with aerated concrete walls, normalised using the same reference unit area and applying: (a) the different scopes in terms of life cycle modules and building parts and generic emission factors from Denmark, Finland and Sweden; (b) the same scope (i.e. parts are excluded from each method to reduce to the same building model) to detect the differences coming from data; (c) Examples of differences in generic emission factors for the products explaining the biggest share of the variation in this particular building case. Note: the new Danish data is used for this calculation, which is not yet integrated into Table 7 of BR18 (Kragh & Birgisdottir, 2023). The new Danish independent limit value for the construction process, A4-5 (effective from 1 July 2025), corresponds to an additional 1.5 kgCO$_2$e/m^2/year and is not shown in the graph (a). The percentual values represent the differences between SWE and DK data. Underlying figure data are provided in Appendix B.*

4.3.5 Approach used to set the limit value

There is no standardised approach for selecting and analysing reference data for deriving carbon limits. Current approaches broadly include are either based on an archetype or sampling method, see also Section 3. Building stocks are complex and vary in many ways, requiring a deliberate method for justifying building carbon regulation. Apart from building properties such as use, size, typology, construction principle or location, building age is particularly sensitive as it reflects the decarbonisation progression. A maximum completion age of, for instance, 5 years is necessary to achieve a representative temporal representativity. However, even by doing so, the building sample would still reflect regulations which are around 6-8 years old, measured from building permit and representing the construction approach of around 7-10 years ago in terms of design and technology.

Examples of sampling and archetype approaches: The background reports from Denmark (Tozan, et al., 2023) and Sweden (Boverket, 2023) represent sample approaches by basically applying repetitive case studies. Representativity increases with the number of cases and the possibility of adjusting the case selection based on the data analysis. The cost-effectiveness and accuracy will also increase, as the sample size grows with mandatory carbon declarations and a systematic case collection. The Danish approach for determining carbon levels from the sample is a progression from the reference year 2023, where 90% of buildings are meant to comply with the lowest level in 2029, with which 10% of the building reference should comply. It was recently agreed (May 2024) that the 2025 threshold along this progression corresponds to 15% of the existing building reference sample should be able to be adhered to (Danish Ministry of Social Affairs, Housing and Senior Citizens, 2024). The archetype approach has been applied in recent EU (Lavagna, et al., 2018; Le Den, et al., 2023) and national projects (Utstøl & Marwig, 2022; Nørsterud, Andvik, & Fuglseth, 2023; One Click LCA Ltd, 2021; Buschka, Bischof, Meier-Dotzler, & Lang, 2021). It allows to control and vary building specifications dynamically opposed to the sampling method, where most parameters are composed randomly and cannot be changed. The number and configuration of archetypes determine the granularity of the possible analyses. The initial development of an archetype model for building stocks requires a large amount of statistical data on the building and stock level such as building use, typology, composition, energy use and so on. Both approaches are valuable and provide different ways of understanding the status quo and the decarbonisation potential.

By monitoring how *actual* projects perform in relation to the limit values, insights can be gained regarding the development of future limit values, keeping in mind the time gap between the case database and state-of-the-art construction. For instance, if a large share of projects manages to fulfil the limit value without major design changes, the limit value can probably be tightened significantly. Monitoring the real performance of the building stock also presupposes a gradual phasing-out of the conservativity factor in generic data as the number of specific EPDs increases and the development of robust industry averages for more product types becomes feasible.

4.4 Further implications

- Carbon limit levels determine whether decarbonisation in the supply chain will be sufficient for compliance, or whether building design changes are required.
- Implications for structural design and architecture are ambiguous, because technological innovation and assessment methods do not suggest major transitions, but rather multiple small adjustments.
- Carbon limits provide a manageable mitigation of environmental impacts of construction; however, they clearly narrow down the overall environmental implications of construction which need to be addressed in the future.
- Building-level carbon limits will scale the innovation level for decarbonising the supply chain, but require other policy instruments.
- Additional consultancy cost for carbon assessments is estimated about 0.14 - 0.5% of the construction cost.
- Additional cost for unconventional design and product choice has not been estimated and relies on the time progression of limit values. Higher cost must be considered, when the mitigation demand is greater than the evolving decarbonisation in the supply chain.
- Sufficiency-based targets for building less, smaller or with lower quality standards are not discussed, but may become vital for achieving ambitious climate goals, which cannot be resolved with relative carbon limits.

Introducing this type of novel carbon regulation entails potentially far-reaching consequences. The construction sector has to adapt to the new regime implying new practices for planners, designers and contractors, but also for material suppliers and the rest of the value chain. Conventional construction activities with high carbon emissions will be phased out and low-carbon solutions will be demanded.

In this section, we discuss some of the most likely consequences of progressively tightened carbon limits. In practice, the occurrence of consequences will depend on the level and speed of limit values and the order and intensity may vary. Also, national economies, digitalisation and material supply are only some of many variables, which affect potential impacts, but are difficult to foresee. This complexity entails a considerable uncertainty, and impacts should be assessed regularly in each specific national context along with the ongoing progression of limit values.

4.4.1 Building design

Carbon limits will affect building design and material choices, if conventional solutions are unable to decarbonise their production processes at a sufficient pace to comply with low-carbon requirements. High limit value levels such as the current 2023 regulation in Denmark, will still allow projects to comply without significant changes in design or material choices. Even tighter limit values might not necessarily impose changes in design and material composition if the supply chain is able to reduce carbon intensities more than expected at the time of developing limit values. For example, the Finnish draft regulation proposal acknowledges that even without building carbon limits, building emissions would still decrease due to the expected decarbonisation of energy production. By 2035, the emission reductions of the built environment with this course of development could reach 30–35 percent of the 2020 level, if the decarbonisation of the energy sector proceeds as planned. Similar considerations are also examined in other Nordic countries by different stakeholders.[7] Using currently available product-specific EPDs rather than conservative generic data will often lead to lower emissions. Selection of optimised products today and the future decarbonisation of material production processes will allow for lower embodied emissions without significant material changes (portrayed in **Figure 15**).

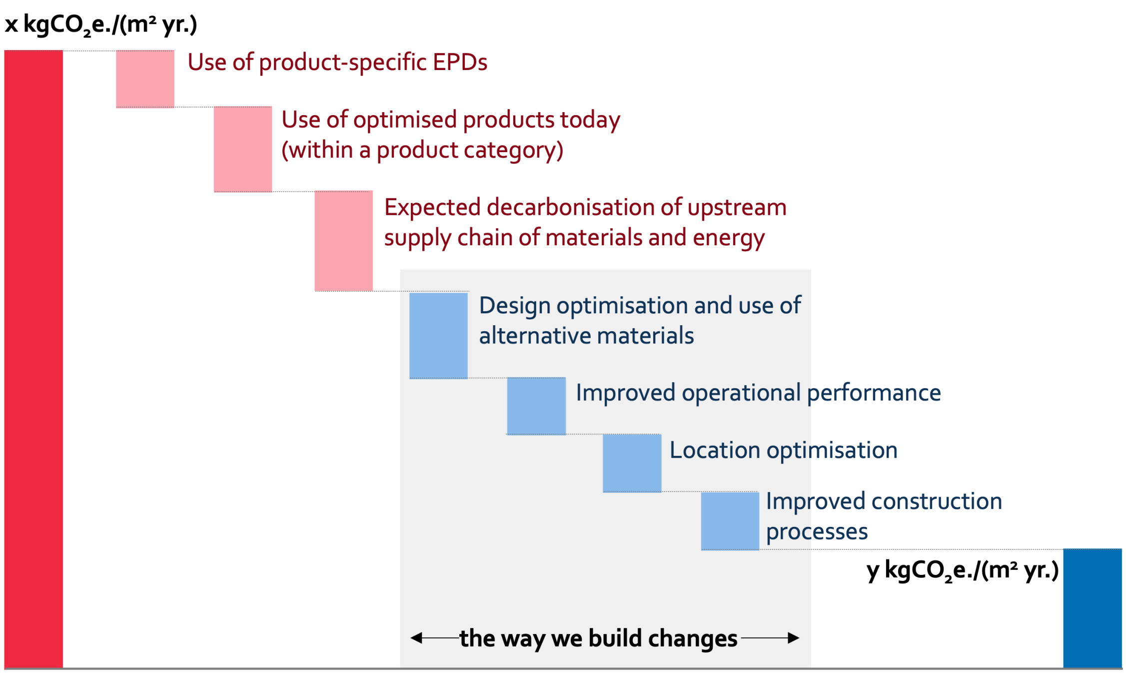
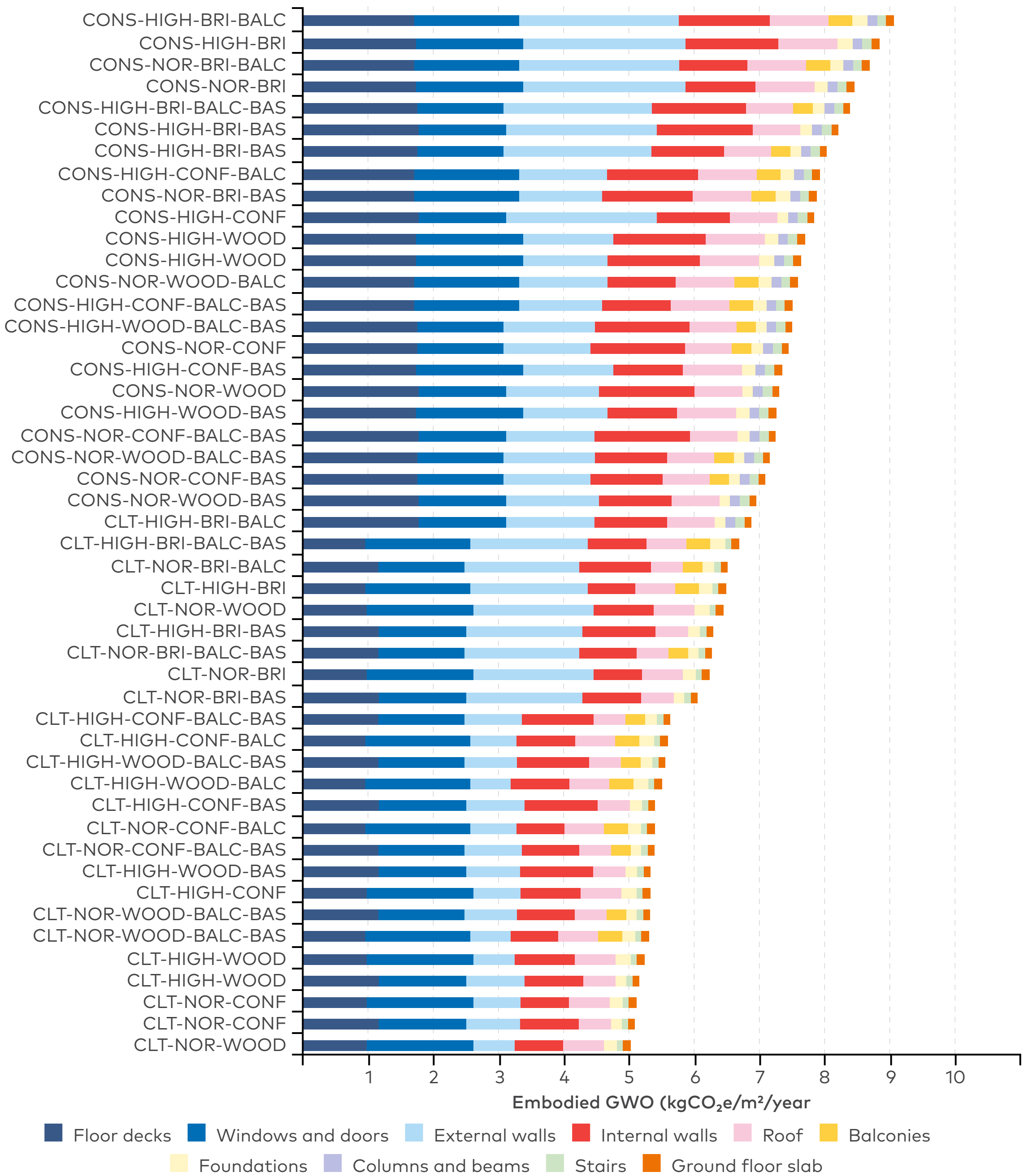


***Figure 15**- Schematic representation of reduction potential distinguishing between measures of low effort for the designer/consultant (use of different data, choose of better products within the same type, changes in the upstream chain) and optimisation measures.*

7. Current Danish study estimating 51% reduction of consumption-based emissions of construction sector between 2021-2030 and translating this change as an expectation for the average climate impact from new construction in a "frozen policy" perspective to fall from approx. 10 in 2021 to approx. 5 kg CO_2/m^2/year. (Byggeriets Handletank for Bæredygtighed, 2024)

However, when limit values are tightened, or if decarbonisation of the supply chain is not as far-reaching as expected, changes in building design and material choices might become inevitable. **Figure 16** shows result of a case study focusing on consequences of variations in building design, without considering other parameters such as supply chain scenarios. This shows embodied impacts of different variants for an archetypal apartment building. It applies the Danish reference area and current Danish generic data without material decarbonisation scenarios. Results should not be generalised, but illustrate potential effects of carbon limits on design choices.



Structural frame material	**Internal wall surface**	**Façade material**	**Balconies**	**Basements, unheated**
CONS Concrete elements	NOR Normal surface	CONF Concrete sandwich	BALC Yes	BAS Yes
CLT Cross-Laminated-Timber	HIGH High surface	BRI Brick	No	No
		WOOD Wood		

Figure 16. *Example of embodied climate impacts (A1-A3, B4, C3-4) of an archetypical apartment building, for various combinations of the parameters above.*

Photo: Almanakken, Sweco DK

If a hypothetical limit value for embodied carbon were to be set at 7 $kgCO_2e/m^2$/year, almost all designs with a concrete frame would overshoot the limit. This implies that a shift to cross-laminated timber (CLT) or other low-carbon structural materials would be necessary (or that the production of concrete would need to be thoroughly decarbonised). If this arbitrary limit value were to be tightened to 6 $kgCO_2e/m^2$/year, all designs with brick facades would also become unfeasible. This illustrates that a tightening of limit values would constrain material choices and potentially restrict the use of common mineral materials, unless a deep decarbonisation of production is achieved. Particularly tight limit values might also constrain other design choices. For instance, balconies lead to higher emissions per m^2 (among the ten variants with the lowest emissions, only one has balconies). If designers are required to be highly ambitious in minimising embodied emissions, they might therefore be led to avoid balconies or design them with alternative solutions, in the absence of deep and fast decarbonisation of concrete and brick industries [8]. Conversely, the surface of internal walls did not seem to be significantly constrained by tight limit values. Even though layouts with fewer partitions might be encouraged, it is unlikely that tight limit values would significantly restrict internal layout choices.

4.4.2 Architectural expression

In most Nordic countries, low-rise buildings in structural timber are the norm, however, the use of wood in mid-rise buildings is a non-standard solution. Wood buildings are often associated with visible wood surfaces, however, depending on climate zone, wood might not be ideal for use as façade cladding for durability and maintenance reasons, especially in multi-story construction. Some of the major implications of limit values for building design affect mid-rise buildings and their expected transition from a structural frame in concrete or masonry to timber. Apartment buildings, offices or public institutions may be those types of building, which will undergo the most visible changes in expression. Unlike facades, roof cladding does not underlie a clear trend towards certain solutions and has therefore more moderate architectural consequences.

From the perspective of inhabitant perception, mid-rise structural timber buildings often expose wooden ceilings, walls or floors. However, this is not a must, since it is possible to

8. This is tied to the definition of the reference area, which in Denmark only includes 25% of the area of balconies. Conclusions might be different with a floor area that includes all balconies (see section 4.3.2)

clad surfaces in other materials as well. A recent study from Finland (Karjalainen & Ilgın, 2021) among inhabitants of novel timber housing units reveals general satisfaction after several years of residence, apart from the wish for better sound insulation.

Recent timber light house projects show a clear tendency of exposing wood on the interior as well as on the façade, assuming a currently high value of wood in construction.

Concrete, aluminium, facing brick and glass are often preferred in mid- and high-rise structures due to low maintenance and durability. However, they are among the largest carbon impact products in the current state of manufacturing processes. Steel offers a comparatively low-carbon substitution for aluminium without affecting the design. Curtain walls are often the preferred choice in mid- and high-rise buildings and include a dominant use of glass. At the same time, curtain walls challenge building energy performance due to high heating and cooling demand. A reasonable alternative in mid- and low-rise buildings are solid façades with punctuated window holes allowing a greater freedom of material choice and a glazing percentage balancing daylight and insulation performance. Here, biogenic materials, stucco, metals and ceramics might offer new architectural expression balancing carbon emissions, exposure to climate or mechanical force and maintenance.

Brick facades and tiles roofs play a key role in the cultural identity in many central European cities and landscapes. While vernacular architecture was dominated by cheap and easily available materials like timber, stone and sun-dried clay, the pre-modern devastating city fires have promoted the use of inflammable brick walls. This tradition has been continued in the last decades with insulated, facing brick facades, cladding load-bearing walls made of other materials. The reduction of the amount of brick material in exterior walls can be continued by using ceramic tile systems, which offer a similar durability at lower carbon emissions. This may however fail to express the sturdiness, durable monumentality, and decorative modelling options of a deeper masonry wall. The cultural reference to bricks and tiles, however, can be challenged by going back just a little more in history, where unburnt minerals, timber and crops were the cultural norm. This requires at least planning authorities to rethink zoning and cultural heritage goals. Alternatively, a higher re-use rate of bricks and bricks burnt with renewable energy might allow continuing brick facades for selected, culturally relevant, buildings.

4.4.3 Illustration of other environmental impact categories

Isolated indicators like GWP risk overlooking other environmental indicators and resource categories. This section shows a quantitative assessment of other environmental indicators applied to the archetypical apartment building study shown before. For each variant and each environmental category, environmental impacts are expressed as a percentage of their value in the base case (a building with balconies, no basement, a concrete structure and a brick façade) (see **Figure 17**).

More importantly, a shift from concrete and bricks to biogenic materials (which might be encouraged by a tightening of CO_2e limit values) has important implications for other impact categories. Using a wood façade instead of a brick façade leads to lower impacts in most categories except for the use of renewable resources, where it understandably leads to higher impacts. However, the use of a CLT structure appears to lead to higher impacts in the categories of ozone depletion, eutrophication, and photochemical ozone formation as well. It is unclear why this is the case, as data quality in these other impact categories, unfortunately, is poor. Biogenic materials could be expected to lead to somewhat similar impacts, but here the impacts measured per volume of the CLT, and wood cladding products (coming from different data sources) were widely different in some impact categories. These differences call for the development of more robust generic data in environmental categories other than climate change, to better understand the consequences of changes in design and material choices. It is recommended to develop better data in all environmental categories found in EN15804+A2, and to include reliable information related to land use, as it is an impact category in which biogenic materials might have significantly higher impacts than their mineral counterparts.

It should be noted that as the Danish calculation method was used in the above-described estimated example, the results cannot be generalised to all Nordic countries (e.g., the reference area used includes 25% of the areas of balconies).

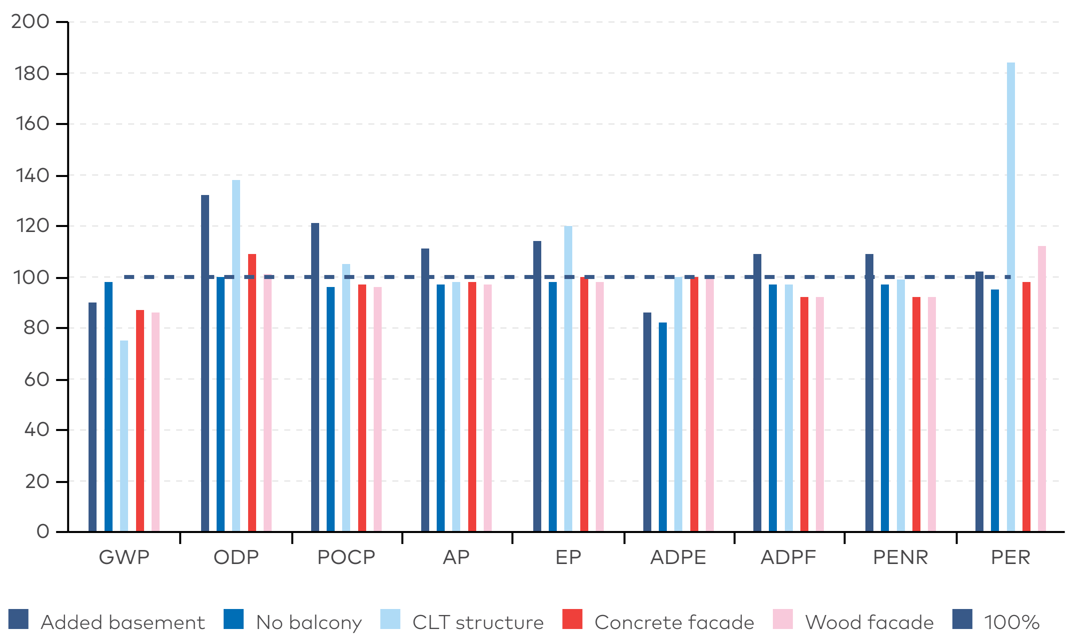


Figure 17. *Impact in all environmental categories for several variants of an apartment building. Environmental impacts are expressed as a% of their value in the base case (a building with balconies, no basement, a concrete structure, and a brick façade). (GWP: global warming; ODP: ozone depletion; POCP: photochemical ozone formation; AP: acidification; EP: eutrophication, ADPE: abiotic depletion, non-fossil; ADPF: abiotic depletion, fossil; PENR: primary energy, non-renewable; PER: primary energy, renewable)*

Photo: Køhlers Have, Sweco DK

4.4.4 Wood supply

The use of timber in construction is expected to increase in the coming decades, partly due to the introduction of incentives and requirements for low-carbon construction. This is actively encouraged by initiatives such as the Build in Wood Consortium (Build-in-Wood, n.d.). However, the scaling up of wood construction entails complex environmental implications due to the increased pressure on forests and the limited availability of sustainable timber. Including such considerations in LCA is difficult and leads to unresolved methodological issues (Andersen, Rasmussen, Habert, & Birgisdóttir, 2021). It is critical to investigate how an increased demand for timber relates to the current and future capacity of forests, the impact of forestry on biodiversity and forest carbon storage, and what systemic barriers should be considered to prevent burden shifting. A 2022 study indicates that the consumption of roundwood in Germany is above its sustainable rate based on the Planetary Boundaries, while forestry in the rest of Europe is close to its sustainable harvest potential (Egenolf, Distelkamp, Morland, Beck-O'Brien, & Bringezu, 2022). Furthermore, increased use of wood in construction may interfere with other policy goals, such as the recent European Forest Strategy and the Biodiversity Strategy for 2030, which both emphasise the multifunctional role of forests and do not favour an increase in wood harvest. As part of the EU Forest Strategy, forest conservation is stressed and it is stated that in the short to medium term, the additional benefits from harvested wood products and material substitution are unlikely to compensate for the net forest sink reduction (The European Commission's Knowledge Centre for Bioeconomy, 2021; European Commission, n.d.).

The EU Biodiversity Strategy aims to legally protect 30% of EU's land area by 2030 which means setting aside forests (European Commission, n.d.). Therefore, a balance must be established between capturing carbon in buildings as temporary sinks, as expressed by the EU Carbon Removal Certification initiative and minimising wood demand in the construction industry (European Commission, 2024).

The limited managed forest area compared with the numerous competing interests between nature and multi-sectoral material demand demonstrate that even renewable resources such as timber have a limited availability. Forest resources and land use change should be considered in a broader perspective, notably in relation with global agricultural systems and bioenergy demand. The availability of roundwood for construction is therefore highly dependent on systemic changes in other sectors, such as moving towards a more sustainable global agricultural sector. A key strategy to expand the available wood supply for construction and increase resource efficiency within the building sector is to implement a cascading use of wood products. Currently, bioenergy and short-lived products such as paper or cardboard packaging utilise most of the harvested timber in Europe (Eurostat, 2023). By redirecting more timber to a primary use in buildings, a higher utility value and temporary carbon storage can be achieved. Before wood fibres are being disintegrated, many engineered wood products can be produced from secondary timber from demolitions under the precondition of using reversible joints and avoiding chemical contamination. Incineration for bioenergy should only be the last step in a chain of multiple life cycles for wood products. Resource efficiency can further be increased by encouraging the reuse of wood products with suitable technical properties, and by minimising waste wood between harvest and installation. To maximise overall carbon storage, it is therefore important to channel a sustainable supply of timber towards optimal uses, ensuring the possibility of future reuse through design for disassembly principles.

On the demand side, the amount of wood needed for buildings is determined by the choice of structural systems and building geometry and should be kept to a minimum, so that more buildings can be built with the given available wood. This also involves a better handling of waste timber that does not disregard its unique qualities and potential for high-value use, which necessitates identifying waste leaks within the timber value chain resulting from sawmilling. Light timber frames in low-rise structures require less wood than mass timber in high-rises, and carbon limits per m^2 will make it harder to build high-rise buildings since these require more materials per m^2. Conversely, low-rise buildings would increase urban sprawl and transport needs. This trade-off must be considered as part of sustainable urban planning. Avoiding unnecessary resource use linked with new construction through sufficiency measures (e.g., preserving buildings, reusing components, and implementing less resource-intensive designs) is an essential part of sustainability strategies for the building sector.

The benefits and impacts of biogenic carbon in timber and other plant products differ widely dependent on the chosen assessment method. Modelling buildings as temporary carbon sinks requires to include the whole life cycle of the building. Current environmental product declarations for timber-based construction products refer to EN 16485, which applies the -1/+1 method, where the Global Warming Potential is accounted as a benefit at the start of the cycle and as a burden (release) at its end. The carbon neutrality approach regarding sequestered carbon is only relevant for wood from sustainable forests. If wood supply comes from native forests the GWP-LULUC indicator covers the biogenic carbon changes that result from, e.g. the loss of forests or other soil-related changes. In brief, biogenic carbon from non-native sources/forests is accounted for based on the -1/+1 kg CO_2e calculation rule under the GWP-biogenic indicator (i.e., the sum is always zero over the life cycle), while harvest wood from native forests is considered fossil, where the -1 kg CO_2e from sequestration is reported as an impact of +1 kg CO_2e under GWP-LULUC indicator. This means that in overall wood from non-sustainable forests has no sequestration account. However, a definition of sustainable forest needs to be defined in the context of LCA and EPD to avoid the risk of double-counting and greenwashing; a definition has been proposed by the Nordic project on data (Karlsson, Mattsson, & Erlandsson, 2024), also as a contribution to the EU future Carbon Removal Certification.

While this approach clearly defines the carbon exchange between building and atmosphere, it fails to account for the beneficial delay of emissions during building operation, compared to an immediate release. The French building regulations RE2020 and several private certification schemes such as FutureBuilt (Resch, et al., 2022) and DGNB Denmark (Green Building Council Denmark, 2024) apply a discounting factor, where future emissions have a gradually lower weight in impacts, based on an assumption of improved technology and delayed atmospheric heating effect. This applies to all materials including biogenic carbon, which in effect equals to benefits for carbon storage. The climate implications of temporary carbon storage effect, however, must not be used in product assessments according to EN15978 and 15804, to avoid excessive use of resources, and only the bulk amount of biogenic carbon has to be included as additional information.

Besides the overlooked benefits of using timber, the assessment method has some shortcomings on the impact side as well. The applied attributional LCA method neglects possible strain on resource supply, in this case timber harvest and secondary timber. A consequential LCA approach also simulates possible changes on the market supply side and related environmental impacts. In contrast to attributional LCAs used in certification and regulation, consequential LCA models co-products by substitution or system expansion. Since residues from timber production are often utilised for short-lived products or energy with immediate biogenic carbon emissions, this kind of consequential modelling often shows lower benefits for timber buildings, depending on the considered substituted production (Hansen, et al., 2024). Substitution can also be used in attributional LC by considering the average market mix instead of the marginal mix. However, the utilisation factor commonly applied for roundwood to timber (about 50%) most likely overestimates wood residues for short-lived products. Overall, prior to the implementation of carbon limit policies, the environmental consequences of an increased timber demand should be assessed as a dynamic function depending on the imposed changes in the total timber demand and supply.

To address potential supply challenges for wood and other resources in future carbon limit trajectories, it is important to be able to estimate the material demand for new buildings and renovations. The building archetype approach discussed in chapter 3 is a good foundation for this scenario simulation, since it contains the material inventory of the building. This inventory can be scaled with the expected share of buildings in future building stocks, eventually based on the EU Building Stock Observatory. This material demand scenario can also be explored for other environmental assessments such as biodiversity, for which initiatives are being prepared in some countries (Jensen & Hill-Hansen, 2023).

4.4.5 Construction supply chain

Carbon limits for buildings will generate a new type of additional regulatory stress on construction with indirect implications for the supply chain as a whole. By reducing the allowed carbon budget of buildings, suppliers of energy, construction products and other services are urged to adapt their products to the new requirements. However, there are other instruments, both planned and hypothetical, for decreasing the carbon intensity of raw materials and construction product manufacturing. The European Calculator programme illustrates the effect of building regulation measures, but also many other possibilities and scenarios not directly related to buildings[9].

Products with energy-intensive manufacturing processes have a great decarbonisation potential. Current short-term improvements include increased efficiency and changing fossil fuel sources towards biogas and electricity. This includes products such as ceramics, mineral wool, glass, or metals. As an example, the cement industry claims that it can potentially achieve large carbon savings by changing fuel source, production processes, concrete mixes with supplementary materials and lower cement content as well as using carbon capture, utilisation, and storage technologies (Global Cement and Concrete Association, n.d.). Other resource efficiency levers for mitigating emissions include the reduction of material amounts and avoiding overdesign (excessive material amounts or quality requirements) in design and construction processes. This includes changes in geometry (e.g., vaulted precast floor slab (Vaulted, n.d.)) or handling, being one of the determining factors for cement content in prefabricated wall elements.

Building carbon limits has a prospective effect on the supply chain, creating a demand for low-carbon products needed for a given carbon level, which would not exist otherwise. This mechanism requires clear expectations regarding future carbon limits among industrial stakeholders, communicated for instance through the limit value roadmaps. An important indicator for determining future carbon levels is the carbon impact range of the current product supply. The lowest carbon levels of today, which can be found in best-in-class products, can be used as the new standard level on which future carbon levels will be based – essentially assuming that today's best practice will be tomorrow's standard practice. This is especially the case for 2030, when all European countries must have introduced carbon limits. This large-scale market demand for low-carbon products is expected to have a considerable effect on construction product suppliers. Limit values can therefore consider the currently best available technology of today to become the new standard.

Nordic limit value reports estimate the reduction potential of best-in-class low-carbon products instead of generic data at 10-30%, depending on the context and for certain types of products[10]. Combining the reduction potential of best-in-class product-specific

9. https://www.european-calculator.eu/
10. (Tozan, et al., 2023) shows a 12% reduced impact for Danish buildings by simply using low-carbon bricks (improved bricks have been achieved by reduced material consumption per unit and purchase of biogas certificates); (Malmqvist, Borgström, Brismark, & Erlandsson, 2023)finds a 13% and 10% overall reduction when using "better choices" instead of generic data for concrete, steel and aluminium (but primarily increased recycling for metals) in the Swedish context for A1-5 and A1-5, B2, B4, C1-4 scopes, respectively; (Utstøl & Marwig, 2022) report shows more than 10% and 20% (SFH and four-person home and apartment/office buildings respectively) through a conscious choice of materials that satisfy recommended 'threshold values', without any cost consequence. Additional potential reductions of 1-13% when switching from class C to class B and A concrete (with additional cost).

instead of generic data with the 1 to 4% annual decarbonisation for all future material production[11] results in a total reduction potential between 1.6 and 4.3 $kgCO_2e/m^2$/year in 2030 (i.e., 15-50% reduction). This is based on a standard case with concrete structure and brick façade using 2025 as the reference year, shown as third solution from the bottom in **Figure 16**.

Low-carbon pathways will also make prefabrication a priority in high-rise construction. This is due to the increased use of wood in the structural frame, which requires a greater caution for damage through moisture, which can be achieved through a weather-proof fabrication indoors. Wooden panels or frames are also well suited for transport due to their compact packing and light weight, which removes the high carbon intensity of heavy concrete element transport. It also improves the possibility of design-for-disassembly through using reversible joints.

Innovations will also be key at the end of the building and material life cycles to increase resource efficiency. In order to maintain materials in the loop at the highest possible functional value, measures have to be taken in all stages from the design of components to maintainability and finally disassembly to prepare for the next product system. Cured materials such as cement and lime cannot be recovered without a new heating process, while versatile wood products can be re-used and recycled numerous times following a cascade. The cascade starts from a higher state of integration such as beams and ends with more disaggregated products like particle boards and finally energy recovery. In some cases, also upcycling might be an option. When the benefits of this multi-life cycle use of wood will be sufficiently expressed in future LCA calculation rules, a greater focus on careful dismantling and waste sorting will be necessary to exploit this potential for long-term carbon storage in product loops including buildings.

Building limit values will increase the demand for low-carbon energy supply from the grid and building-integrated energy production. This might impose a conflict in energy systems planning. Local district heating or cooling and large-scale electricity grids operate on system level, where the individual building is only a small part of the consumer side. Moreover, buildings are increasingly helping to balance the grid by flexible use and storing heat and electricity and not least producing energy on site. Building-level carbon regulation fails to include this complexity in performance assessments and there is a risk of sub-optimisation and conflict with system-level optimisation. This risk may be mitigated by maintaining a separation between operational energy regulation and other processes, which allows for a more nuanced management in line with the system-level goals. This can be combined with traditional minimum building-level energy performance standards, which work independent from carbon regulation. This would acknowledge the fact that buildings are both artefacts with carbon impacts and nodes in a greater energy system.

Finally, all considerations of efficiency improvements in material production and energy use must be seen in the light of potential rebound effects. It is important to ensure that

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11. considering that there are roadmaps estimating 60% or higher emission reductions for concrete, bricks and steel by 2035, see Section 3.7.1.

efficiency improvements do not lead to increased consumption (e.g. because the product or energy carrier becomes cheaper, or because more of it can be used without overshooting the limit value). The benefits of efficiency improvements will not be fully realised unless incentives and policy measures are actively taken to prevent consumption from increasing.

4.4.6 Socio-economic impacts

The above-discussed influence of carbon limits on innovation in building composition and the supply chain are not technological challenges alone, but also require adaptation at societal and economic levels. In order to secure societal acceptance, policymakers need to involve and prepare stakeholders to gain support for the proposed path. This can be done by conducting a socio-economic analysis of a proposal for limit values based on a survey of the current situation and expert interviews, as was the case in Sweden. This section discusses the consequences of limit values for new buildings, based on the regulatory experiences in Sweden, Finland, and Denmark. **Table 15** provides an overview of potential impacts on building owners, the construction supply chain and public administration.

Economic impacts in the construction sector result from new assessment and reporting requirements on the one hand and changes in building design, materials and energy supply on the other. Small and medium-sized consultancies, contractors and manufacturers are particularly dependent on support for new reporting requirements. The preparatory process for limit values in the Nordic countries has mainly focused on the new reporting requirements in light of the first generation of limit values. The numerous support programmes for supply chain innovation and decarbonisation are not specific for the construction industry and will not be treated here.

Reporting is considerably supported by available assessment tools, environmental data and default libraries for products and systems. Capacity building prior to carbon regulation has been accelerated by voluntary sustainability schemes to increase the stakeholder readiness, see the report "Harmonised Carbon Limit Values for Buildings in Nordic Countries" (Balouktsi, Francart, & Kanafani, 2024) for the detailed measures in the Nordic countries. Other measures include industry networks and workings groups, which often overlap with stakeholder consultation processes. A major driver for readiness and adaptation is the early introduction of a regulatory timeline for carbon limit trajectories.

Table 15. *Non-exhaustive list of positive (+) and negative (-) economic impacts of carbon limit values to affected stakeholders (Main sources if not stated otherwise: the Finnish government's proposal to the parliament for the construction law (Finlex, 2022) and Boverket's proposal on limit values (Boverket, 2023))*

Stakeholder	(+) Positive impacts	(-) Negative impacts
Building owners and clients	• Implementation of climate-friendly solutions, and communication of climate impact information would increase marketability. • Carbon declaration provides opportunities to acquire green mortgages with lower interest rates. • Stricter limit values would lower the lifetime costs; Cost increase may be in the order of 1–5% of the production cost, for projects that take action by changing the choice of materials, depending on the country. For example, the Minister for Social Services and Housing in Denmark estimates that the average additional cost for the tighter requirements announced for 2025 is approx.220 DKK/m_2 (i.e. EUR 30/m^2). In the case of a single-family house of typical size and climate impact, the tightening will cost approximately 1.8% of the total construction cost[12]. However, resource savings can offset the higher costs for sustainable materials. • Limit value regulation would support the transition from fossil energy to other heat sources derived from renewable energy in housing. • Better indoor climate of bio-materials. Increased health, well-being, and productivity through natural materials, emitting less harmful volatile organic compounds, presupposed that naturally occurring toxic substances like formaldehyde are controlled.	• The obligation to prepare a climate report would only marginally increase the costs of small house construction, compared to other construction costs. • If the household, deviating from the general rule, were responsible for the project without a house manufacturing company involved, the preparation of a climate report would have to be added to the tasks of the designers, which would result in an estimated additional cost of a few hundred euros. • A potential increase of construction cost depends on carbon limit level, the time of implementation and the adaptation cost in the supply chain. Today, some product types are being decarbonised gradually, while for others, only expensive low-carbon versions are offered (Utstøl & Marwig, 2022). A quick limit value progression would increase demand at limited supply, leading to higher prices.

12. Typical size and impact for single-family house correspond to 150 m^2 and 8.89 $kgCO_2e/m^2$/year, respectively. An example of cost estimation is also presented for a newly built school (Danish Ministry of Social Affairs, Housing and Senior Citizens)

Stakeholder	(+) Positive impacts	(-) Negative impacts
Construction supply chain	• Observed increase in the value creation of low-impact construction. In Sweden (Statistics Sweden, 2023), the production of environmentally friendly goods including nearly-zero energy buildings, renewable energy production and forestry, has almost doubled from SEK 326 billion to SEK 606 billion between 2013 and 2021. • Growth and job opportunities in low-carbon construction products, services, and methods in light of increasing international demand. • Company branding and a competitive advantage for domestic products on the European market. • Support the creation of jobs in the Nordic region's sustainably managed timber and bio-based materials industry (Jensen & Craig, 2019). • Develop the nascent construction materials for the recycling and reuse industry. Jobs creation through the transition to a more resource-efficient circular economy, related skills as a key transitional sector (Jalava, et al., 2021; Barth & McKinnon, 2023). To support the latter, a special teaching programme Skills4Reuse (Skills4Reuse, n.d.) has been developed as part of the Nordic project Competencies for Reuse in the Construction Industry.	• In the initial phase, the low-carbon calculation and assessment practices cause a small additional cost in the planning phase of the new building, estimated to be around 0.5% (Finlex, 2022). • There will be additional cost associated with the preparation of the climate report of about 0.14% of construction cost (Danish study (Tozan, et al., 2023)). The amount will depend on the type of building and the agency preparing the report. Small enterprises would be the most affected, since they often lack in-house expertise. There would be a need for upskilling, purchase of software for climate, or subcontracting. • Choice of different materials than in standard practice would lead to changes in working practices during the construction stage such as construction time, cost or a change in construction method. • A greater demand for EPDs would increase costs for construction product manufacturers to produce EPDs (especially if the manufacturer has a large number of products). This investment is also associated with a great deal of uncertainty due to the lack of standardisation and ongoing revisions of the Construction Products Regulation. To assist small enterprises, some industry associations, such as Swedish Concrete and Swedish Wood have developed what are known as EPD generators. • Competition in resource supply. Product decarbonisation is limited by a cross-sectoral and cross-national competition for access to the available share of low-carbon resources like solar and wind power or wood.
Public administration		• Administrative costs for policy development, stakeholder consultation and technical development of requirements and guidance, generic emission data, carbon declaration registers and supervision.

Photo: Nordic Sustainable Construction

4.4.7 Other valuable considerations

This report assumes a relative regulation regime, where carbon limits must mitigate emissions per building area unit. This is a common approach and also known in building energy performance, however it does not regulate how much is being built, which is a key factor affecting the total emissions of construction. To tackle this, a policy instrument would need to consider a limitation of construction activity, thus applying a sufficiency regime as suggested by several carbon roadmap initiatives (Le Den, et al., 2023; Reduction Roadmap, n.d.). This could, for instance, be achieved by regulating the per capita carbon intensity, de facto leading to a reduction in floor area per person or function. This would lead to smaller housing units and typologies that have less impact on the environment, such as low-rise multifamily housing units rather than detached houses. Also, the utilisation and refurbishment of the existing building stock will become more profitable. Common to all sufficiency scenarios is a much wider range of societal consequences than expected from relative regulation. In that case, the policy will have to focus much more on the currently low acceptability of such paradigm-shifting measures. A survey performed in several countries demonstrates this (Alexander-Haw, et al., 2024).

Another assumption is that carbon limits are measured as total cumulative life-cycle GWP, meaning a total result for all life cycle stages according to the current EPBD proposal. This implies a 1:1 weighting of upfront impacts and future scenarios as well all included processes including manufacturing, transport, construction, energy systems and waste treatment. As a consequence, cumulative carbon limits are a very broad measure for a large number of factors and industries, which underly varying regulatory regimes and undergo different decarbonisation paths. Since the specific contribution of each of these processes is constantly varying, the regulatory pressure cannot be designed to specific processes, but will be dependent on other decarbonisation level of other processes.

This broad approach implies a strength viewed from a market perspective, where market actors are expected to find the most feasible carbon reductions. It gives the client flexibility to compensate high emissions in one process with mitigation in another. An alternative strategy implies differentiated carbon limits, for instance for upfront carbon and scenarios. This would allow regulating the current emissions which are easy to measure and regulate. Further, operational energy use might stay regulated on a separate track, allowing a specific decarbonisation path including a systems level approach.

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Appendix

A – Background studies analysed for Figure 11

Aspect	Studies
Deep foundations/ soil stabilisation (A1-A3)	**One Click LCA Ltd (2021)** Steel piling: 1.6 $kgCO_2e/m^2$/year Soil stabilisation: 6.8 $kgCO_2e/m^2$/year (commercial buildings), 6.9 $kgCO_2e/m^2$/year (school and service buildings), 4.6 $kgCO_2e/m^2$/year (residential and office buildings) **BUILD report 2020:04** Only five of the cases analysed in this report made use of pile foundations, and in very different proportions. When pile foundations were used, they accounted for about 45% to 100% of the GWP of foundations, from 0.008 to 0.9 $kgCO_2$/m2 GFA per year (median value 0.77 $kgCO_2/m^2$yr.), and from 0.2% to 17% of the building's upfront GWP.

Basement parking (A1-A3, C3-C4)	**BUILD report 2023:21** Appendix 5 of this report explores the effect of parking basements on the building's overall climate impact. The investigation aims to determine if including the entire parking basement area is beneficial in terms of the building's climate impact. The study examines whether there is a correlation between low climate impact, the building's reference area and the presence of a parking basement. However, when analysing the entire building sample, no climate advantage was found in including parking basements in the calculation. Further analysis focused on three specific case buildings with basement parking. The climate impact on these buildings was assessed using the current method in BR18, which includes 100% of the basement area in the reference area, and three alternative scenarios including different proportions of the basement area and the materials of the basement. The impact of basement parking on these three buildings, according to the current Danish method, ranges from 1.0-1.80 $kgCO_2e/m^2$/year. However, excluding the parking basement from both the area and material inventory can, in some cases, lead to higher total building impacts. If the parking basements are investigated separately, their impact for these 3 cases ranges from around 5.60-9.40 $kgCO_2e/m^2$/year. **One Click LCA Ltd (2021)** 0.7-1.2 $kgCO_2e/m^2$/year depending on the building type considering net heated floor area as the reference area.
External works/ landscaping (varied system boundaries)	**ZEN report 2020:24** This study reports that outdoors is responsible for 28% of total greenhouse gas emissions (approx. 3.3 $kgCO_2e/m^2$/year). What are the parts of external works included in this study is unclear (varied system boundaries). **One Click LCA Ltd (2021)** From a sample of more than 450 analysed buildings some of them contain external works (number undefined) where averages per building type seem to range between 0.15-0.5 $kgCO_2e/m^2$/year. Outdoor parking spaces correspond to 0.2 $kgCO_2e/m^2$/year.

Construction site (A5)	**BUILD report 2023:21** This study examines the relevance of A5 module based on monitoring data from 52 construction sites. The boundary includes the use of electricity, heating energy, fuel and construction waste. Also, transport on and from the site is included. The analysis takes the larger expected share of renewable energy in 2025 into account. Construction waste has the largest share in A5 with 38%. The resulting median for module A5 of 1,0 $kgCO_2e/m^2$/year. 25^{th} percentile: 0,713 $kgCO_2e/m^2$/year (considered as the lowest value here); 90^{th} percentile: 1,720 $kgCO_2e/m^2$/year (considered as the highest value here)
Building services (A1-3, A4-5, B4, C3-4 – varied system boundaries)	**Malmqvist et al. (2023)** Standard values are provided per building type and range from: 12-60 $kgCO_2e/m^2$ (A1-5), i.e. 0.24-1.2 $kgCO_2e/m^2$/year. Systems include: drainage installations, water installations, heating, ventilation and cooling installations, firefighting system, electricity systems such as cables, sockets and fixed lighting, elevator. **Danish Technological Institute & SWECO (2022)** Standard values are provided per building type and range from: 33-65 $kgCO_2e/m^2$ (A1-3, C3-4), i.e. 0.66-1.3 $kgCO_2e/m^2$/year. Systems include: drainage installations, water installations, heating, ventilation and cooling installations. **Finnish standard values** Standard values are provided per building type, and range from: 48-266 $kgCO_2e/m^2$ (A1-3, B4), i.e 0.96-5.32 $kgCO_2e/m^2$/year. Systems include: drainage installations, water installations, heating, ventilation and cooling installations, firefighting system, electricity systems such as cables, sockets and fixed lighting.
Refrigerants (B1)	**BUILD report 2023:23** This study calculates 10 building cases and finds a median value of 0.58 $kgCO_2e/m^2$/year and a maximum value of approx. 1 $kgCO_2e/m^2$/year., however, considering values from currently used products and a 2% annual leakage rate. Considering a max GWP value of 750 $kgCO_2e/kg$ for used refrigerants, the impact is reduced, while for a higher% of leakage the impact will be higher.

Fixed furniture (A1-A5, B4)	**Malmqvist et al. (2023)** Few studies consider the impact of fixtures (fixed furniture). This study provides A1-A5 standard values for internal finishes and fixed furniture differentiated for six building types. For fixed furniture the values range from 4.05 -30.4 kgCO_2e/m^2. The Swedish method does not yet cover replacements. An approximate value for B4 impacts can be estimated by assuming a rate of replacement occurrence. According to Level (s), such fit-outs typically occurs every 10 –20 years. If one assumes a mean rate of occurrence every 15 years for a building with a life span of 50 years (I.e. two replacements during building's life), the total impact of fixtures could range from 12.2-91.2 kg CO_2e/m^2 of heated floor area (0.25-1.82 kg CO_2e/m^{2}yr).
Internal finishes (A1-A5, B4)	**Malmqvist et al. (2023)** The impact ranges from 13.5 -22.33 kgCO_2e/m^2. When B4 impacts are added under the assumption of two replacements during building's life, the impact increases to 53-67 kg CO_2e/m^2 of heated floor area (1.06-1.34 kg CO_2e/m^{2}yr).
Maintenance (B2)	**BUILD report 2023:23** This study calculates 10 building cases and finds a median value of 0.15 kgCO_2e/m^2/year, when only cleaning and small maintenance processes are included, and 0.46 kgCO_2e/m^2/year when window glass replacement also is included (in some countries, glass replacement is part of B4). The maximum value is approx. 0.7 kgCO_2e/m^2/year, which is halved if glass replacement in windows is not considered. The base of estimation is B2 values from product and industry EPDs, when available.
Deconstruction and transport (C1-C2)	**BUILD report 2023:23** This study finds a median value of 0.15 kgCO_2e/m^2/year and a maximum value of approx. 0.30 kgCO_2e/m^2/year. The base of estimation is C1 and C2 values from product and industry EPDs, when available. **Finnish standard values** The standard value for C1 is 10 kg CO_2e/m^2 (0.20 kgCO_2e/m^2/year).

B – Results behind Figure 14

The same single-family house is calculated with Swedish, Finnish and Danish generic data following the national scopes (included life cycle stages and building parts), but normalised using the same reference area (145 m^2). The results are provided in the Tables below. Values in "blue" represent standard values taken from the national generic data bases and studies. To limit the comparison to the same scope, only A1-A3 is investigated, subtracting the following parts from the three scopes:

- **Sweden**: foundation (as they will most likely not be included in the Finnish method) and fixed furniture (as it is not included in the Danish method)
- **Finland**: PV installation (as they will most likely not be included in the Swedish limit values) and fixed furniture (reason earlier mentioned)
- **Denmark**: PV installation and foundation (reasons earlier mentioned)

Detailed values representing notable differences observed in the used generic data are shown in the last Table. The versions of the generic data used are as of March 2024.

SWE Proposed system boundary for 2025 limit value				
Building parts (scope)	**A1-3 (no BIO)**	**A4**	**A5**	
			(Waste)	**(Energy)**
Sub- and superstructure (without foundation)	52224	4292.9	2214.3	
Foundation	4836.7	1106.7	188.9	
Internal finishes	1943	113.1	134.85	
Building services (without PV installation)	1595	36.25	71.05	
PV installation	*not incl.*	*not incl.*	*not incl.*	
Fixed furniture	1972	78.3	13.05	
Sums	62571	5627.3	2622.1	
Sums per m^2	431.5	38.8	18.1	10.8
Total sum per m^2		**499.2**		
Total sum per m^2 and year		**9.98**		

FI Likely system boundary of climate declaration										
Building parts (scope)	**A1-3 (no BIO)**	**A4**	**A5**			**B4**	**B6**	**C1**	**C2**	**C3-C4 (no BIO)**
			(Waste)	**(Energy)**	**(Earth-work)**					
Sub- and superstructure (without foundation)	38187		1370.8			3857				21563
Foundation	*not incl.*		*not incl.*			*not incl.*				*not incl.*
Internal finishes	1704		136			1279				216.5
Building services (without PV installation)	2794.4		22.80			2491				748.27
PV installation	640.9		6.41			677				29.7
Fixed furniture	1972		13.05			3970				-
Sums	45298		1549			12274				22558
Sums per m²	312	27	10.7	46.0	7.0	84.6	44.23	7.0	27	155.6
Total sum per m²					**721.1**					
Total sum per m² and year					**14.4**					

DK Current **s**ystem boundary calculated with new data (emission factors for energy supply and some major building products) applicable from 2025							
Building parts (scope)	**A1-3**	**A1-3 (no BIO)**	**B4**	**B6 (BR25)**	**C3**	**C3 (no BIO)**	**C4**
Sub- and superstructure (without foundation)	29626	35876	4474.5		12747	6498	1133.6
Foundation	4318.3	4318.3	0		457.2	457.2	70
Internal finishes	998.8	1570.8	532.8		896	324	28.5
Building services	2700.2	2700.2	922.6		747.9	747.9	5.8
PV installation	2006.4	2006.4	2053.4		45.9	45.9	1.1
Fixed furniture	*not included*	*not included*	*not included*		*not included*	*not included*	*not included*
Sums	39650.8	46472.3	7983.3		14894.3	8072.9	1239.0
Sums per m^2	273.5	320.5	55.1	23.5	102.7	55.7	8.5
Total sum per m^2				**463.3**			
Total sum per m^2 and year				**9.26**			

Product	kgCO_2e/kg			
	SWE	FI	DK	DK (original)
Ready-mixed concrete C20/25	0.122	0.106	0.097	215 kgCO_2e/m^3 (industry EPD)
Cement screed	0.385	0.28	0.182	
Aerated concrete	0.539	0.41	0.639	243 kgCO_2e/m^3 (new generic data)
Mineral wool	1.6	1.5	0.528	26.4 kgCO_2e/m^3 (new generic data)
EPS insulation	4	3.5	3.23	59.8 kgCO_2e/m^3 (new generic data)
Facing brick	0.314	0.28	0.081	147 kgCO_2e/m^3 (new generic data)

About this publication

Decarbonisation of the building stock

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