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Reduction Roadmaps: methods of determining limit-values for climate impact in construction

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Abstract. Legal and organisational limit-values for the climate impact of new buildings have emerged as an important tool to transition new construction toward emissions levels acceptable with regards to the ecological planetary boundaries while remaining feasible in terms of social needs and economic restraints. However, since no agreed-upon methods for defining the limit-values exist, organisations have developed their own bespoke methodologies, making limit-values difficult to compare directly. Decision-making may thus be conducted based on methodologies lacking scientific rigour. The aim of the present work is to compare the approaches in terms of proposed methodologies and resulting limit-values. Specifically, the objective was to identify key methodological choices which need to be made in order to establish a comparable limit-value. In a review of 14 approaches in Nordic countries, including legislative and industrial initiatives, 27 such key methodological choices were identified and organised into a conceptual framework. The initiatives were characterised as applying bottom-up or top-down approaches to define limit-values. Bottom-up approaches based on available technologies generally allow more emissions than top-down approaches based on carbon budgets, indicating a need for harmonisation and hybrid approaches. The findings can support actors in harmonising approaches and help initiatives benchmark their stated limit-values. Finally, knowledge gaps related to important methodological choices when establishing limit-values for the environmental impact of new construction are identified.

Keywords: climate impact; sustainable construction; planetary boundaries; life cycle assessment; environmental legislation

1. Introduction

Urgent action is needed in the construction sector to sharply reduce its environmental impact [1]. Legal and organisational limit-values for embodied carbon have emerged as an important tool to transition new construction toward emissions levels acceptable with regards to the ecological planetary boundaries while remaining feasible in terms of social needs and economic restraints [2]. In Nordic countries, restrictions on embodied carbon are in the process of being imposed by governmental bodies [3]. Meanwhile, in response to the urgent need for a green transition of the construction industry to avoid contributing further to the accelerating climate crisis, formal and informal *Reduction Roadmap* networks are emerging where construction actors are committing to even more ambitious limit-values than imposed in regulations [4]. A roadmap in a broad sense is a planning instrument linking shorter-term targets to longer-term goals [5]. We use the term Reduction Roadmap (RRM) to describe short-term targets for the climate impact of an industry to achieve long-term global temperature goals. An example is the development in Denmark, where an RRM initiative gathered strong support and were able to influence national decision-making in terms of the introduction of limit-values [6].

Since no internationally or nationally agreed methods for defining the limit-values exist, the governmental bodies and RRM networks in different countries have developed their own bespoke methodologies, which subtly differ in terms of approaches and resulting conclusions [3]. This leads to a situation where limit-values are difficult to compare directly, and by extension, that decision making may be conducted based on methodologies which are not scientifically sound.

Our aim is thus to identify important methodological choices related to the definition of limit-values for the climate impact of new construction, and further to compare limit-values proposed and implemented in Nordic countries. Nordic countries are chosen as they have been spearheading the proposed introduction of limit-values, and have still developed different methodologies despite strong efforts to harmonise approaches [2]. We thus pose the following two research questions:

- How can the methodological choices in the development of limit-values for the climate impact of new construction be defined and categorised?
- What limit-values for the climate impact of new construction have been proposed and/or implemented by legislative bodies and industrial initiatives in the Nordic countries?

Previous studies on limit-values for climate impact have investigated legislative approaches in the Nordic context [7]. However, they have not included industrial initiatives, and further have not provided a conceptual understanding of methodological choices. Hollberg, Lützkendorf, and Habert [8] differentiate between top-down, climate-based approaches and bottom-up approaches based on available technologies and economical considerations. Using such a bottom-up approach focusing on cement and steel industries, Karlsson et al. [9] indicate that a halving of climate impact from 2020 until 2030, with a retained construction rate, could be possible using already available measures. Meanwhile, carbon budget estimations in the Danish context using a top-down approach indicate that the safe operating space for the construction industry requires a 96% reduction of climate impact [4]. Other studies indicate that this reduction can only be achieved through a combination of technological advances in efficiency, and a reduced construction rate [6], enabled through an improved utilisation of the existing building stock [10]. The performance gap identified between top-down and bottom-up approaches motivates further studies into harmonisation, and an improved conceptual understanding [7].

2. Method and materials

We conducted a review of proposed legislation as well as industrial initiatives in four Nordic countries. The focus is on initiatives targetting new construction as it is responsible for a large portion of emissions from the construction industry. The analysis is intended to support the harmonisation of approaches and allows benchmarking of limit-values proposed in the future, while providing a conceptual framework for the description of methodological choices when defining limit-values for the environmental impact of the construction industry.

National and industrial initiatives have been collected based on local or national relevance and attention. The selection was made to include initiatives from Sweden, Norway, Finland, and Denmark, and to, if possible, include both governmental, municipal, and industrial initiatives from each country. The initiatives were systematically analysed in order to identify 1) key methodological choices and 2) defined limit-values. It should be noted that this analysis was conducted using documentation publicly available from each initiative, which means some data inconsistencies are present due to differing documentation methods. In a first step, a preliminary list of key methodological choices was developed. In a second step, the approaches in each initiative in relation to these methodological choices were identified. Finally, the methodological choices were categorised and reorganised into a conceptual framework. The initiatives include different life cycle scopes. Hence, to allow for benchmarking, where data was available the limit-values were recalculated using the scope of the Swedish Climate declaration, which only covers the life cycle assessment (LCA) modules A1-A5.

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Table 1. Overview of investigated initiatives. L.C.: Life Cycle; Ref.: Reference; Ind.: Industrial; Leg.: Legislative.; Int.: International; Emb.: Embodied impact; Op.: Operational impact

Initiative	Country	Context	Approach	Geographic	L.C. scope	Ref.
Climate declaration†	Sweden	Leg.	Bottom-up	National	Embodied	[11]
HS30	Sweden	Ind.	Top-down	Local	Embodied	[12]
Göteborgs stad	Sweden	Ind.	Top-down	Local	Embodied	[13]
LFM30	Sweden	Ind.	Bottom-up	Local	Emb. + Op.	[14]
Uppsala klimatprotokoll	Sweden	Ind.	Top-down	Local	Embodied	[15]
Reduction Roadmap Sverige	Sweden	Ind.	Top-down	National	Embodied	[16]
BR18	Denmark	Leg.	Bottom-up	National	Emb. + Op.	[17]
Reduction Roadmap	Denmark	Ind.	Top-down	National	Emb. + Op.	[18]
TEK17	Norway	Leg.	N/A	National	Embodied	[19]
Klimakrav i tek	Norway	Ind.	Top-down	National	Emb. + Op.	[20]
Limit-values†	Finland	Leg.	Bottom-up	National	Emb. + Op.	[21]
Low-carbon roadmap	Finland	Ind.	N/A	National	N/A	[22]
City of Helsinki	Finland	Leg.	Bottom-up	Local	Emb. + Op.	[23]
EPBD	EU	Leg.	Bottom-up	Int.	Emb. + Op.	[24]

† decisions to introduce the proposed limit-values in legislation have been retracted or postponed

3. Results

In analysing the investigated initiatives, four key characteristics could be established: 1) context of initiative: legislative vs. industrial; 2) approach: bottom-up (technology-based) vs. top-down (climate-based); 3) geographic scope: local, national, or international; and 4) life cycle scope: inclusion of embodied and/or operational impacts.

An overview of the investigated initiatives is provided in Table 1. We see that the legislative initiatives each apply bottom-up, technology-based approaches to defining limit-values, whereas most industrial initiatives apply top-down, climate-based approaches.

3.1. Methodological choices

From the investigation of the initiatives, 27 key methodological choices could be identified. These were organised into three categories, namely *Goal and scope for impact assessment*, *Implementation strategy*, and *Carbon budget definition*. Here we focus on the key elements, while the approaches applied in each investigated initiative can be requested from the authors.

3.1.1. Goal and scope for impact assessment The first category relates to the LCA methods used to define limit-values and carry out benchmarking during the construction process. The methodological choices include the type of buildings covered, the physical and temporal system boundaries, functional unit, reference study period, impact categories, and inclusion of biogenic carbon. The major contrast here can be seen in terms of the temporal scope (inclusion or exclusion of operational and recurring embodied carbon) and physical system boundaries (inclusion or exclusion of specific building components). While arguments exist for each proposed approach, these differences make harmonisation and comparison of limit-values difficult.

3.1.2. Implementation strategy The second category is related to the administrative and political dimensions of implementation. Firstly, the implementation process: the development process, availability of calculation tool, database, template data and supporting resources, implementation timeline, year of introduction, frequency of adjustments, initiative status. Secondly, issues of compliance: stakeholder responsibilities, timing of reporting and benchmarking certification of calculation professionals, compliance control, verification process, calculation model for operational emissions. While we see a range of approaches here, these choices can likely be explained through different organisations at local, national, and international levels. It should be noted that all methodologies presented are self-declared and lack independent verification.

3.1.3. Carbon budget definition The third category deals with the definition of carbon budget for top-down initiatives. This includes the allocation principle per country and sector, the climate data used, and climate scenarios considered.

We can see that while most of the top-down approaches state to build on global carbon budgets as defined by IPCC, the definition and allocation of carbon budgets to the construction of new buildings lack full transparency, particularly regarding the methodologies and principles used. Methodologies differ in how emissions are calculated and allocated to the construction industry and the building level, for example if they are based on territorial emissions (Reduction Roadmap Denmark) or consumption-based emissions (Reduction Roadmap Sweden). These differences can have implications for how responsibility is assigned and how ambitious the resulting limit-values are.

There is also a variation in the required rate of emission reductions across initiatives: between 2020 and 2030, targets range from 70% (Uppsala klimatprotokoll, HS30, Göteborgs Stad) to 96% (RRM Sweden, RRM Denmark) reductions. These discrepancies are partly due to the timing of the implementation of each initiative and the version of the global carbon budget available at that time. The calculations are based on IPCC global carbon budget 2018 (Uppsala Klimatprotokoll) to 2023 (RRM Denmark, RRM Sweden). Further, where some of the initatives only define limit-values for specific years (Göteborgs stad, LFM30, Klimakrav i tek), others define limit-values as continuous pathways (Uppsala klimatprotokoll, RRM SE/DK, HS30).

This raises the critical question of whether and how often climate impact limit-values should be updated to reflect the latest climate science. While updates ensure alignment with evolving knowledge and shrinking carbon budgets, it also introduces uncertainty for project planning, building design, and long-term strategic decisions within organizations.

Table 2. Limit-values for multifamily housing in each initiative. Impl.: Currently implemented.

Initiative	Limit-values 2025	2030	Unit	LCA modules (beyond A1-A5)	Impl.	2025 A1-A5 limit (recalculated)
Climate declaration† (SE)	375	280	kg CO_2eq./m^2	No	No	375
HS30 (SE)	200	110	kg CO_2eq./m^2	No	Yes	200
Göteborg stad (SE)	200	120	kg CO_2eq./m^2	No	Yes	200
LFM30 (SE)	216	150	kg CO_2eq./m^2	No	Yes	216
Uppsala klimatpr. (SE)	200	105	kg CO_2eq./m^2	No	Yes	200
Reduction Roadmap (SE)	270*	56*	kg CO_2eq./m^2	No	No	270
BR18 (DK)	8.6	7.2	kg CO_2eq./m^2,a	B4, B6, C3, C4	Yes	312
Reduction Roadmap (DK)	5.8	0.4	kg CO_2eq./m^2,a	B4, B6, C3, C4	Yes	210
Limit-values† (FI)	16	14	kg CO_2eq./m^2,a	B4, B6, C1-C4	No	N/A**
City of Helsinki (FI)	14	N/A	kg CO_2eq./m^2,a	B4, B6, C1-C4	Yes	N/A**

†decisions to introduce the proposed limit-values in legislation have been retracted or postponed
*using scenario: 50% probability of limiting the global temperature increase above pre-industrial levels to 1.5°C; constant construction rate; linear reduction assumed from benchmark value in 2023
**data for only A1-A5 modules not available

3.2. Limit-values

Table 2 shows the limit-values defined by those initiatives where limit-values have been established and are publicly available. For comparative purposes, the last column shows the 2025 limit-values in each initative, recalculated to use the same life cycle scope as the Swedish climate declaration proposal.

We see that the legislative initiatives applying a bottom-up approach generally have less ambitious limit-values than the industrial initiatives which apply top-down approaches. Especially, we see that not only is there already a discrepancy for the initial limit-values proposed in 2025, the rate of sharpening the limit-values is also much higher for the industrial initiatives. For the legislative initiatives, a 12-25% reduction of climate impact is proposed, whereas the industrial initatives propose a 30-90% reduction from already more ambitious starting levels.

4. Discussion

From the review, two key findings can be highlighted:

- Methodological choices can be characterised as related to LCA goal and scope; implementation strategy; and carbon budget definition.
- There are large gaps between top-down (climate-based) industrial initiatives and bottom-up (technology-based) legislative initiatives.

4.1. Methodological choices

We see that while methodological choices are largely similar, some subtle differences exist, especially in terms of LCA scope (temporal and physical system boundaries). For harmonisation purposes, this makes it difficult to directly compare proposed limit-values. While it seems reasonable that each country defines the LCA methodology based on local conditions, available data, etc., it would be beneficial to also introduce a standardised scope internationally that would be reported to allow benchmarking. Especially, since reporting of embodied carbon is included in each proposed initiative, reporting of A1-A5 impacts using unit kg CO_2eq./m^2 in addition to any locally reported indicators would be a good starting point for this [3]. A recent study also demonstrates that focusing on upfront carbon emissions does not lead to different design choices compared to limit-values including recurring embodied carbon emissions throughout the lifecycle (B2-B4) [2]. There are several arguments for an emphasis on upfront carbon emissions: they make up a large share of the emissions over the lifetime of a building; they remain locked in; and they take place at the point of construction, not in a distant future [1]. It should be noted that all initiatives propose limit-values involving square metre of new construction as functional unit, which means benchmarking against carbon budgets requires assumptions about future construction rates [7]. With regards to the implementation of limit-values, a range of strategies are identified, which is logical as they are developed in different national and local contexts. The recommendation is to learn from best practices, establish knowledge exchange networks, and collaborate for instance around tool development and supporting resources, aiming for harmonisation in terms of level of compliance control.

4.2. Top-down and bottom-up approaches

Most legislative, bottom-up approaches are based on case studies representing widespread construction practices using available technologies [2]. However, by applying bottom-up approaches only, there is no guarantee that derived limit-values guide the construction industry toward fulfilling internationally agreed climate targets. The support behind top-down approaches in industry, and the growing number of examples of projects achieving ambitious benchmarks presented by these initiatives, reveal that there are no technical and economical barriers toward a far less climate intensive construction practice, only a lack of legislative incentives. On the other hand, too ambitious limit-values may be considered unrealistic in the short term, and dismissed by the industry [7]. Hence, as proposed by Hollberg, Lützkendorf, and Habert [8], we encourage the definition of hybrid approaches, which are based on available technology and economic considerations, but are also benchmarked in relation to scientifically defined carbon budgets. While our results indicate the feasibility of such an approach, our literature review yields no examples of practical case studies of such approach, which would be a valuable future research direction.

The likelihood of staying within the carbon budgets defined by hybrid approaches would be increased by considering not only the relative climate impact per built square metre, but also the absolute climate impact reduction of the entire built environment achieved through a reduced construction rate [6]. Strict limit-values for new construction would then need to be complemented by focusing on a better utilisation of the existing building stock as a feasible means to reduce carbon emissions [10].

5. Conclusion

In order to support harmonisation and scientific rigour, this article presents a review of 14 initiatives defining limit-values for greenhouse gas emissions from new construction in Nordic countries. 27 key methodological choices were identified. These can be categorised as firstly *goal and scope for impact assessment*, treating the methodology for life cycle assessment; secondly *implementation strategy*, treating the political and administrative approaches to implementation in practice; and thirdly *carbon budget definition*, treating how carbon budgets are defined and taken into account in relation to the defined limit-values. It was found that the initiatives could be described as either top-down (carbon-budget based) or bottom-up (technology-based). The top-down, industrial initatives were generally more ambitious in terms of lowering limit-values than bottom-up, legislative approaches. This can be seen both in terms of the initial ambition level, and the rate of sharpening limit-values in the next five year period. The findings provide the foundation for the future harmonisation and benchmarking of proposed and implemented limit-values toward reducing the environmental impact of the construction industry. In a first step, this could be applied in a Nordic context, and then further scaled up to the establishment of globally agreed limit-values which take into account the need for human development internationally.

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