Towards embodied carbon benchmarks for buildings in Europe

#4 Bridging the performance gap: A Performance framework

Tozan, Buket; Birgisdottir, Harpa; Steinmann, Jacob; Le Den, Xavier; Horup, Lise Hvid; Sørensen, Andreas; Röck, Martin

DOI (link to publication from Publisher):
10.5281/zenodo.6120874

Publication date:
2022

Document Version
Publisher's PDF, also known as Version of record

Towards embodied carbon benchmarks for buildings in Europe

#4 Bridging the performance gap: A Performance framework

RAMBOLL
Bright ideas.
Sustainable change.

BUILD DEPARTMENT OF THE BUILT ENVIRONMENT
AALBORG UNIVERSITY

Laudes Foundation

Towards embodied carbon benchmarks for buildings in Europe

#4 Bridging the performance gap: A Performance framework

Project name	Towards EU embodied carbon benchmarks for buildings
Date	March 2022
Authors	Buket Tozan, Harpa Birgisdottir, Jacob Steinmann, Xavier Le Den
Contributors	Martin Röck, Lise Hvid Horup, Andreas Sørensen

Ramboll
35, Square de Meeûs
1000 Brussels

Belgium
T +32 02 737 96 80
F +32 02 737 96 99
https://ramboll.com

Disclaimer

In this report, the widely used term 'embodied carbon' is applied. Herein it is considered synonymous with 'embodied GHG emissions'. The data and values presented in the following consider both CO2 and non-CO2 GHG emissions, the reference unit applied is kilogram CO2e (equivalent) expressed per m², per capita, or m² and year, respectively.

Acknowledgements

We would like to express our gratitude towards everyone that has accompanied the work in this project and helped improve the results with valuable input and critical comments. This includes:

The Built Environment team of Laudes Foundation, in person of Maya Faerch and James Drinkwater

The steering committee of the study, composed of Stephen Richardson (World Green Building Council), Josefina Lindblom (European Commission, DG Environment), Sven Bienert (International Real Estate Business School at Regensburg University), and Lars Ostenfeld-Riemann (Ramboll)

The expert reviewers of this report: Thomas Lützkendorf (Karlsruhe Institute of Technology), Stephane Arditi (European Environment Bureau), Michael Neaves (Environmental Coalition on Standards), Zsolt Toth (BPIE), and Phil Kelly (Ramboll).

Lastly, we would like to thank the Communications teams of Ramboll and Laudes Foundation for getting the message spread.

Cite as

Tozan B, Birgisdottir H, Steinmann J, Le Den X, Horup L H, Sørensen A, Röck M. Towards EU embodied carbon benchmarks for buildings – Bridging the performance gap: A benchmarking framework, 2022, https://doi.org/10.5281/zenodo.6120874.

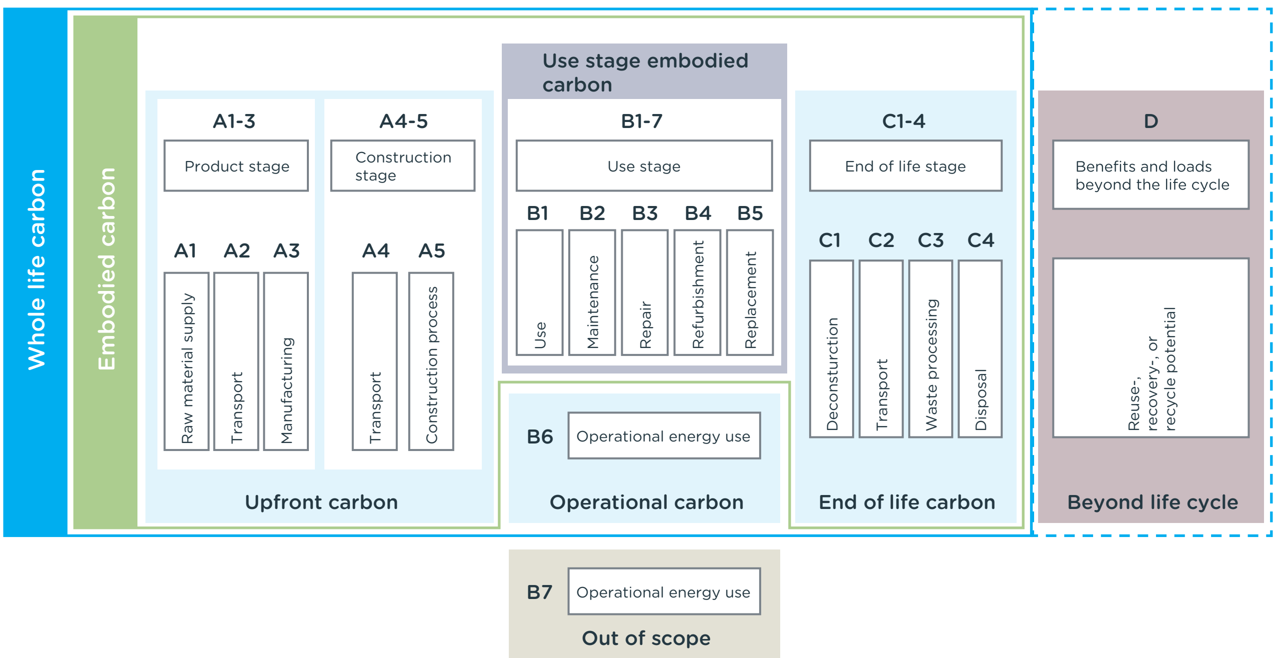
Executive summary

Rationale – Why is this important?

"Embodied carbon" consists of all the greenhouse gas (GHG) emissions associated with the construction products (materials, products, and building components and systems), construction processes, use and end of life of the whole life cycle of a building[1]. While past efforts have mostly focused on increasing energy efficiency in building operation, recent research on the GHG emissions across the full life cycle of a building highlights the increasing importance of embodied GHG emissions in relation to producing and processing construction products. The urgent state of climate change requires rapid action without any further delay.

The "Towards Embodied Carbon Benchmarks for buildings in Europe" project was set up by Ramboll and BUILD AAU - Aalborg University with the support of the Laudes Foundation. The objective is to improve our understanding of embodied carbon in buildings and to set framework conditions for reducing it. In particular, the focus lies on upfront embodied emissions which represent the largest share of embodied carbon and can be addressed at the design stage (Figure 1). In order to do so, the project explores the concept of embodied carbon baselines, targets and benchmarks for buildings in Europe.

Figure 1: Definition of whole life carbon based on the life cycle stages and modules from EN15978:2012



1. Embodied carbon therefore includes: material extraction, transport to manufacturer, manufacturing, transport to site, construction, maintenance, repair, replacement, refurbishment, deconstruction, transport to end-of-life facilities, processing, disposal.

To drive embodied carbon emissions reduction, a performance framework is needed. This performance framework is based on reference values built on a solid data foundation and combining the status quo with the embodied carbon levels required to limit global warming to 1.5oC. This report outlines how such a performance system could be created, what building blocks are needed and how the remaining gap between reality and climate necessity can be bridged.

Sustainability benchmarks for buildings – How do they work?

A benchmarking system defines reference values to measure and manage performance in relation to a key parameter: embodied carbon. In accordance with ISO 21678:2020, two types of reference systems are possible:

- Bottom-up benchmarks relate to the values of the existing level of embodied carbon based on an empirical dataset. Possible bottom-up reference values can, for instance, remain below the average for current buildings or not cause more emissions than the best-in-class buildings.
- Top-down benchmarks relate to values determined by external factors, such as the global carbon budget. The relevant top-down benchmark is to limit embodied emissions below the levels required by downscaled budgets for the building sector.

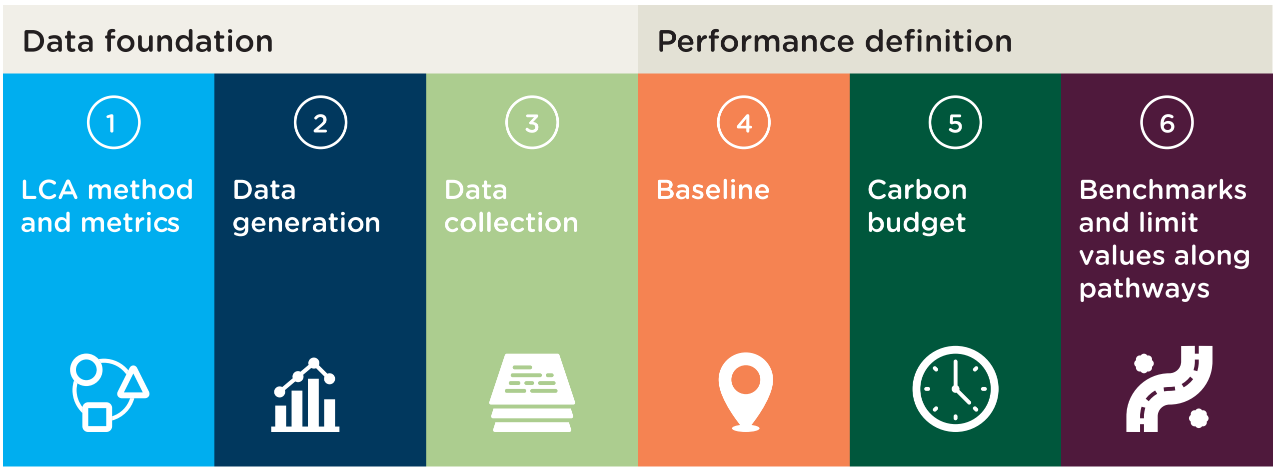
In existing sustainability performance systems, benchmarks for embodied carbon in buildings are rare. Only a few initiatives such as DGNB, BNB and national legislation in Denmark and France define reference values. These benchmarks are all based on bottom-up methods and relate to national building samples or a business-as-usual scenario for the building project.

The comparison of the baseline on embodied carbon in new buildings in five EU Member States (see report #2 "Setting the baseline") and the calculation of a carbon budget and pathway (performed in report #3 "Defining budget-based targets") reveal a gap between the reality of the building sector and the necessity of climate science. The embodied carbon performance gap **benchmarks are a useful tool for closing this gap gradually with efficient but ambitious reference values**.

A performance system – How can we close the embodied carbon performance gap?

A successful and efficient performance system for embodied carbon from new buildings needs to first build the data foundation on new constructions and subsequently set a framework consisting of a baseline, a carbon budget and decarbonisation pathways that translate into intermediate benchmarks or limit values.

Figure 2: Overview of the proposed benchmarking system



In detail, the elements of the performance system are the following:

Table 1: Elements of the performance system for embodied carbon

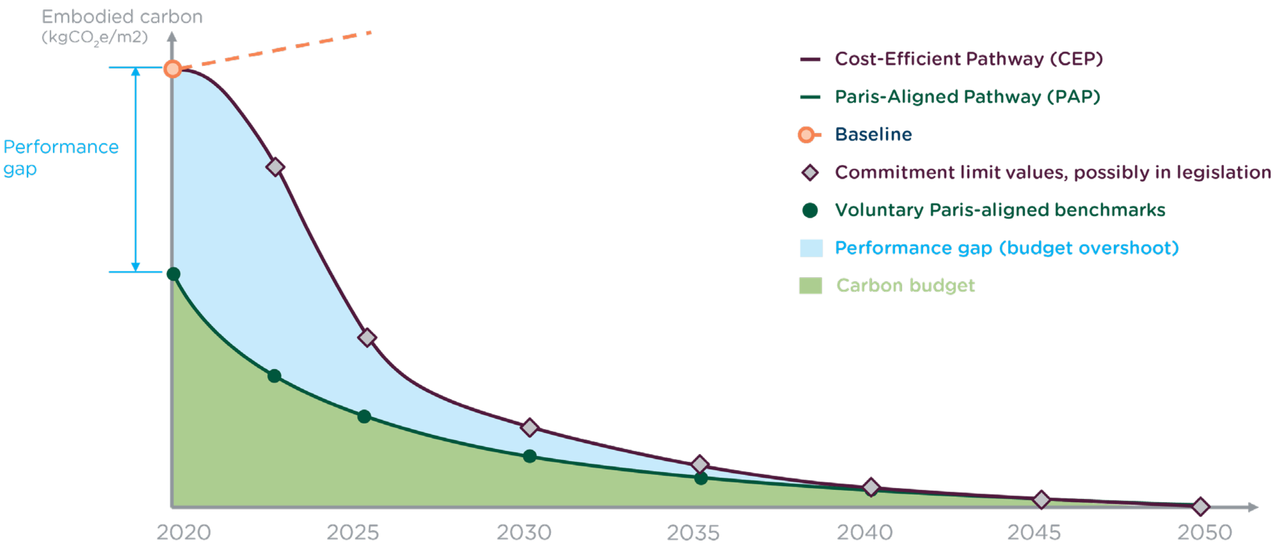
Performance system for embodied carbon	
Data foundation	
LCA method and metrics	• Nationally standardised LCA methods following the ISO and EN standards • Environmental data on building products and materials based on the EN standards. Data should be both industry and product specific. • Clearly defined parameters for the LCA calculations (including life-cycle scope, building elements, service life of buildings, handling of biogenic carbon and reused and recycled materials.) • Reporting metrics (per m2 and per capita) • Includes extended documentation requirements, e.g. supported by the Level(s) framework or Digital Building Logbooks
Data generation	• Obligation or strong incentives to conduct LCAs for new buildings • Based on extended documentation requirements of contextual factors • Obtain a representative sample of new buildings for developing a baseline
Data collection in databases and software tool	• Centralised collection of LCA data for new buildings • Central database for calculating and comparing future buildings • Supported by a software tool for LCA calculations and data input • Aligned with a national LCA method • Open data available to stakeholders
Performance framework	
Baseline	• Baseline/reference value of status quo building practice • Calculated based on data collected in steps 1-3 • Expressed in embodied carbon levels per square metre and per capita • Updated regularly based on data on new buildings
Carbon budget	• Paris-aligned emission levels for embodied carbon • Calculated based on downscaled global budgets • Expressed in embodied carbon budgets per square metre and per capita • Representing target values for decarbonisation that should be reached as soon as possible • Updated regularly based on revisions of the global carbon budget and sectoral overshoot

Benchmarks and limit values along pathways	• Two sets of reference values along two pathways:
	  ◦ Voluntary benchmark values in a Paris-Aligned Pathway (PAP) based on the carbon budget pathway
	  ◦ Limit values in a Cost-Efficient Pathway (CEP) based on a shared commitment by the industry after consultation

The resulting performance framework is illustrated in Figure 2. The Cost-Efficient Pathway should be ambitious so as to minimise, as much as possible, the overshoot of embodied emissions over the budget limit. However, as this will not eliminate the overshoot completely, further considerations are required.

- Firstly, it highlights the **urgency in taking action** to reduce embodied emissions per built square metre. Any delay in starting the reduction will increase the overshoot and mean that the budget is depleted even faster, thus decreasing the likelihood of limiting global warming.
- Secondly, a **reduction in new construction activity** increases the budget available for new square meterage. Therefore, strong emphasis on renovating existing buildings and promoting sufficiency in building space use will reduce the budget overshoot.
- Thirdly, **carbon removals** created by removing carbon from the atmosphere and capturing it in building materials, for example in biogenic substances, may balance some of the emission overshoot in the future if the carbon can be captured at the end-of-life stage. However, this perspective comes with a high number of limitations, which means that relying on carbon removal can only be one supportive measure in a combination of actions to reduce the budget overshoot. Additionally, from a life cycle perspective, the carbon emissions associated with the end-of-life stage must be considered and might not result in negative emissions.

Figure 3: Embodied carbon performance framework



Call to action – What should we do?

Implementing this performance framework will require a combined effort from the whole value chain in the building industry, certification bodies, researchers, and policy makers. A national approach is suggested here, as many existing sustainability certification schemes are operating at the national level and some countries have already adopted legislation on whole life carbon emissions in buildings. However, the EU also has a highly relevant role in facilitating the harmonisation of calculation methods for LCA baselines and carbon budgets through instruments such as the Level(s) framework, as well as defining a European roadmap to steer the sector across the whole of the EU. The key responsibilities for actions in each step are summarised in Table 2.

Table 2: Call to action on combined effort for establishing a performance framework

Call for action	Who?	What?
Foundation		
LCA method and metrics	Policy makers Researchers Product manufacturers Building designers Certification bodies Non-profit organisations	• Develop a robust national LCA method and develop environmental product declarations applicable to the country, both industry-specific and product-specific • Create basis for harmonising national methods
	Policy makers	• Integrate LCA method into national building regulations or otherwise promote the use of the method
	Building designers Real-estate investors	• Adopt whole life cycle thinking and the national method and integrate into everyday practice
Data generation	Policy makers	• Create obligations or other strong incentives to use the LCA method developed in step 1
	Researchers Product manufacturers Certification bodies Building designers Non-profit organisations	• Use the method to monitor embodied carbon and publish reports regularly
Data collection in databases and software tool	Researchers Certification bodies Building designers Non-profit organisations	• Initiate and maintain national data collection for LCA data
	Policy makers Certification bodies	• Develop a software tool for LCA calculation, data collection and analysis • Create open-source database for LCA data
	Building designers Real-estate investors	• Use data and tool to assess and compare projects

Performance framework		
Baseline	Policy makers Researchers	• Determine the baseline based on the current building practice compiled in the database • Monitor progress and regularly update the baseline
Carbon budget	Policy makers Researchers Building industry NGOs	• Define carbon budget based on data and support from the industry, researchers and certification bodies
	Policy makers	• Publish carbon budget in a policy document
Benchmarks and limit values along pathways	Policy makers Researchers Building industry NGOs	• Agree on and commit to a Cost-Efficient Pathway
	Policy makers	• Define Paris-Aligned Pathway based on carbon budget distribution over time and Cost-Efficient Pathway based on sector agreement • Set reference values for limit values and voluntary benchmarks at intervals of 3-5 years • Monitor progress and regularly update the pathways and reference values
	Certification bodies	• Align with voluntary benchmarks, go beyond limit values

Contents

1. Introduction

As the effects of the accelerating climate and ecological crises are becoming evident, the need for transformational climate action is growing. Based on decades of climate science and driven by increasing pressure from civil society, policymakers in the European Union (EU) and beyond are making bold claims to reduce greenhouse gas (GHG) emissions in their respective regions and activities.

Building construction and operation are among the most significant activities driving current GHG emissions, representing 37% of global GHG emissions [1]. At the same time, increasing the energy efficiency of existing and new buildings, along with shifting to sustainable construction practices, are considered major opportunities for decarbonising the economy in the coming decades.

Altogether, the total amount of embodied and operational emissions is referred to as whole-life carbon emissions. Reducing this total sum of a building's emissions is the highest priority, to which this work aims to contribute.

While past efforts have mostly focused on increasing energy efficiency in building operation, recent research on GHG emissions across the full life cycle of a building highlights the increasing importance of embodied GHG emissions in relation to producing and processing construction material. "Embodied carbon" includes all the greenhouse gas (GHG) emissions associated with materials and construction processes, use and disposal throughout the whole lifecycle of a building[2].

These embodied emissions in buildings are rarely addressed in policy strategies and instruments. However, if embodied carbon is not included in building decarbonisation targets, a failure to meet global decarbonisation targets is highly likely. This is because the total climate impact of buildings would remain only partly addressed. Thus, the need and potential for reducing embodied emissions require attention and alignment as part of European and global efforts to combat climate change. It was against the backdrop of increasing efforts to understand and reduce the whole carbon life cycle of buildings that the project "Towards Embodied Carbon Benchmarks for the European Building Industry" was set up.

In particular, setting a performance system for embodied emissions at building level can provide relevant guidance for policymakers and the building industry. Developing the foundations of such a performance system for new buildings has been the objective of the project "Towards Embodied Carbon Benchmarks for buildings in Europe", set up by Ramboll and Build AAU - Aalborg University, with the support of the Laudes Foundation. This includes a baseline for current embodied carbon levels in new buildings, as well as considerations of the available carbon budget for these emissions. Together with a review of data availability and quality, these elements form the basis for a performance system in the form of reference values for reducing embodied carbon.

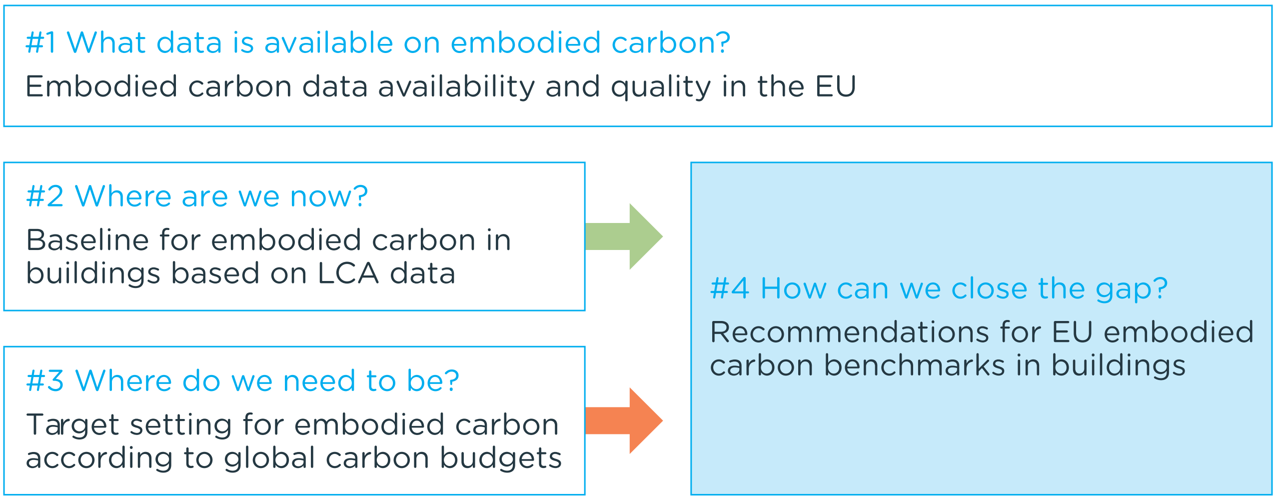
The project focused on the EU. This is due to its position as a pioneer in energy use reduction initiatives such as Energy Performance of Buildings Directive, and in GHG emission reduction policies with instruments such as the Taxonomy for Sustainable Activities and the EU Climate Transition Benchmark Regulation. Additionally, there is increased policy awareness of the life cycle perspective of buildings. These instruments and initiatives will have an increased impact on the building industry. This project seeks to inform the current debate involving policymakers and industry alike and to stimulate the development and application of reference values for embodied carbon in the EU and beyond.

2. Embodied carbon therefore includes: material extraction, transport to manufacturer, manufacturing, transport to site, construction, use phase, maintenance, repair, replacement, planned refurbishment, deconstruction, transport to end of life facilities, processing, disposal.

The series of reports produced as part of this project provide insights and developments on the following questions:

1. What data is available on embodied carbon in the EU?
2. Where are we now? What is the current status of embodied carbon in new buildings?
3. Where do we need to be? What level of embodied carbon is aligned with the available carbon budget?
4. How can we close the gap? How can benchmarks to reduce embodied carbon be set?

Figure 4: Overview of the series of reports produced for the "Towards Embodied Carbon Benchmarks for buildings in Europe" project



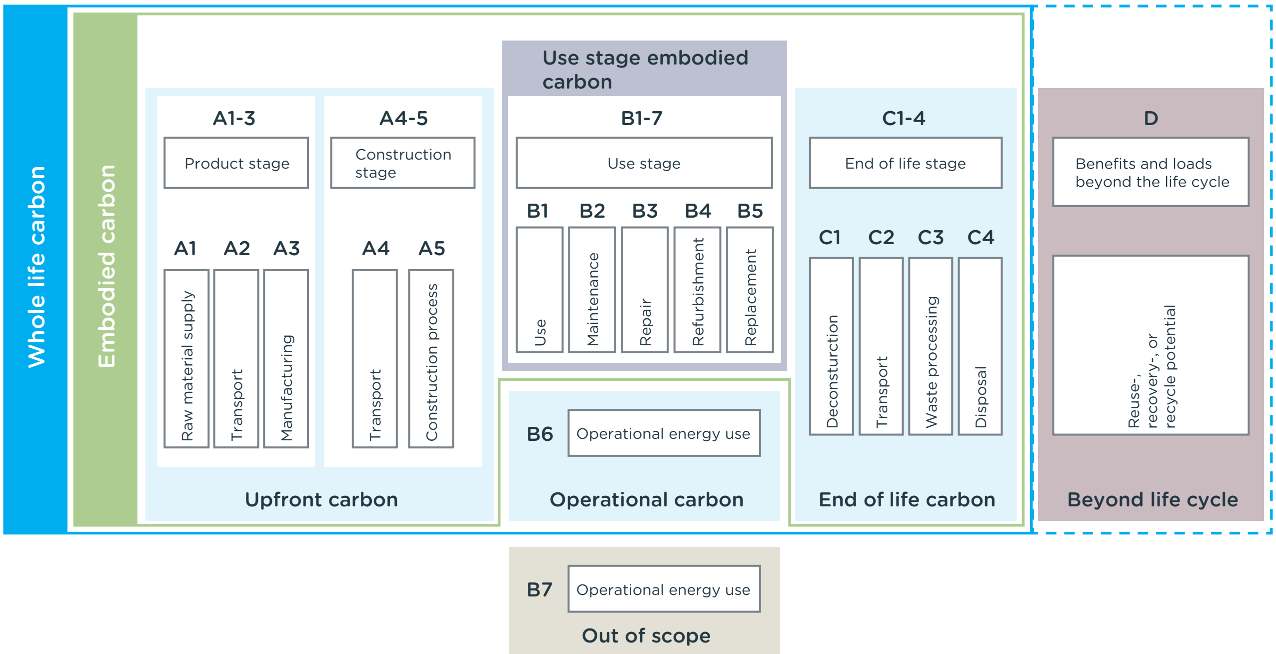
The purpose of the report herein is to outline how a performance framework for embodied carbon, that is based on bottom-up data as well as top-down climate science, can complement existing initiatives on sustainability in buildings. For this purpose, **the insights gained in the three previous reports are combined in a proposal for a performance framework** that is able to address the data challenge and minimise the embodied carbon performance gap between the embodied carbon in the baseline data and the levels required by the carbon budget.

2. What are benchmarks and what is the challenge for embodied carbon?

2.1 Embodied carbon from new buildings

To determine the embodied carbon emissions in a new building, a life cycle assessment (LCA) must be conducted. The life cycle of a building is divided into different life cycle stages and into several life cycle modules, in accordance with EN15978:2012. The embodied carbon emissions from buildings are associated with the product stage (Modules A1-5), which is referred to as upfront carbon; the use stage associated with the materials and construction products (Modules B1-5), defined as the use stage carbon; and finally the end-of-life stage (Modules C1-4), denoted as end-of-life carbon. Carbon emissions associated with operational energy use (Module B6) are not taken into consideration in the embodied carbon. An illustration of the carbon emissions throughout a building's life cycle is provided in Figure 5. Module D indicates the potential carbon benefits from reuse, recycling or recovery which can be taken into consideration, but which are not usually included in the total embodied carbon emissions due to the system boundaries.

Figure 5: Definition of whole life carbon based on the life cycle stages and modules from EN15978:2012 [2]



Several environmental impacts are usually considered in the life cycle assessments of buildings as defined in EN15978:2012. The focus here, however, is on the global warming potential of embodied carbon emissions.

2.2 Benchmarking approaches for buildings

In general, benchmarks are reference points for a comparison that allows the performance of a process, product or result to be assessed. This principle can be applied to carbon emissions from buildings, and embodied carbon more specifically, as part of assessing the sustainability performance.

A standard by the International Organisation for Standardisation (ISO) exists for Sustainability in buildings and civil engineering works – Indicators and benchmarks (ISO 21678:2020). In this standard, benchmarking is defined as the process of collecting, analysing, and relating performance data of comparable buildings or other types of construction works.

Various types of benchmarks exist, which are described in ISO 21678:2020 and summarised in Table 3. In the benchmarks, the reference values are set on the basis of a performance level. The performance level is defined as the value indicating the relative performance required (or provided) for a particular attribute on a relative scale, from the level of the least (performance) to the level of the most (performance) pursuant to ISO 21678:2020 [3].

Table 3: Elements of the performance system for embodied carbon

Type of benchmark	Statistical analysis	Determination of reference level
Upper limit values	10th or 25th percentile	• The upper acceptable performance level on a performance scale. 10% or 25% of all values shall be below this limit.
Reference value/ Baseline	Median, mean, or modal value	• The present state of the art based on relevant statistical information that describes the performance of buildings.
Lower limit value	90th or 75th percentile	• The minimum acceptable performance level on a performance scale. 90% or 75% of all values shall be below this limit.
Best practice	N/A	• The level representing the best available real performance
Target value	N/A	• This value is set by e.g. policy makers to set targets for varying performance aspects.

The previous reports for this project have laid the foundation for a baseline, as well as a budget for embodied carbon. The former constitutes a **bottom-up approach based on empirical data** from current new buildings. The latter **takes a top-down perspective of the decarbonisation** required to achieve global targets.

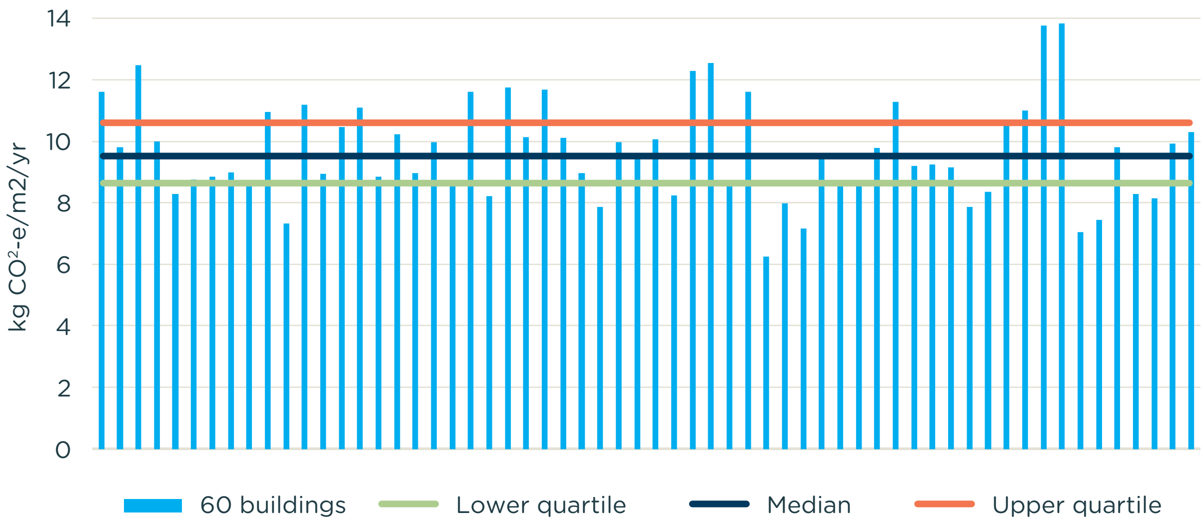
Both approaches can be translated into benchmarks. Bottom-up benchmarks can be defined and oriented on the best-in-class cases. In respect of the types of benchmarks defined in ISO 21678:2020, the top four types are defined on the basis of empirical data and only the last one has an external target value as the reference level.

Bottom-up benchmarks have the benefit of being relatable to practitioners because current cases of buildings at the reference level exist. This facilitates communicating the required actions and providing practical examples. Box 1 illustrates the underlying mechanism of whole-life carbon benchmarks for buildings, on which the Danish legislation is based (see also Chapter 3).

Box 1: Exemplary case of whole-life carbon benchmarks in Danish legislation

In **Denmark**, in 2020, a report documenting bottom-up based reference values for Danish buildings based on 60 new buildings (mainly residential and office buildings) was published by BUILD [4]. Based on those reference values, in 2020 the Danish climate partners, who advise the government, recommended introducing CO2-limit values. It was suggested that the limit value should be 12 kgCO2e/m2/year and tightened from 2023 to 2030, and that the voluntary CO2-limit value should be 8.5 kgCO2e/m2/year tightened from 2023 onwards. Based on these recommendations, in March 2021, the government introduced a plan for sustainable construction including the mandatory CO2-limit value of 12 kgCO2e/m2/year and the voluntary value of 8 kgCO2e/m2/year, which will become effective in 2023.

Figure 6: The reference values for carbon emissions from 60 Danish buildings



However, establishing benchmarks based on the empirical baseline data requires such data to be available, accessible, of high quality and comparable between the cases. This project has encountered the challenges of obtaining such data at national level in many forms. The experiences, limitations and possible solutions are summarised in the first report “Facing the data challenge”.

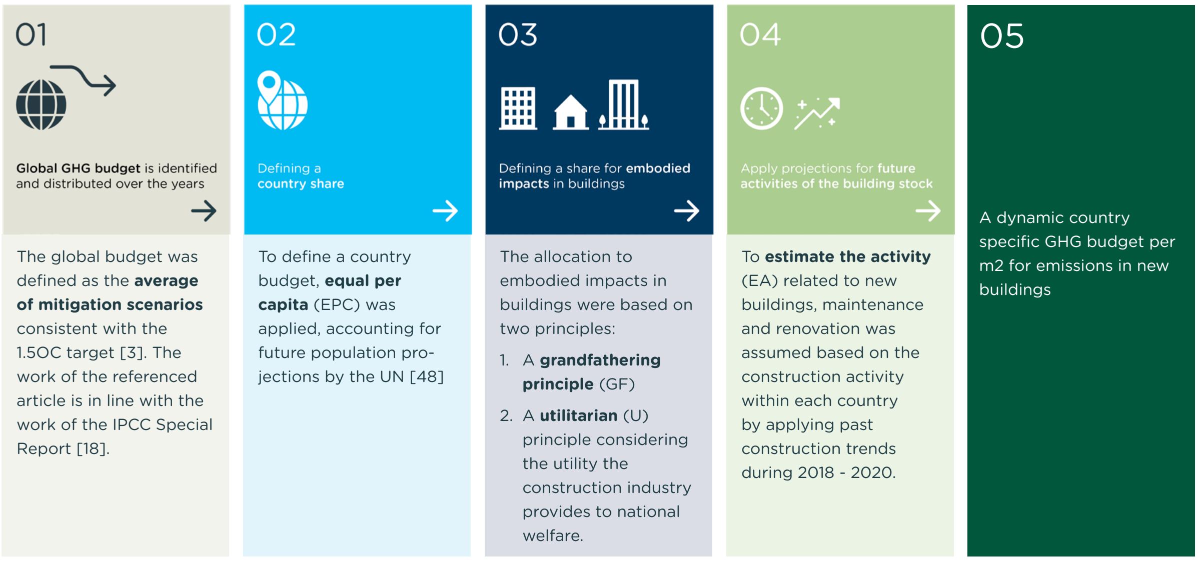
Top-down benchmarks, on the other hand, can steer the sector quickly towards the necessary decarbonisation for Paris-aligned emission limits by aligning with the available carbon budget as rapidly as possible. In the context of the increasing urgency of GHG emission reductions, an orientation based on target values provides the benefit of stressing the scale of transition needed.

The results of the report on top-down budgets for embodied emissions are illustrated in Box 2. They highlight the difference between the baseline and the budget, including a breakdown of the embodied carbon share of the Danish legal limits. This performance gap on embodied carbon calls for increased decarbonisation action, but may also result in purely top-down, budget-based upper limit values for embodied carbon to be dismissed as unrealistic by the industry, at least in the short term. Additionally, the necessary methods and data for establishing an embodied carbon budget – be it at global, national, municipal or portfolio level – are still underdeveloped. Our concept for embodied carbon budgets provides one possible solution, but wider application is also limited by data challenges.

Box 2: Example of top-down targets derived from the global carbon budget

In this project, a target pathway based on the carbon budget was calculated in the carbon budget report (#3 "Defining budget-based targets"). For this purpose, the global budget was downscaled to the Danish national level based on the population share (equal per capita, EPC), and further-specified for new construction activities based on past emission levels (grandfathering, GF) or welfare contribution (utilitarianism, U) and projected figures based on recent economic activity (EA). Figure 3 illustrates this applied process.

Figure 7: Approach to top-down carbon budget pathways for embodied carbon



Summary

In summary, a performance framework for embodied carbon has to rely on both, bottom-up and top-down considerations in order to rapidly, but feasibly, bridge the gap between reality and necessity. In particular, for the bottom-up elements a high-quality data foundation is needed first. All these elements will form part of the performance framework proposed in Chapter 4.

3. How are sustainability benchmarks currently used for buildings?

Before proposing a framework for comparing and reducing embodied carbon, it is important to understand the existing landscape of sustainability performance frameworks for buildings. Benchmarks, following the idea of reference values and relying on the types cited above, are crucial in four categories of initiatives aiming to foster sustainability in the building sector:

- Certification schemes that incentivise sustainable building design by offering recognition for voluntary ambition. To this end, a set of requirements defined by benchmarks need to be met
- Reporting frameworks that develop voluntary guidelines for collecting and presenting sustainability parameters of buildings to increase transparency and, consequently, raise ambition
- Regulation specifying legal, mandatory requirements for building design, emission levels or reporting
- Other local or public initiatives which frame mandatory requirements for either new public buildings or all new buildings within cities

In the initiatives in these three categories, benchmarks are already used to a varying extent for operational carbon, embodied carbon or whole life carbon. The key initiatives and their consideration of embodied carbon are presented below and summarised in Table 4.

Certification systems

Sustainability certification systems provide voluntary guidelines that motivate the industry to design and construct more sustainable buildings. The use of certification systems has paved the way for the use of LCAs in the construction sector. Several of these systems are in use in Europe, including LEED, BREEAM, and national initiatives such as the German DGNB which has been adapted in other countries like Denmark as well, and the French HQE. A large portion of the voluntary sustainability systems is organised by the different national Green Building Councils.

However, the scope, methods and level of ambition varies between each of these initiatives. Some certification systems, such as DGNB, require a full life cycle assessment (LCA) for a building in accordance with a specific methodology in order to be certified, while other systems, such as LEED and BREEAM, have used a life cycle approach to evaluate materials or building elements and not necessarily a full LCA of a building [5]. Level(s) on the other hand requires a holistic LCA to be performed, but does not prescribe a specific methodology [6] or reference points.

As indicated in Table 4, only the LEED and DGNB schemes set any form of limit values or other reference points for embodied carbon. **Where they exist, the current benchmarking schemes are voluntary and the reference values are not aligned with the ambition of the Paris Agreement.** Significant reductions in the environmental impacts from buildings have so far not been observed [7]. In order to achieve significant decarbonisation in the building and real estate sector, embodied carbon benchmarks with a sufficient level of ambition are, therefore, urgently needed.

Table 4: Relevant existing sustainability initiatives for buildings and their use of benchmarks for embodied carbon

	Purpose	Building coverage	Emission scope	Existence of embodied carbon benchmarks
Certification schemes				
BREEAM	Promotes sustainability considerations in construction by certifying robust assessments of impacts from material choices.	• All types of buildings • Different standards for new construction and retrofits.	Requirements for material inputs and construction stage, optional inclusion of other life cycle stages	No benchmark or limit value used.
LEED	Promotes sustainability considerations in construction by certifying robust assessments of impacts from building life cycles.	• All types of buildings • Different standards for new construction and retrofits.	Cradle to grave life-cycle stages.	Reduction of whole-life carbon emissions compared to baseline scenario receives higher scores.
DGNB	A sustainability scheme for new and retrofitted buildings which, amongst other things, has brought attention to life cycle assessments for buildings.	• All types of buildings both new, renovations and existing buildings.	Upfront carbon (A1-3), Use stage embodied carbon (B4), Operational carbon (B6) and End of Life carbon (C3-4).	Benchmarks for embodied carbon is a fixed reference value based on the bottom-up approach that applies for all building types.
HQE	Certification scheme for buildings that primarily focuses on the occupants' health and comfort.	• New buildings, renovations and existing buildings.	Assessment of emissions is carried out on construction product-level and not building level. No required scope.	No benchmark or limit value used.
Reporting frameworks				
Level(s)	Common framework for more sustainable buildings in Europe. Specific criteria for quantifying GHG emissions for different experience levels in the construction industry.	• All types of buildings.	Upfront carbon (A1-5), Use stage embodied carbon (B1-5), Operational carbon (B6) and End of Life carbon (C1-4) – also denoted as cradle to grave.	No benchmark or limit value used.
Global Real Estate Sustainability Benchmarks (GRESB)	GRESB systematically reports and evaluates the disclosure of environmental, social and governance (ESG) data from listed real-estate companies.	• All real-estate elements of companies' portfolios.	All life cycle stages can be included.	Disclosure of embodied carbon emissions can be included, if available. No benchmark or limit value used.
Carbon Disclosure Project (CDP)	The Carbon Disclosure Project (CDP) runs a global disclosure system for companies or cities to manage their environmental impacts.	• No specification of the building coverage.	Primary focus on scope 1 and 2, but scope 3 can also be disclosed.	Using their system, CDP members can achieve science-based targets. No benchmark or limit value used.
Taskforce on Climate-related Financial Disclosure (TCFD)	The Task Force on Climate-related Financial Disclosure supports organisations to improve and increase their reporting of climate-related financial information.	• No specification of the building coverage but can be included if scope 3 is disclosed.	The framework suggests that organisations in general should provide emissions associated with scope 1 and 2 and, if possible, scope 3 GHG emissions. Should be reported in alignment with the GHG protocol.	No benchmark or limit value.

Principles of Responsible Investment (PRI)	The Principles for Responsible Investment (PRI) work to encourage investors to use responsible investment. The strategy here is to incorporate environmental, social and governance (ESG) factors.	• Buildings occupied by organisations using the framework can be reported.	The recommendations of the TCFD are integrated in PRI, which allows organisations to voluntary report scope 1, 2 and 3.	No benchmark or limit value.
Science-Based Targets Initiative (SBTi)	Standardises an organisation's approach to emissions reduction targets.	• No specification of building coverage.	Focus on scope 1 and 2 emissions, which relate predominantly to operational emissions. No specific criteria for embodied carbon as part of scope 3 so far.	No benchmark or limit value used.
Building System Carbon Framework by WBCSD	Framework to transparently report, account and measure whole life carbon	• Whole life carbon emissions. New buildings and construction work, major retrofitting and system emissions.	Reporting and accounting of whole life carbon: Upfront carbon (A1-5), Use stage embodied carbon (B1-5), Operational carbon (B6) and End of Life carbon (C1-4) and beyond life cycle (D). Also, scope 3 in accordance with the GHG Protocol.	No benchmark or limit value used.
Regulation				
EU Taxonomy for sustainable activities [8]	Defines criteria for sustainable economic activities in the EU.	• New construction (separate criteria for renovations).	Operational emissions in detail, plus whole-life carbon.	Requirement for reporting on whole-life carbon for all new buildings. No limit or reference value is fixed.
EU Energy Performance of Buildings Directive (EPBD, proposal for revision of December 2021) [9]	Part of the Fit for 55 package which sets the vision for zero-emissions building stock by 2050. EPBD focuses on the operational carbon from buildings, but recently expanded to embodied carbon for new buildings.	• The whole life carbon of all new buildings shall be calculated as of 2030, while new buildings with floor area greater than 2000 m2 must be calculated as of 2027.	The whole life carbon shall be reported in accordance with the Level(s) framework.	No benchmark values are provided yet.
Danish legislation in the National Strategy for Sustainable Construction [10]	Places focus on carbon emissions from Danish buildings with LCA and aims for reductions in the future.	• All new buildings to report whole life carbon emissions.	Upfront carbon (A1-3), Use stage embodied carbon (B4), Operational carbon (B6) and End of Life carbon (C3-4).	Buildings larger than 1000 m2 to fulfil limit value of 12 kgCO2e/m2/year. Voluntary limit value of 8 kgCO2e/m2/year. Limit values will be tightening up in the period 2023-2029.
French legislation in Décret n° 2021-1004 [11]	Reducing the climate impact from new buildings by integrating energy and carbon requirements.	• Residential buildings in the form of detached and attached houses and social housing.	Upfront carbon (A1-5), Use stage embodied carbon (B1-4), Operational carbon (B6), End of Life carbon (C1-4) and beyond life cycle (D).	From 2022 CO2-limit values will be introduced and tightened up until 2030 starting from 640 to 415 kg CO2e/m2 for detached and attached houses, and from 740 to 490 kgCO2e/m2 for social housing, respectively.
Finnish proposal for a Method for a whole life carbon assessment of buildings [12]	The proposal contributes to developing legislation that aims to achieve low-carbon construction.	• New buildings and extensive repairs.	Upfront carbon (A1-5), Use stage embodied carbon (B4), Operational carbon (B6) and End of life carbon (C1-4).	No benchmark or limit value provided, however this is planned to be implemented by 2025.

Reporting frameworks

Reporting frameworks also create voluntary mechanisms to increase transparency on climate-related parameters for building construction and operation. In contrast to certification schemes, reporting usually happens at an organisational level, and is aggregated for the portfolio of buildings owned by an organisation. Such frameworks provide support and recognition for the standardised measurement of climate impacts so as to be able to manage and mitigate them.

The frameworks define elements, on which reporting is mandatory to obtain the approval, or on which disclosing data can be optional. As can be seen in Table 4, most reporting frameworks cover a wide range of economic activities and focus on emissions in scopes 1 and 2, while indirect emissions from the value chain in scope 3 are often voluntary. **Therefore, embodied carbon emissions are less specifically addressed, and no reference values are provided.** Only GRESB targets the real-estate sector specifically, but does not define benchmarks in its requirements.

A framework that is specially made for buildings is Level(s). **Level(s) has great potential to encourage the construction industry in Europe to think sustainably,** since it provides a holistic method that considers every aspect of sustainability. It gives guidance on how to design and construct more sustainable buildings, although it does not provide a benchmark value yet [13].

However, the purpose of reporting frameworks is to be able to compare an organisation or building asset to others in the market. This is strongly supported by these frameworks, even though the embodied carbon, as indirect emissions in the value chain, does not take a prominent role. This concept of benchmarks also uses a bottom-up approach based on the reported data from companies, buildings or portfolios and does not include reference to the carbon budget.

Regulation

In contrast to most certification systems and reporting frameworks, regulations create legal obligations. In relation to embodied carbon, these can relate to limit values for the quantity of emissions from buildings or spatial development, requirements for building design, or emissions reporting.

The **European Union** has adopted a taxonomy for sustainable activities, which specifies sustainability requirements for a wide range of sectors. Reporting on alignment with these criteria will become mandatory for many EU companies in the future. For Construction and Real Estate, benchmarks are set for operational carbon, while whole-life carbon emissions have to be calculated for buildings larger than 5000m2 [8]. Reference values for whole-life or embodied emissions would improve the ability to be able to interpret the reported data and enable limits to be set in the future. However, such benchmarks are not included in the current list of criteria.

Additionally, the EU Commission has proposed revisions to the Energy Performance of Buildings Directive (EPBD). The Directive has required national benchmarking frameworks for operational energy use for a long time, expressed in Energy Performance Certificates (EPC) for buildings. The proposal aims to introduce the obligation to calculate the life-cycle global warming potential and to include this in the EPC for new buildings above 2000m2 from 2027 and for all new buildings from 2030. However, only disclosure is provided for in the proposal, without any reference levels, as is the case with energy efficiency classes for operational emissions. [9]

Increasing the ambition for embodied carbon in these instruments, by applying limits for embodied carbon, would require reference values or even mandatory limit values that express the ambition required for, as well as the practical feasibility of, decarbonisation.

At **national level**, several EU Member States have also adopted or proposed regulations on embodied carbon levels. Several countries have introduced requirements to carry out LCAs for new buildings and to document the results. This is the case in Denmark, France, the Netherlands and Sweden.

Denmark and France have also adopted limit values for whole life carbon emissions that represent reference values for new buildings. In Denmark, the whole life carbon limit is based on the bottom-up approach of 12 kgCO2e/m2 per year. The legal requirements are supplemented with a voluntary CO2 class of 8 kgCO2e/m2/year. The limit value will apply for all new buildings greater than 1000 m2 from 2023 and is expected to be lowered every second year resulting in a new value in 2025, 2027 and 2029 [10]. In France, the building Regulation sets whole-life carbon thresholds for houses and apartments, which will be valid from 2022. These thresholds take into account both operational and embodied carbon [11]. For upfront embodied emissions, the requirements provide that new buildings will emit at least 30% less in 2030, compared to 2013 by gradually tightening the reduction requirements of 15% in 2024, 25% in 2025 and 30-40% in 2027 [20]. Similar instruments are being developed in Sweden and Finland.

In total, however, **only a few countries are implementing embodied carbon benchmarks or limit values into building regulations,** and these are not necessarily aligned with the ambition of the Paris Agreement, that the EU and all its Member States have committed to. The difference between the current approaches and the Paris-aligned benchmarks is explained in the following section.

Other local or public initiatives

Several other initiatives have introduced requirements for embodied carbon at local level for public buildings moving from voluntary sustainability assessments to mandatory requirements [14]. Not all of them are aligned with the climate goals which the countries have committed to, while some have been aligned with the climate targets.

As one example, Germany introduced the Sustainable Building Assessment System (BNB) in 2013 [15] as a requirement for new public buildings. With this assessment system, a holistic evaluation of the whole-life cycle of public buildings is achieved [16]. The BNB defines a bottom-up based reference value of 9.4 kgCO2e/m2NFA/year for whole-life carbon emissions, thus aligning with the DGNB certification system benchmark. Recently, new bottom-up based reference values for the German DGNB system were determined, resulting in a reference value of 8.7 kgCO2e/m2NFA/year [17]. This could also potentially become an updated benchmark for BNB.

An example for a local initiative is the Swiss Federal Office of Energy which, in compliance with their vision for a 2000-Watt Society, has developed an energy efficiency path for the city of Zurich, where one of many objectives is to establish a sustainable basis for the building stock. The aim of the efficiency path is to reduce GHG emissions to 1 ton CO2e/capita and achieve 'climate neutrality by 2050' [18]. Based on the 2000-Watt Society, the Swiss Society of Engineers and Architects has produced the SIA 2040 report, in which the limit value value of 11 kg CO2e/m2/year is proposed for public buildings [19].

Summary

In summary, the overview of existing sustainability initiatives for buildings indicates the growing awareness for reducing embodied and whole-life carbon, but only few have defined benchmarks or limit values for this type of emissions. Where reference values exist, these have been defined in a bottom-up approach based on good practices from current new building construction projects.

A performance framework that accelerates the decarbonisation of the construction sector in line with science-based, Paris-aligned, carbon budgets would enable increased ambition in the certification systems, reporting frameworks and regulations.

4. What should a performance framework for embodied carbon look like?

The previous chapters have highlighted the need for embodied carbon benchmarks as an enabler for the transition of the construction sector towards a climate-neutral society by bridging the embodied carbon performance gap between reality and necessity. This is needed to support both national policies and several important European initiatives such as Level(s), EPBD and EU Taxonomy.

The goal of an embodied carbon performance framework must be to efficiently lower the carbon emissions from buildings. However, the report so far, which has also been informed by the other three reports produced by this project on: data availability, baseline and budgets, shows that the development of a performance framework has to build on a robust data base and also reflect sufficient ambition to bridge the gap between the baseline and the available budget.

In this respect, the two benchmarking approaches should supplement each other. **A bottom-up component building on baseline data and an agreed industry pathway has to gradually align with the top-down component of the carbon budget.** Bringing together these two components will enable efficient reference and limit values.

The concept for the efficient benchmarking system is built on six elements, as shown in Figure 8. The first three elements constitute the foundation which ensures that an evidence base is available for defining the benchmarks, while the three further elements represent the performance framework which must be established based on the foundation and on additional calculations and consultations. Establishing the benchmarks, as proposed below, is very ambitious, but they are efficient in combining the feasible with the necessary. Each element is presented in detail below.

Figure 8: Overview of the proposed performance system

4.1 The data foundation

As mentioned above, a data foundation constitutes a crucial element for the performance framework and, therefore, has to be the initial focus. It provides the robust evidence base in the benchmark setting process, and also the structure for measuring whether future buildings comply with the reference values.

1. LCA method and metrics

As a first step, it is crucial that a standardised calculation method for life cycle assessments is formulated. Currently, as can be seen in the overview of certification schemes, national methodologies are common. Building on this basis, national LCA methods for buildings, that can calculate and document whole-life carbon emissions, are the most efficient solution and should be developed or agreed upon more widely. This can be considered the first right step in developing a methodology. The key parameters, on which the methodology must provide standardisation, are as follows:

- ISO standards and EN standards to define the overall method
- Environmental data on building products and materials and technical systems
- A fixed reference study period
- Service life of construction products, materials, processes and systems
- Life cycle modules included
- Building elements included
- All environmental impact categories considered and their respective units
- An agreed method for allocating emissions from reused or recycled materials
- An agreed method for estimating quantities for the building
- An agreed method for handling biogenic carbon

The existing schemes and experiences in similar countries can be used as highly relevant starting points.

The EU must take a role in this process as well, by defining the requirements for these LCA methods, for example based on the relevant ISO standards[3] and EN standards[4]. The Level(s) framework has the potential to greatly influence a harmonised data framework and establish a common language for assessing the environmental impacts from buildings. This is a key focus of Level(s) indicator 1.2 and is also stressed by the World Business Council for Sustainable Development (WBCSD) in SBT4forbuildings[5]. Combining these existing approaches creates a good starting point and will support harmonisation across national borders in the future.

In order to conduct standardised life cycle assessments of buildings, a **database containing environmental data** on construction products, materials, systems and processes is necessary, based on environmental product declarations that follow the EN standard.

The **metrics**, on which the resulting whole-life carbon emissions should be reported, should also be standardised. As described in the previous reports for this project, by quantifying emissions per square metre (based on the definition in the national building regulations), and also per capita (at least for residential and office buildings), each convey relevant information on the decarbonisation contribution and carbon efficiency of a building. These metrics can be normalised to values per annum with the suggested reference study period, as this facilitates comparison with operational carbon in the aim of minimising the whole-life emissions from a building.

3. ISO 14040 Environmental management – Life cycle assessment – Principles and framework and ISO 14044 Environmental management – Life cycle assessment – Requirements and guidelines
4. EN15978:2012 Sustainability of construction works – Assessment of environmental performance of buildings – Calculation method and EN15804+A1:2012 or EN15804:2012+A2:2019 Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products
5. SBT4buildings A framework for carbon emissions management along the building and construction value chain by WGCSD: https://www.wbcsd.org/contentwbc/download/6321/91663/1

The focus of this step of the data foundation is not on harmonised LCA methods across Member States, but rather on supporting the development of Member States' LCA competencies to enable reference values. However, if Member States develop LCA methods based on Level(s), for example, harmonisation can eventually be achieved.

2. Data generation on embodied carbon and contextual factors

In the second step, the LCA data needed to calculate embodied carbon baselines should be generated in accordance with the method defined in the first step. To this end, a legal obligation or other form of incentive for using the method should be created. In order to fully use the data and assess its representativeness, it is also highly necessary that extended reporting requirements are also included in this data generation. In addition to the levels of embodied carbon and operational carbon[6], other highly relevant contextual data points include:

- Building typology
- Year of commissioning
- Number of floors above and below ground
- Gross and heated floor area
- Energy performance class
- Energy consumption and energy supply
- Included life cycle modules in the LCA
- Included building elements in the LCA
- Materials used for the building frame and envelope
- Total weight of the building
- Climatic zone
- Planned number of occupants

The data generation process is crucial in the initial phases to reach a sample size of buildings that is sufficiently large and representative in order to enable an assessment of the baseline across building types. In the following section, the continued data generation on cases remains highly important in order to maintain an up-to-date status of the changing embodied carbon levels in construction projects as the benchmarks evolve. In addition, the points listed above will support building design professionals in the construction sector with identifying the reduction potential in their buildings, which will enable a broader understanding of which design parameters should be changed to achieve significant reductions in carbon emissions.

3. Data collection in a database and a software tool

The third element of the foundation is a central data collection of results from the LCAs on new construction projects, including the extended documentation requirements. This data should be compiled in an accessible database on embodied carbon as part of whole-life carbon that summarises, in an anonymised and aggregate form, the national data collected in accordance with steps 1) and 2). The database should be accessible by building designers to view and export data. However, the data should not be editable so as to ensure correctness and reliability. As the data will have been collected in accordance with the LCA method from step 1), new buildings can be compared to the current status in the database.

6. Additionally, it is highly recommended that data on environmental impacts other than the global warming potential, that are quantified in an LCA, such as water consumption, eutrophication, etc. are collected to enable future benchmarks to be set for these impacts as well.

In order to facilitate the expansion of the database, a software tool can be developed. The tool can calculate the whole-life carbon emissions from buildings aligned with the national methods and directly input the information into the database. A tool such as this would strongly support the updating of benchmarks in the future, as will be outlined in the following steps of the performance framework. Also, the software tool can ensure that all LCAs are based on the same prerequisites, thus resulting in a minimal number of mistakes in terms of the points listed in step 1).

4.2 The performance definition

While the foundation is a necessary basis for being able to define benchmarks or limit values, the performance definition sets the reference values for the decarbonisation of new construction.

4. Baseline

In the fourth step, the data collected in the first three steps feeds into a baseline of the current level of embodied carbon. A similar exercise has been performed as part of this project for five EU Member States in report #2 “Setting the baseline”. This represents the bottom-up starting point of decarbonisation efforts, and thus the pathways that will be defined. An overall baseline and specifications for building types should be envisaged.

As mentioned above, the baseline should state the embodied carbon per square metre and per capita, and it should be updated regularly based on cases being added to the database.

5. Carbon budget

In the fifth step, a carbon budget for embodied carbon in buildings must be calculated to understand the remaining emissions in order to limit global warming to 1.5°C, as specified in the Paris Agreement. Currently, a widely recognised global budget or national sectoral budgets are not available for embodied emissions, which is why efforts for calculating this budget will have to be made at a national level. In line with the baseline metrics, a budget should also be calculated per square metre and per capita.

Fundamental elements for the budget calculation method will have to be agreed on to set a budget which is consistent with the overall global one, or comparable national ones. For instance, principles for allocating emissions are a key element of the budget calculation and can influence the detailed results significantly. Therefore, the use of these principles and the models used for calculation must be aligned and agreed on in a wide consultation. As the budget essentially makes normative statements on future emissions, the involvement of various stakeholders is key for the robustness and acceptance of the results.

Spreading the budget over the years defines top-down, budget-based targets for embodied emission reductions that will form the basis for the Paris-aligned decarbonisation pathway in the sixth step. Report #3 “Defining budget-based targets” provides a concept for budget and target calculation for Denmark and Finland.

As with the baseline, the budget needs to be updated regularly to take into consideration developments in climate science, global emission levels and overshoot (or, less likely, overperformance) which may have taken place since the last budget calculation.

6. Benchmarks and limit values along two pathways

As the sixth and final step, benchmarks or limit values have to be set along pathways that align the baseline and the budget. To account for the difference between reality and climate necessity, two pathways should be developed:

- One the one hand, a Paris-Aligned Pathway (PAP) based on the carbon budget distribution. This pathway can be calculated based on step 5) and steer the decarbonisation process in a way so that the required levels of embodied emissions are reached as quickly as possible.

- On the other hand, a Cost-Efficient Pathway (CEP) should be defined based on the baseline and the carbon budget figures in a wide consultation with the building industry along the entire value chain and including non-profit actors. The World Business Council for Sustainable Development's Building System Carbon Framework provides a structured map of the sector and the relevant actors. This pathway constitutes a realistic, but ambitious, scenario of embodied emission reduction based on available and economically-feasible reduction solutions[7], which the sector can commit to, while also considering social and technological parameters.

The combination of the two pathways brings together the bottom-up and the top-down perspectives into a comprehensive benchmarking system for embodied carbon. The commitment to the CEP should represent limit values per square metre and per capita in the process to decrease emissions below the carbon budget. Ideally, it can be supported with legislation to create mandatory limits that tighten over time. The PAP initially represents voluntary reference values as benchmarks at building level. Respecting these values would allow a building to be referred to as 'Paris-aligned'. Legislation could foresee classes of buildings based on their embodied carbon levels. In this case, staying within the PAP could be acknowledged as class A.

Similarly, in addition to the updated calculations of the current baseline and the carbon budget, the pathways also have to be updated regularly based on those two elements. This underlines the importance of a dynamic data collection system and central database.

7. For example, circular economy actions are compiled and described in the "The decarbonization benefits of sectoral circular economy actions" report. https://ramboll.com/media/environ/decarbonisation-benefits-of-sectoral-circular-economy-actions

4.3 The complete performance framework

The elements of the performance framework and its key features are summarised in Table 5.

Table 5: Proposal for an efficient performance framework that enables aligned bottom-up and top-down reference values to be achieved.

Performance system for embodied carbon	
Data foundation	

LCA method and metrics	• Nationally standardised LCA methods following the ISO and EN standards:
	  • ISO 14040 **Environmental management – Life cycle assessment – Principles and framework** and
	  • ISO 14044 **Environmental management – Life cycle assessment – Requirements and guidelines**
	  • EN15978:2012 **Sustainability of construction works- Assessment of environmental performance of buildings – Calculation method** for the building level
	  • EN15804+A1:2012 or EN15804:2012+A2:2019 **Sustainability of construction works – Environmental product declarations – Core rules for the product category of construction products** for the building product level
	• Environmental data of construction products, materials, processes and systems based on the EN standards. Data should be both industry-specific and product-specific and applicable (representative) to the country.
	• Clearly defined parameters for the LCA calculations (including life-cycle scope, building elements, service life of buildings, handling of biogenic carbon and reused and recycled materials.)
	• Reporting metrics (per m2 and per capita)
	• Includes extended documentation requirements, e.g. supported by the Level(s) framework or Digital Building Logbooks

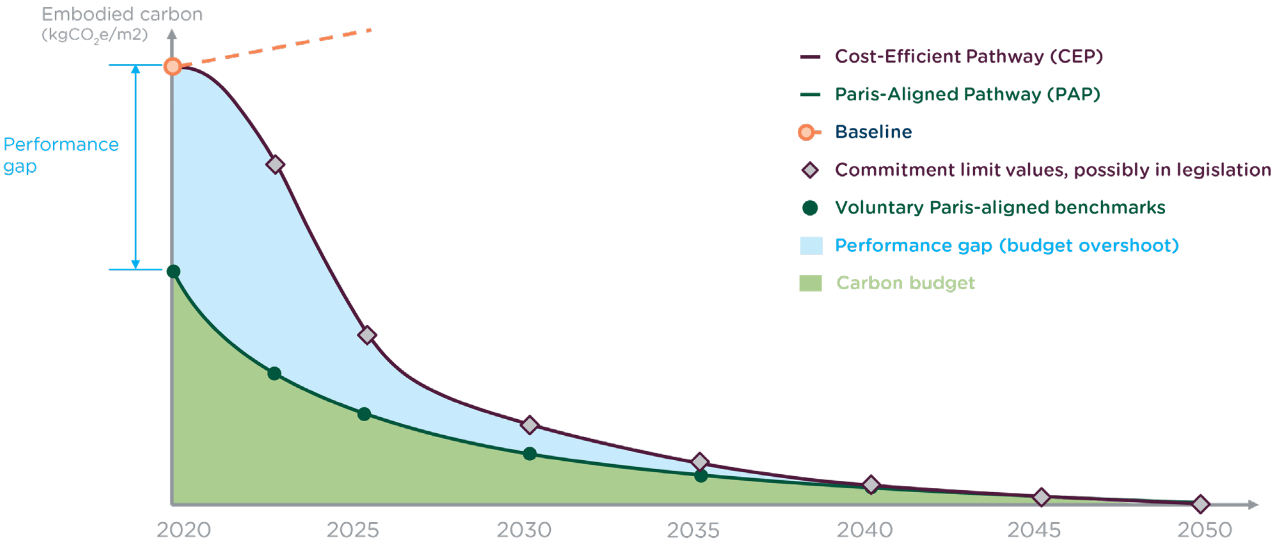
Data generation	• Obligation or strong incentives to conduct LCAs for new buildings • Based on extended documentation requirements of contextual factors • Obtain a representative sample of new buildings for developing the baseline
Data collection in databases and software tool	• Centralised collection of LCA data for new buildings • Central database for calculating and comparing future buildings • Supported by a software tool for LCA calculations and data input • Aligned with national LCA method • Open data available to stakeholders
Performance framework	
Baseline	• Baseline/reference value of status quo building practice • Calculated based on data collected in steps 1-3 • Expressed in embodied carbon levels per square metre and per capita • Updated regularly based on data for new buildings
Carbon budget	• Paris-aligned emission levels for embodied carbon • Calculated based on downscaled global budgets • Expressed in embodied carbon budgets per square metre and per capita • Representing target values for decarbonisation that should be reached as soon as possible • Updated regularly based on revisions of the global carbon budget and sectoral overshoot

Benchmarks and limit values along pathways	• Two sets of reference values along two pathways:
	  • Voluntary benchmark values in a Paris-Aligned Pathway (PAP) in accordance with the carbon budget pathway
	  • Limit values in a Cost-Efficient Pathway (CEP) in accordance with a shared commitment by the industry after consultation

By assembling the elements described in the three steps of the performance definition, a performance framework in the form of Figure 9 will be created. This figure represents the embodied carbon baseline, budget and pathways per square metre as one of the two metrics, as this is more widely applicable to building types. However, these reference values should be supplemented with per capita calculations for specific building types wherever, and as soon as, possible.

The graph highlights again the performance gap between the baseline and the carbon budget for embodied carbon. The purple line of the CEP bridges the gap to the PAP. However, a budget overshoot is inevitable as long as the CEP levels are higher than those of the PAP.

Figure 9: Embodied carbon performance framework



The following chapter will outline possible measures to minimise the embodied carbon performance gap and budget overshoot.

5. How can the embodied carbon performance gap be minimised?

Considering the urgency of reducing global GHG emissions to mitigate climate change, the embodied carbon performance gap must be minimised. The CEP represents the first step towards decarbonisation that summarises the potential for innovation and the potential for reducing embodied carbon per square metre. This relates to advances in low carbon production methods for construction materials or the substitution of traditional materials with low carbon alternatives.

However, the reduction of embodied emissions per square metre needs to take place rapidly and additional efforts and measures will be necessary to minimise the gap. The following section outlines and discusses the relevance of three key additional actions:

- Urgent action is needed, as delayed action results in additional overshoot
- Reducing new construction activity as a means to increase the available budget per square metre
- Carbon removal from biogenic building materials with capturing and removing the end-of-life emissions in the near future being a last resort to balance the budget.

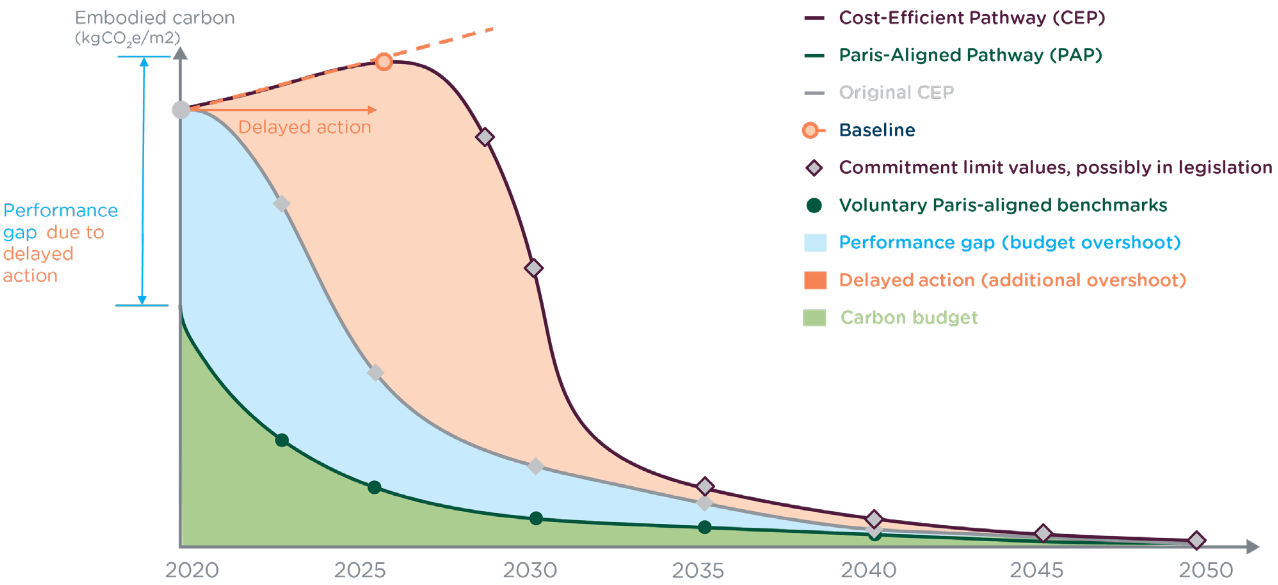
None of these actions can be expected to substantially reduce or even close the performance gap in isolation. Rather, a combination is needed, and the specific potential of each measure needs to be assessed, as they may vary between countries, building types and other contexts.

5.1 Urgent action is needed

Research on embodied carbon has identified an increasing trend both in absolute emissions and in the relative share of building emissions [19]. Therefore, the baseline of embodied emissions per square metre is expected to increase further if no specific commitment to a reduction is made. This means that any delay in taking action and committing to a CEP will result in the gap to the PAP becoming wider and the budget overshoot more significant. **The greater the overshoot in the near future also means that the available carbon budget depletes more quickly, meaning that a comprehensive reduction of embodied carbon has to take place even quicker.**

Figure 10 shows an example illustration of the consequence of delayed action on developing the performance framework: as the later and higher baseline results in additional overshoot, this in turn reduces the budget.

Figure 10: Effects of delayed action on developing an embodied carbon performance framework



Existing feasible and cost-effective strategies for reducing embodied and whole life cycle carbon emissions should be promoted and employed. This includes **optimised space and material use depending on the building type and purpose, selecting low carbon materials, as well as the use of recycled building materials**. A starting point for the uptake of strategies to reduce embodied carbon could be producing reports that present the potential of different solutions[8]. The sooner a reduction in the CEP is initiated, the more limited the embodied carbon performance gap and the lower the budget overshoot will be.

5.2 Reducing construction activity increases the budget available per square metre

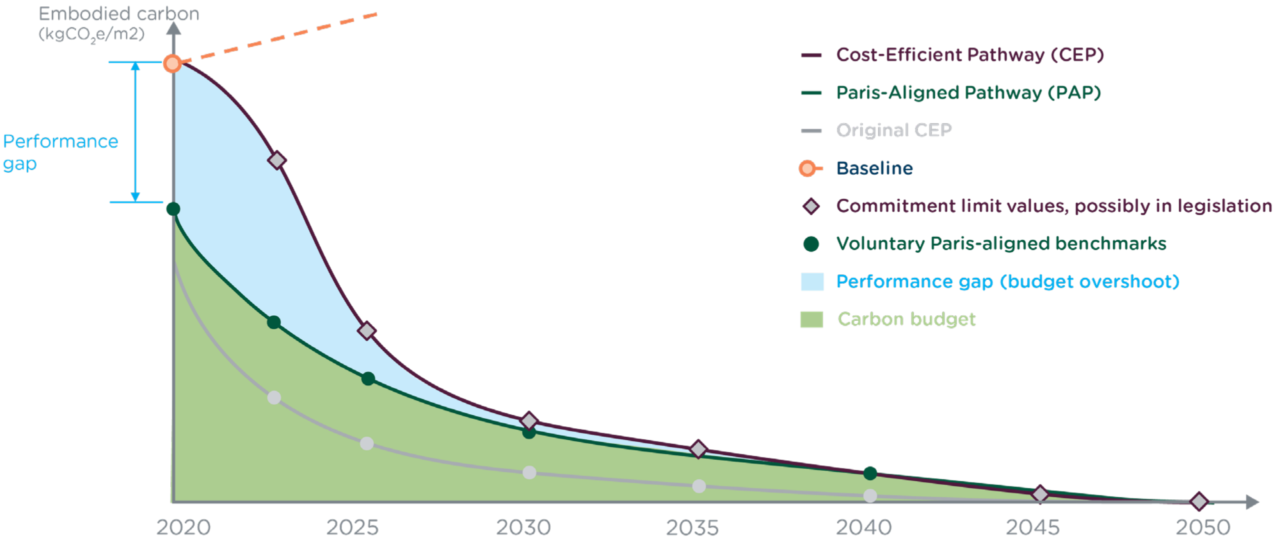
A reference value of embodied emissions per square metre can be influenced by the number of square metres built. As the carbon budget and relative pathway are based on past construction trends (see report #3 Defining budget-based targets"), a change to this trend also changes the available carbon budget for each unit.

An increase in new construction activity would mean that less budget can be attributed for each square metre, but inversely, a reduction of construction activity increases the carbon budget per m2 and therefore helps to align the two pathways.

Figure 11 illustrates the exemplary effect of a reduced construction activity with fewer square metres built. **As a result, alignment between the two pathways is possible earlier than in the original scenario, and the overshoot is substantially lower.** Mapping the embodied carbon per capita and aligning the respective pathway with the carbon budget, will be important in ensuring that a total reduction is achieved.

It should be noted that, in line with the focus and scope of this study, this scenario only relates to new buildings. In the case of older constructions, renovation plays an even greater role than in the current discussions, as it reduces the need for new buildings. Renovation also involves embodied carbon emissions, but at a lower amount as core building parts, such as the structure and frame, can be retained.

Figure 11: Effects of reduced construction activity on a performance framework



8. For example:
Malmqvist et al. (2018). Design and construction strategies for reducing embodied impacts from buildings – Case study analysis
Ramboll et al. (2020). Quantification methodology for, and analysis of, the decarbonisation benefits of sectoral circular economy actions.

5.3 Carbon removals may help balance the carbon budget

Carbon removals refer to activities that remove GHGs from the atmosphere. Using biogenic construction materials that naturally capture CO2 and other GHGs means removing and capturing the emissions for the duration of the building's existence or until the said materials are replaced. This can be achieved by using plant-based products such as wood. However, it should be underlined that in a whole life cycle perspective, the captured and stored CO2 in the materials will eventually be emitted back into the atmosphere corresponding to the end-of-life carbon. The storing of the emissions can be elongated if the construction products are not demolished and disposed of. Potentially, emissions at the end-of-life stage could be captured and removed for even longer.

Carbon removals are one way to balance the embodied emissions that occur in the budget overshoot at the beginning. The need for negative emissions at a global scale is documented in most global emission scenarios (for example in IPCC reports and IEA scenarios). In the EU as well, initiatives are underway to structure, certify and thus promote promising carbon removal techniques. The underlying scenarios for the carbon budget calculation in report #3 "Defining budget-base targets" of this study also consider negative global emissions from 2073 onwards [21].

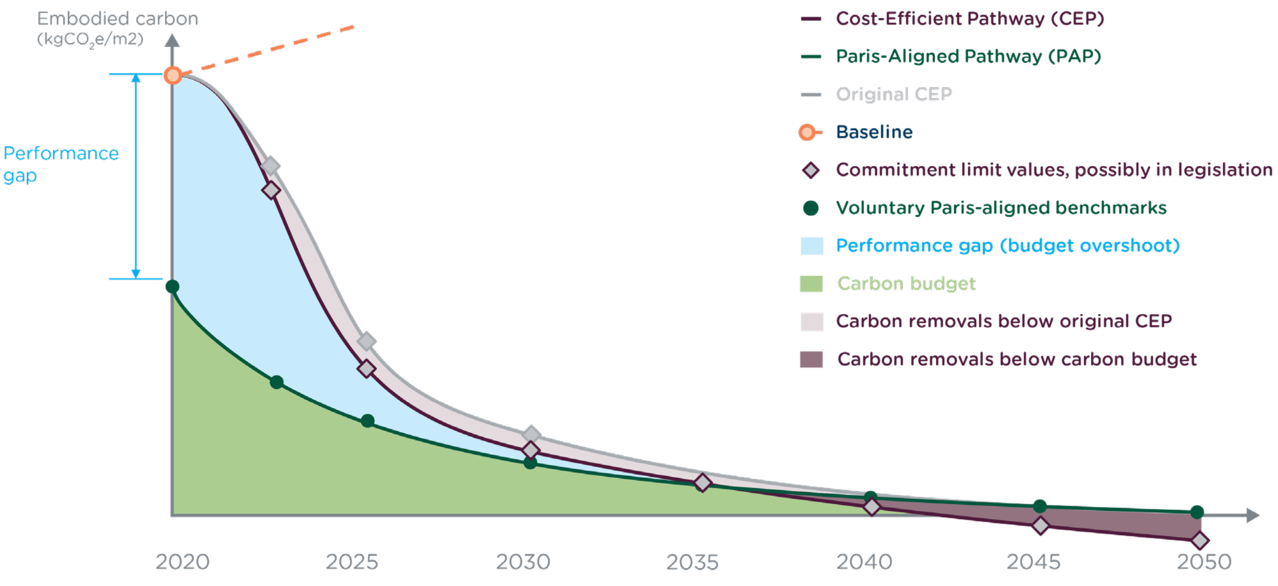
However, there are **important limitations to removing carbon as part of** achieving climate action. Firstly, the amount of carbon removed in the future is uncertain, in particular as technological removal solutions are not yet available at a significant or commercial scale. Secondly, the storage duration in a building is also uncertain, as early demolition may release the captured GHGs back into the atmosphere. These two reasons result in a risk in relation to relying on future negative emissions to balance short-term overshoots. As a third limitation, the emissions will have had their greenhouse effect over the period between their release and the removal. Thus, global warming may have continued, and a direct balancing may not be appropriate.

Nonetheless, the contribution of carbon removals through biogenic materials and end-of-life carbon capture – as one measure in combination – can be a relevant factor in mitigating the performance gap of embodied carbon.

The sum of emissions is assumed to be negative in the CAP after 2073. Therefore, an excess in the global emission scenario could lower the budget overshoot. It is stressed that using biogenic materials and preparing for further carbon removal needs to start without any delay and must reach a negative sum prior to 2073 in order to balance the overshoot from the earlier years.

Figure 12 illustrates the possible effect of carbon removals with an earlier start, in the 2040s. As the illustration shows, expanding negative emissions at a speed comparable to previous emission reduction rates only balances small shares of the initial overshoot.

Figure 12: Effects of carbon removals on a performance framework



6. Conclusions and recommendations

A performance framework is urgently needed to close the embodied carbon performance gap between the baseline of current embodied emissions and the available carbon budget for these emissions. To achieve this, both bottom-up and top-down considerations need to be reflected in the reference or limit values. However, data availability is a crucial challenge in this context, as standardised LCA data for buildings is needed to calculate a baseline, budget and to inform the definition of decarbonisation pathways.

Therefore, the proposed performance framework builds on a **foundation** that aims at making the necessary data accessible and usable, in order to then be able to define a **performance framework** in which benchmark values are set as milestones for the future.

This performance framework requires broad efforts at national level, involving policymakers, existing certification schemes, the building industry value chain and academia, as summarised in Table 6. **The role of the EU** is, however, also important in enabling cross-national comparison through general standards and supporting and harmonising national efforts with initiatives, for example the Level(s) framework. Moreover, an EU-level g system as a framework, guidance and reference for national advances is highly relevant.

Table 6: Call to action on combined effort for establishing a performance framework

Call for action	Who?	What?
Foundation		
LCA method and metrics	Policy makers Researchers Product manufacturers Building designers Certification bodies Non-profit organisations	• Develop a robust national LCA method and develop environmental product declarations applicable to the country both industry-specific and product-specific • Create basis for harmonising national methods
	Policy makers	• Implement LCA method in national building regulations or otherwise promote the use of the method
	Building designers Real-estate investors	• Adopt whole life cycle thinking and the national method and integrate in everyday practice
Data generation	Policy makers	• Create obligations or other strong incentives to use the LCA method developed in step 1
	Researchers Product manufacturers Certification bodies Building designers Non-profit organisations	• Use the method to monitor embodied carbon and publish reports regularly
Data collection in databases and software tool	Researchers Certification bodies Building designers Non-profit organisations	• Initiate and maintain national data collection for LCA data
	Policy makers Certification bodies	• Develop a software tool for LCA calculation, data collection and analysis • Create open-source database for LCA data
	Building designers Real-estate investors	• Use data and tool to assess and compare projects

Performance framework		
Baseline	Policy makers Researchers	• Determine the baseline based on the current building practice compiled in the database • Monitor progress and regularly update the baseline
Carbon budget	Policy makers Researchers Building industry NGOs	• Define carbon budget based on data and support from the industry, researchers and certification bodies
	Policy makers	• Publish carbon budget in a policy document
Benchmarks and limit values along pathways	Policy makers Researchers Building industry NGOs	• Agree on and commit to a Cost-Efficient Pathway
	Policy makers	• Define Paris-Aligned Pathway based on carbon budget distribution over time and Cost-Efficient Pathway based on sector agreement • Set reference values for limit values and voluntary benchmarks at intervals of 3-5 years • Monitor progress and regularly update the pathways and reference values
	Certification bodies	• Align with voluntary benchmarks, go beyond limit values

Out of the steps needed to develop the proposed performance framework, **defining a harmonised data collection method** is the first priority, where collaboration is needed to align the potential existing practices used by public institutions, the different certification schemes, research methodologies and information on material production fed into an LCA calculation method, that is efficient and robust on all of a building's life cycle stages. Promoting the resulting method and requiring its application by policymakers would provide highly relevant support to ensuring fast and widespread uptake.

As a result, **data could be generated and collected** by researchers, building designers, investors or shared via the certification bodies. This collective work would help create the database required within the shortest possible time, while maximising the data collection efficiency and representativeness.

The **calculation of the carbon budget** will be needed on the same scale as the LCA method. Again, a combined effort of academia, policymakers, industry and certifiers is needed to obtain the necessary data points. A broad coalition of credible institutions across the building industry is needed to form the basis of the calculation. An agreement on principles at the global or EU level is considered to be very useful to ensure a harmonised and consistent approach at national level, and in organisations and municipalities. Ultimately, policy documents should define a carbon budget for embodied emissions, for example as part of a whole life carbon emission roadmap for buildings.

As mentioned, **defining the Cost-Efficient Pathway** requires an agreed commitment by the sector and should, therefore, be based on a wide consultation. This should be managed by a credible and well-accepted institution in the national sustainable buildings landscape, either from public policy institutions or from independent bodies.

Establishing this performance framework will be an important step towards reducing embodied carbon in maximum alignment with global climate objectives and would provide a framework for further actions and measures in the sector.

Appendix 1- REFERENCES

[1] Global Alliance for Buildings and Construction, Global Status Report for Buildings and Construction, 2020.

[2] World Green Building Council, Advancing Net Zero, Ramboll, C40, Bringing embodied carbon upfront, Bringing Embodied Carbon Upfront. (2019) 35. https://www.worldgbc.org/sites/default/files/WorldGBC_Bringing_Embodied_Carbon_Upfront.pdf.

[3] ISO21678:2020, Sustainability in buildings and civil engineering works – Indicators and benchmarks – Principles, requirements and guidelines, (2021).

[4] R.K. Zimmermann, C.M.E. Andersen, K. Kanafani, H. Birgisdottir, Whole Life Carbon Assessment of 60 buildings Possibilities to develop benchmark values for LCA of buildings (BUILD Report 2021:12), 2021.

[5] Danish Building Research Institute, Sustainable Building Certifications, 2012.

[6] N. Dodd, S. Donatello, Level(s)-A common EU framework of core sustainability indicators for office and residential buildings User Manual 1: Introduction to the Level(s) common framework (Publication version 1.1), (2021). https://ec.europa.eu/jrc (accessed December 9, 2021).

[7] H. Gervasio, S. Dimova, A. Pinto, Benchmarking the Life-Cycle Environmental Performance of Buildings, Sustain. 2018, Vol. 10, Page 1454. 10 (2018) 1454. https://doi.org/10.3390/SU10051454.

[8] European Commission, Construction of new buildings - EU Taxonomy Compass | European Commission, (2020). https://ec.europa.eu/sustainable-finance-taxonomy/activities/activity_en.htm?reference=7.1 (accessed February 17, 2022).

[9] European Commission, Proposal for a Directive of the European Parliament and of the council on the energy performance of buildings (recast), 2021.

[10] Ministry of the Interior and Housing, National Strategy for Sustainable Construction, 2021.

[11] Ministère de la Transition Ecologique, Décret n° 2021-1004 du 29 juillet 2021 relatif aux exigences de performance énergétique et environnementale des constructions de bâtiments en France métropolitaine, 2021.

[12] Ministry of the Environment, Method for the whole life carbon assessment of buildings (2019:23), 2019.

[13] N. Dodd, S. Donatello, Level(s) indicator 1.2: Life cycle Global Warming Potential (GWP) User manual: introductory briefing, instructions and guidance (Publication version 1.1), (2021).

[14] Z. Toth, J.V. Reviewed, B. Jeffries, C. Milne, H. Sibileau, M. Stambler, S. Steuwer, O. Rapf, M. Fabbri, WHOLE-LIFE CARBON: CHALLENGES AND SOLUTIONS FOR HIGHLY EFFICIENT AND CLIMATE-NEUTRAL BUILDINGS, (2021). https://www.bpie.eu/ (accessed January 19, 2022).

[15] A. Rietz, N. Kerz, M. Welsch, Experiences from the Implementation of the Assessment System for Sustainable Building (BNB) in Germany, IOP Conf. Ser. Earth Environ. Sci. 290 (2019). https://doi.org/10.1088/1755-1315/290/1/012059.

[16] BBSR, Assessment System - Bewertungssystem Nachhaltiges Bauen (BNB), (2020). https://www.bnb-nachhaltigesbauen.de/en/assessment-system/ (accessed January 19, 2022).

[17] DGNB Germany, BENCHMARKS FÜR DIE TREIBHAUSGASEMISSIONEN DER, (n.d.).

[18] Swiss Society of Engineers and Architects, SIA Energy Efficiency Path SIA 2040_2017 Construction.pdf, (2017).

[19] M. Röck, M.R.M. Saade, M. Balouktsi, F.N. Rasmussen, H. Birgisdottir, R. Frischknecht, G. Habert, T. Lützkendorf, A. Passer, Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation, Appl. Energy. 258 (2020) 114107. https://doi.org/10.1016/j.apenergy.2019.114107.

[20] ATIBT, A look back at the new guidelines of the French Environmental Regulation (RE 2020) | ATIBT, (2020). https://www.atibt.org/en/news/12902/a-look-back-at-the-new-guidelines-of-the-french-environmental-regulation-re-2020 (accessed December 8, 2021).

[21] J. Rogelj, A. Popp, K. V. Calvin, G. Luderer, J. Emmerling, D. Gernaat, S. Fujimori, J. Strefler, T. Hasegawa, G. Marangoni, V. Krey, E. Kriegler, K. Riahi, D.P. Van Vuuren, J. Doelman, L. Drouet, J. Edmonds, O. Fricko, M. Harmsen, P. Havlík, F. Humpenöder, E. Stehfest, M. Tavoni, Scenarios towards limiting global mean temperature increase below 1.5 °C, Nat. Clim. Chang. 8 (2018) 325–332. https://doi.org/10.1038/s41558-018-0091-3.