Towards embodied carbon benchmarks for buildings in Europe

Summary report

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Project name	Towards EU embodied carbon benchmarks for buildings
Date	March 2022
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Disclaimer
In this report, the widely used terms 'embodied carbon' and 'carbon budgets' are applied. Herein it is considered synonymous with 'embodied GHG emissions' and 'GHG budgets'. These terms therefore refer to both CO_2 and non-CO_2 GHG emissions. The data regarding global emission budgets presented in this report do, however, differentiate between carbon only and GHG emissions and thus refer to either GHG emissions (CO_2-eq) or CO_2 emissions.

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Executive summary

This study, conducted by the engineering, architecture and consultancy firm, Ramboll, in collaboration with leading European researchers from AAU Built and KU Leuven, and funded by Laudes Foundation, puts forward a framework for assessing and monitoring embodied emissions at the building level and a recommended benchmarking process related to European Member States' carbon budgets.

The series of reports provides critical guidance for policymakers, investors and developers, advocating for greater cooperation across the value chain. This is desperately needed for gathering life cycle assessment data and setting targets that are aligned with the 2015 Paris Agreement to support the built environment's transition to a lower-carbon future.

Embodied carbon matters

The built environment generates **37% of annual global carbon emissions, of which 10% is embodied carbon.** However, embodied carbon has long been a hidden part of a building's climate impact, as many climate policies and reduction initiatives focus on the operational emissions related to the use of the building. By gathering data from multiple sources, and from case studies in five European countries, the report shows that the **embodied carbon in a new building amounts to 600 kgCO_2e/m²** on average (with there being great variation depending on the building type, structure and material used), that **70% of this embodied carbon is emitted upfront** (before the building is used), and that embodied carbon emissions in new buildings are continuing to increase.

Carbon budget considerations are missing from the discussion on embodied carbon

Reducing embodied carbon to levels aligned with the Paris Agreement **requires an emissions pathway based on the available budget for these emissions** (calculated from the total remaining carbon budget, on a per-country basis. The study shows that this kind of consideration is not yet sufficiently developed in existing reduction initiatives. Critically, it proposes a new methodology to define and implement Paris-aligned budgets and therefore pathways related to embodied carbon in buildings. A comparison of the budget pathways with the current embodied carbon levels of the baseline highlights a **substantial embodied carbon performance gap between reality and climate necessity.**

Data on embodied carbon is largely lacking

Effective measures to reduce the embodied carbon in buildings **require robust data on the current levels of such emissions** from different life cycle stages, building types, building elements and materials. The report shows that large samples of such data are critically missing, and existing datasets face a series of challenges in order to be useful for producing robust embodied carbon benchmarks.

We propose a performance framework that bridges the gap between the baseline and the carbon budget

The study proposes a **performance framework** which will help to overcome the data challenges to building the foundation and enable the defining of reference values to increase reduction and close the embodied carbon performance gap. **Two sets of reference values are proposed: (1) industry limit values** based on a Cost-Efficient Pathway as agreed upon and committed to by the entire value chain, non-profit organisations and policymakers; and **(2) Paris-aligned benchmarks on the budget-based pathway that form reference points for all stakeholders. Both pathways have to converge as soon as possible to limit the budget overshoot**. This can be supported by measures to reduce new construction and expand the use of carbon removals through biogenic building materials and the storage of carbon after demolition.

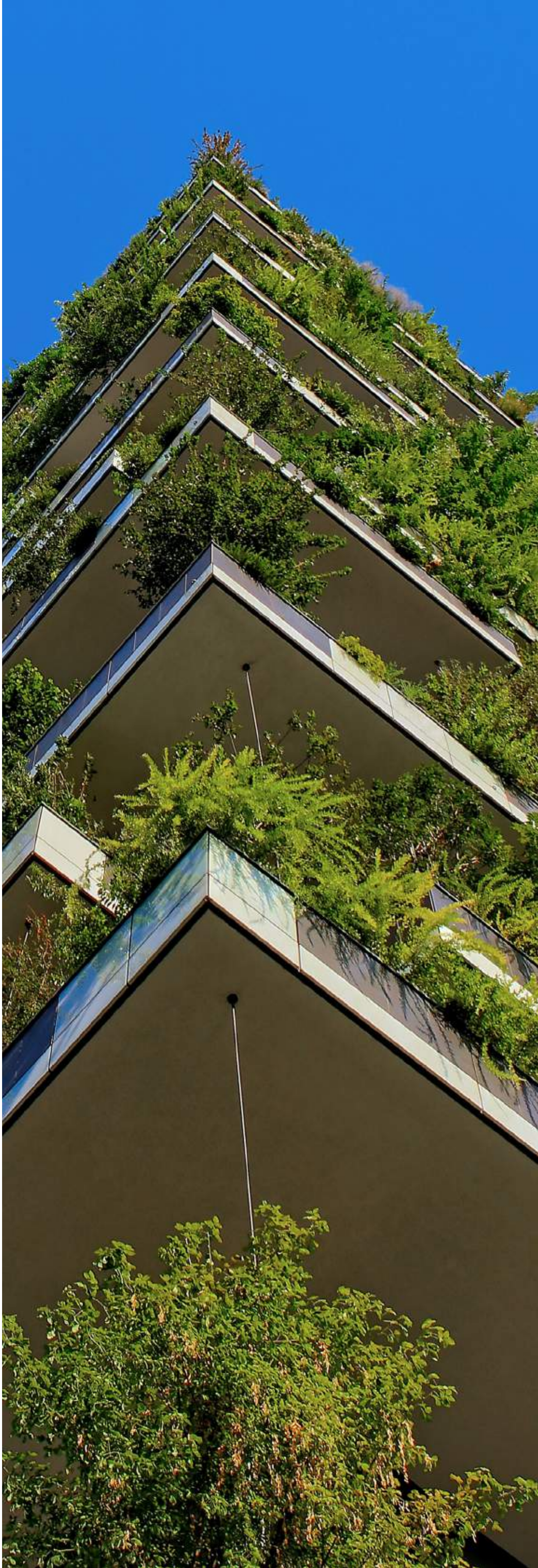
All stakeholders needs to respond with urgency

The detailed reports formulate solutions to measure embodied carbon, define carbon budgets and targets and reduce embodied carbon. They include recommendations for a baseline of current embodied carbon levels in new buildings, as well as consideration of the available carbon budget for these emissions, to form the basis of a performance system in the shape of benchmarks for the reduction of embodied carbon.

The **key recommendations in the study** on how to establish the elements needed for accurate benchmarking of embodied carbon are:

- **Policymakers** need to define and promote standardised and centralised data collection methods for emissions life cycle analysis (LCA), and establish reference values – and wherever possible limit values – for the built environment, aligned with remaining science-based carbon budgets
- **Certification bodies** must require LCAs for all new buildings, share available data, and promote benchmarks aligned with the remaining carbon budgets
- **Investors** should require LCAs for all new buildings financed, and align their portfolios with the reference values if they wish to be Paris-aligned and anticipate regulatory risks
- **Designers** must design with these benchmarks in mind, advocating low-carbon solutions

All parts of the new-build and renovation chain must **cooperate in establishing such a performance system** based on Paris-aligned and cost-efficient pathways to guide the building sector and reduce embodied carbon.



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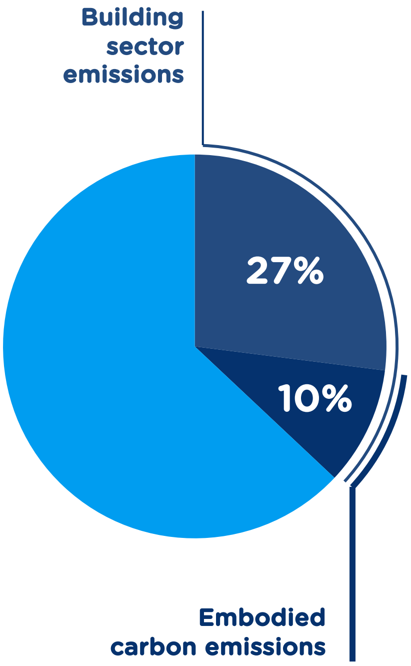
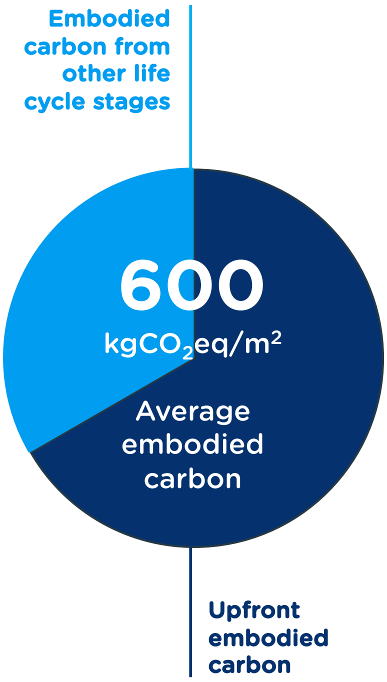




Building construction and operation are among the most significant activities driving current greenhouse gas (GHG) emissions, representing 37% of global GHG emissions[1]. Approximately one third of these relate to the carbon emissions caused by the use of materials in a building – the so-called embodied carbon.

Embodied carbon includes emissions from all steps of a building life cycle, except the emissions caused by operational energy use from electricity consumption or heating and cooling during the time when the building is used by occupants. The total sum of emissions – both embodied and operational – are called whole life carbon (WLC) emissions from a building. Past efforts to reduce these emissions have mostly focused on increasing energy efficiency in building operation. **Embodied carbon, on the other hand, is rarely addressed in policy strategies and instruments.**

This is an issue, as the absolute quantity of embodied carbon, as well as the relative share of a building's WLC, are increasing. As found in this study, the **current levels of embodied carbon are 600 $kgCO_2eq/m2$ in the EU average**. Therefore, if embodied carbon is not included in building decarbonisation targets, failure to meet global decarbonisation objectives is highly likely. Almost two thirds of embodied carbon are emitted upfront, before the building is put into use, making new construction a major emitting activity and requiring urgent reduction actions

The project "Towards Embodied Carbon Benchmarks for the European Building Industry" was established to support the reduction of embodied carbon by **putting forward a framework for assessing and monitoring embodied emissions at the building level and a recommended benchmarking process related to European Member States' carbon budgets.** It was carried out by Ramboll in collaboration with researchers from BUILD at Aalborg University and supported by the Laudes Foundation.

In **four detailed reports**, the study developed the following elements of a performance framework and recommendations for next steps towards their broad implementation.

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?

The report herein **summarises the findings and key messages** of the whole study.

[1] GlobalABC (2021). Global status report. Available at: https://globalabc.org/resources/publications/2021-global-status-report-buildings-and-construction

2. Data on embodied carbon is largely lacking

In order to establish the baseline of current levels of embodied carbon in buildings, the study tried to gather data from European countries. **The objective was to compile LCA data from European countries, for which 50 cases or more could be found.** Each case represents a building where LCA data was available which could be used to provide information on the current level of embodied carbon in buildings. This would allow relatively robust conclusions to be made regarding the baseline level.

However, the data collection process conducted across Europe resulted in only five countries being identified for which sufficient data could be used. These were Belgium, Denmark, Finland, France and the Netherlands. Figure 1 summarises and illustrates the situation across Europe.

The data collection process highlighted a series of data challenges which resulted in the low number of cases which could be used. These challenges are summarised in Table 1.

The experience from those countries for which data could be collected shows that overcoming the challenges is the result of incentives to conduct LCAs and to make the results available being included in national legislation and other policy initiatives. Additionally, the **effectiveness of data collection can be increased through triple-helix cooperation between the public sector, the building industry and real estate sector, as well as academia and not-for-profit partners.**

This calls for urgent action on creating a stronger data foundation across all European countries. Any delay will mean that embodied carbon levels continue to be high with no reduction impact on global warming.

Standardised data collection tools are particularly helpful in creating useful databases and overcoming the challenges described above. To this end, legal or sectoral requirements that mandate the production of LCAs in accordance with standardised calculation and documentation methodologies are highly relevant at national level, as well as harmonisation at EU level through tools such as the Level(s) framework.

Data collection and compilation efforts are needed from all those involved in designing and assessing buildings. For this purpose, collaboration and complementary activities between public institutions, building designers, investors, certification organisations and researchers are needed. This step also relies on a common language and standardised method for LCAs, as well as the commitment and infrastructure to share the data.

During the time that it takes to develop such standardised and harmonised methods, data challenges can be mitigated in three transitional ways, as proven in this study:

Figure 1: Overview of data availability in Europe

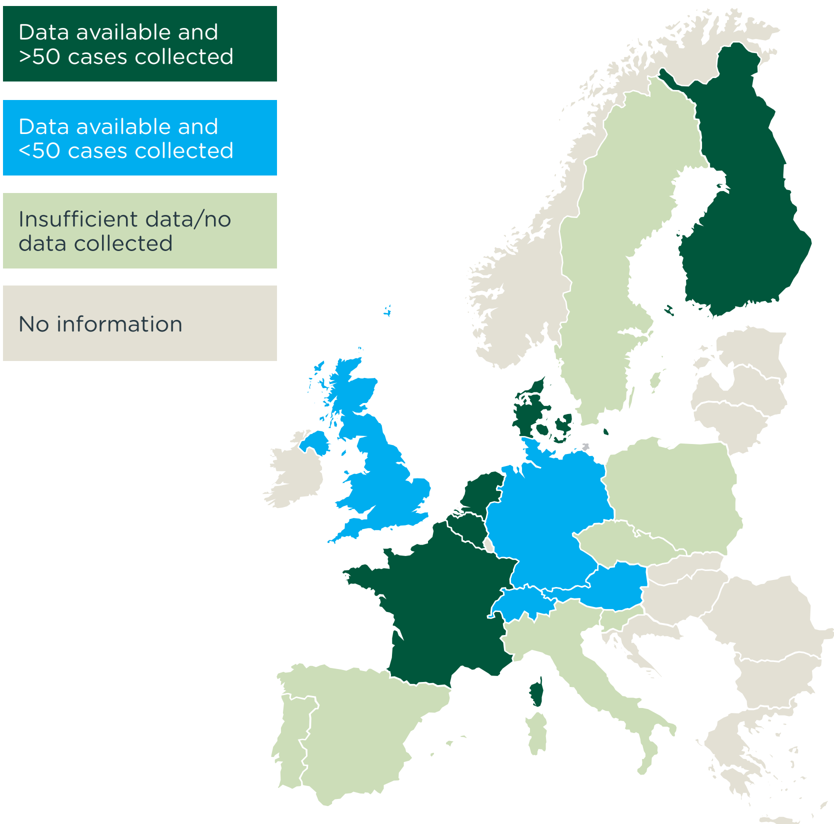
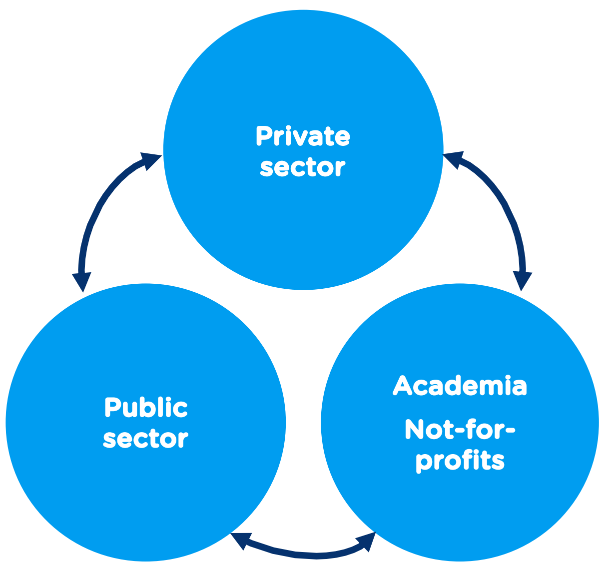


Table 1: Key challenges encountered in the LCA data collection

Challenge	Description	Effect on building LCA data
Availability	Existence of data at national level	In many European countries, the practice of conducting LCAs does not exist, or the results are not fed into a central repository.
Accessibility	Possibility to access existing data	LCA data may be collected into a central repository but is not shared by the owner because of data protection or intellectual property concerns.
Quality	Data meets accuracy, completeness, timeliness, validity and uniqueness criteria	Entries in national databases vary in completeness, have unclear time origins or include duplications.
Comparability	Data scope and collection methods are comparable with each other	The scope of life cycle stages, building parts or environmental impacts, or the data collection and results calculation methods differ. This is a particular challenge when comparing data across countries.
Representativeness	Data represents the building stock, in terms of new construction, well	Even if all the above factors are met, data can come from selected buildings with high environmental performance, for instance where obtaining sustainability certification is envisaged. This delivers a skewed and incomplete picture of the embodied carbon in new buildings. Sufficient data points are needed for each different building type to be able to draw representative conclusions. The larger the sample, the better it is in this respect.

- Data on recent and current building projects could be generated at a centralised level by applying a single LCA method in order to provide information on these specific cases, as it is likely that this data can still be obtained.
- Existing data, that has been created in a scattered form using varying methodologies by different stakeholders, has the potential to be gathered together and harmonised to form a centralised database.
- Where empirical data faces the challenges described in this report, relying on results from modelled building archetypes could provide an insight into the life-cycle impacts.

Figure 2: Triple-helix cooperation



3. Building types and material choices for structure shape embodied carbon levels

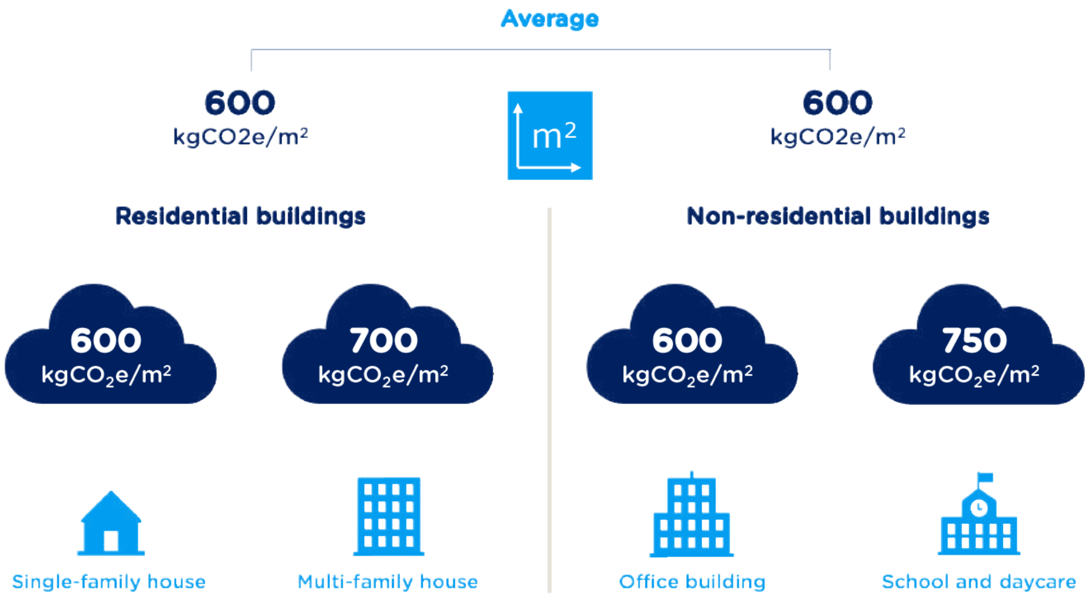
Understanding the current level of embodied carbon in buildings, or baseline, is important, as it is the basis required to be able to establish performance benchmarks, and it is also a starting point for developing roadmaps to reduce the whole life cycle carbon in buildings across Europe. Understanding the baseline is, therefore, crucial for informing and shaping both national requirements and decarbonisation strategies, and is particularly important within the context of European initiatives, such as Level(s) sustainability reporting and the EU taxonomy for sustainable activities, amongst others.

The main findings of our analysis show that the full life cycle embodied carbon in a building on average amount to 600 kgCO_2e/m². This mean value is found for both residential and non-residential buildings. However, the range of values is substantially larger for non-residential buildings (between 100 and 1,200 kgCO_2e/ m²) than for residential ones (between 400 and 800 kgCO_2e/ m²).

The majority of embodied life cycle carbon - around 2/3, or close to 400 t CO_2e on average - is emitted upfront, i.e. during the building production and construction (life cycle stages A1-A5). This highlights the need to focus both the discussion and the reduction efforts on upfront carbon emissions rather than on (future) end-of-life scenarios and potential benefits. The ongoing discussion around the latter is often used to exaggerate uncertainty issues in the life cycle assessment of buildings, and hence detracts from the importance and urgency of acting on upfront embodied carbon emissions today.

A comparison between per-m² versus per-capita values for full life cycle embodied carbon suggests that the building typology and design, as well as occupational patterns, have a substantial influence. These

Figure 3: Life cycle embodied carbon per square meter (m²) in kg of CO_2e per m²

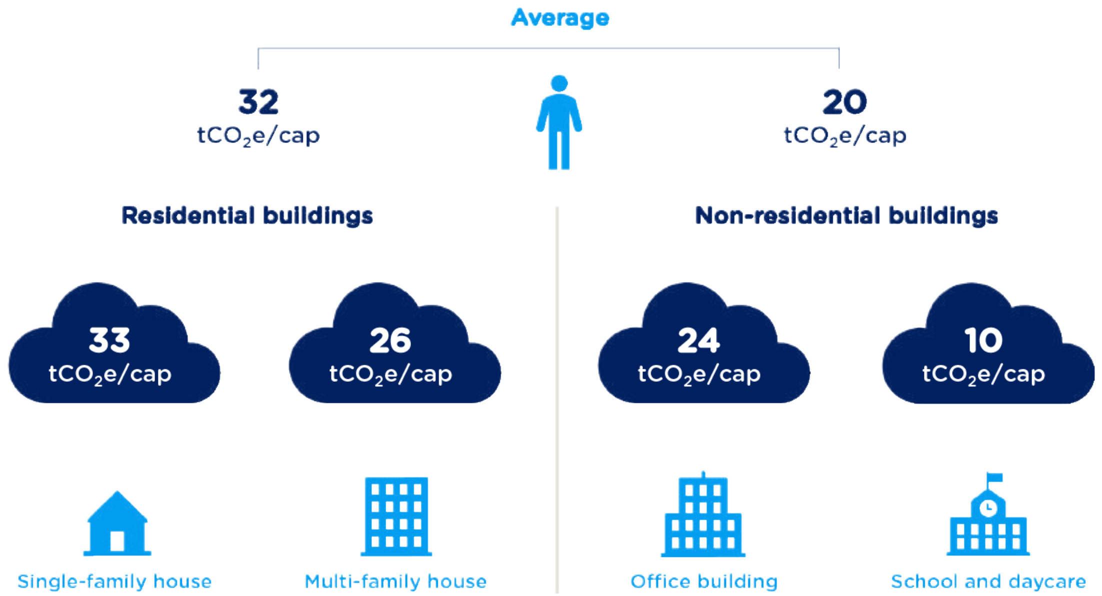


observations are in line with findings from previous studies in the field of building energy efficiency, which included rebound effects where a lowering of energy consumption per m² coincided with increased m² per capita, leading to an overall levelling of, or even increase in, energy consumption, especially in residential buildings. To account for similar rebound effects and trade-offs, both reference units should be used to express the embodied and whole life cycle carbon performance of buildings to effectively monitor and reduce life cycle embodied carbon per capita.

The dataset also shows that there is no straightforward solution to reducing embodied carbon in buildings, but multifaceted strategies need to be applied which combine, for example, material-efficiency when designing structural systems, the use of low-carbon building materials and energy systems, as well as a general consideration of occupational density and sufficiency principles in building design to reduce the required floor area and hence material consumption, among others. Furthermore, the conscious application of (fast-growing) bio-based construction materials (such as timber, bamboo, straw or hemp) for building construction and renovation offers the potential for a temporal fixation of the biogenic carbon taken up during plant growth.

Establishing a baseline of embodied and whole life carbon has to be developed more widely, building on the standardised LCA methodologies and requirements or strong incentives for data collection and documentation. The ideal solution for moving away from ad-hoc data compilation and analysis is to establish an openly accessible, central database on the whole life carbon performance of buildings across the EU. Existing initiatives like the EU's Level(s) programme could provide a good basis for developing related documentation standards, and for ensuring the involvement of relevant stakeholders and the long-term success of an open data platform.

Life cycle embodied carbon per capita (cap) in tonnes of CO_2e per cap



4. Carbon budget considerations are missing from the discussion on embodied carbon

To drive embodied carbon emissions reduction as part of a reduction of whole-life emissions, a carbon budget for embodied carbon is needed. Such a budget defines the number of emissions that can be emitted in line with scientific and political decarbonisation requirements to hold global warming to well below 2oC, and preferably limit it to 1.5oC, compared to pre-industrial levels, to avoid the worst impacts of the climate crisis.

Existing methodologies for budget calculation and target setting are designed for purposes other than addressing embodied carbon. This is because initiatives that calculate these budgets have focused on other areas of emission reduction (e.g. operational carbon from buildings in CRREM, or direct emissions from a corporation or organisation in the case of the SBTi). Moreover, budget calculation needs to reflect the cross-sectoral and international nature of embodied carbon, as well as finding agreement on the basic elements. A key example where agreement is needed is the choice of allocation principles that distribute the carbon budget over emitters, and pathways that distribute the budget over time.

The study proposes a new method for budget calculation that downscales the global budget to the national one and enables targets to be defined in line with the national budget. Figure 4 presents a concept for setting targets for embodied impacts in new buildings, through downscaling from a global budget to embodied carbon in buildings. This method – while several limitations remain – shows that it is possible to set budget-based targets for embodied carbon at the national level.

This finding calls for the integration of carbon budget considerations in the reduction pathway for embodied carbon in order to align the sector and national policies with global climate commitments. Paris-aligned reduction targets, as formulated by the budget pathway, need to guide the performance system to achieve alignment as soon as practically feasible.

Figure 4: Downscaling from a global budget to embodied carbon in buildings - a concept for setting targets for embodied impacts in new buildings per m2.

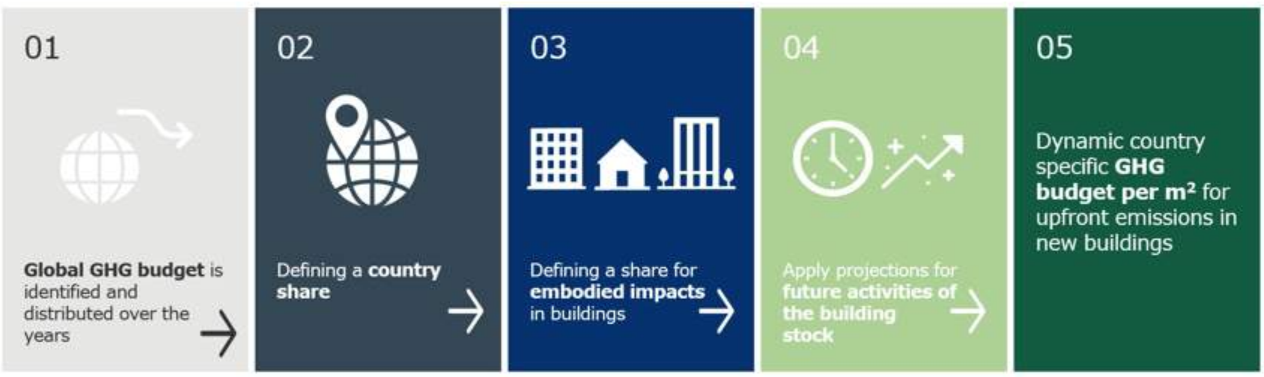
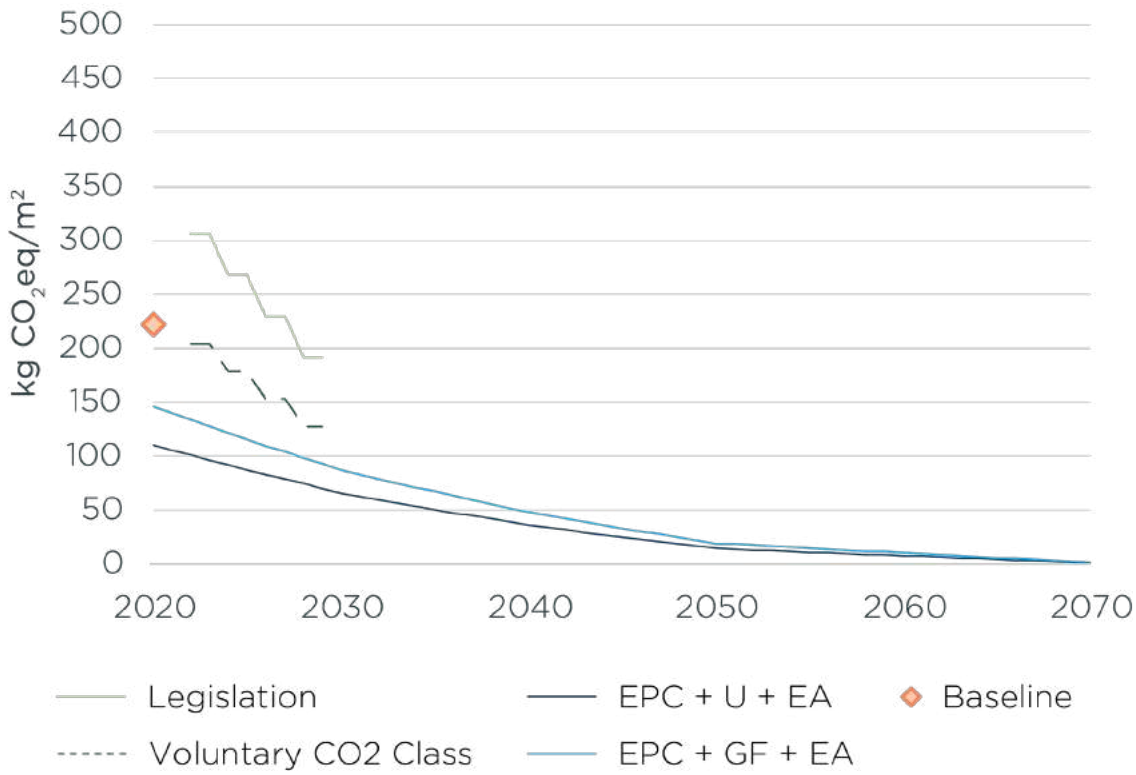


Table 2: Comparison of upfront embodied emissions (in kgCO_2eq/m2) according to empirical baseline and budget-based targets

Year	Denmark	Finland
Baseline	222	333
2025	87-155	52-163
2030	66-117	39-122
2050	15-25	8-25

Table 2 presents the calculated budgets for upfront embodied carbon for Denmark and Finland and compares these with the baseline for each of the countries. As illustrated in Figure 2, the budget-based targets are significantly lower than current embodied carbon levels and much more ambitious than the national legislation, where it exists.

Figure 5: Budget-based targets for upfront embodied emissions (in kgCO_2eq/m2) for Denmark[2]



[2] The two carbon budget pathways represent different principles of allocating the carbon budget to industrial sectors. Further details are provided in Report 3 “Defining budget-based targets”.

5. We propose a performance framework that bridges the gap between the baseline and the carbon budget

To inform and 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 1.5 °C.

International standards define different types of benchmarks that can serve as reference values to measure and manage performance in relation to a key parameter.

- **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.

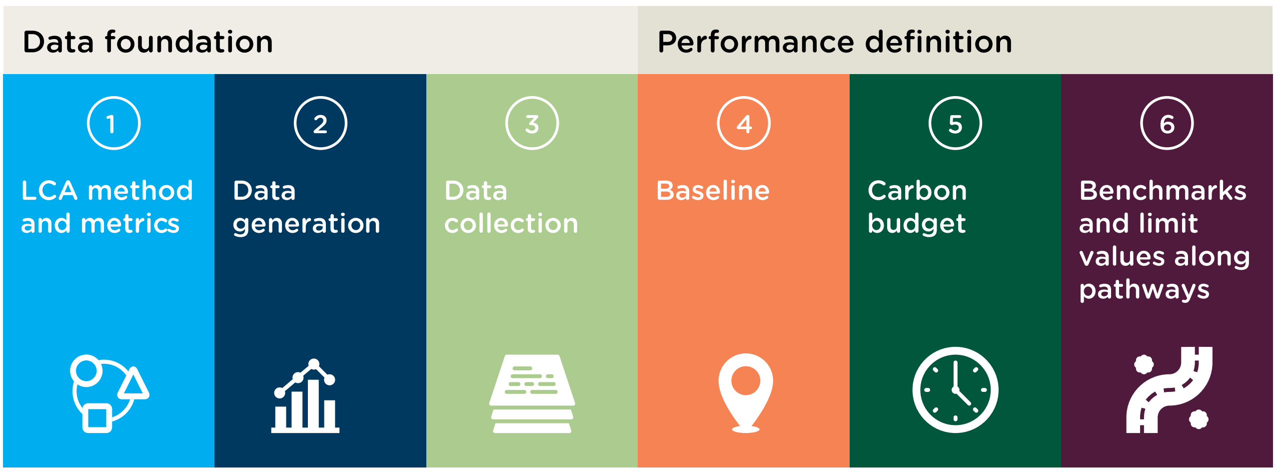
Multiple initiatives in the building sector, from certification bodies to reporting frameworks and regulation, use sustainability benchmarks. However, only a minority of these initiatives apply benchmarks to embodied carbon and, where this is the case, almost exclusively bottom-up benchmarks are used.

Crucially, the comparison of the baseline on embodied carbon in new buildings in five EU Member States and the calculation of a carbon budget and pathway reveals the embodied carbon performance gap, i.e. a gap between the reality of the building sector and the necessity of climate science.

A performance framework with benchmarks is the tool required to gradually close this gap with efficient, but ambitious, reference values. In order to be useful and successful, the performance framework needs to consider and help to overcome the challenges encountered in this study.

Therefore, critical efforts are needed from all actors in the building sector, including investors, designers, certifiers and policymakers, to build the data foundation as quickly as possible and to use this foundation to define performance.

Figure 6: Overview of the proposed performance framework



In detail, the elements of the performance system are as follows:

Table 3: Elements of the performance system for embodied carbon

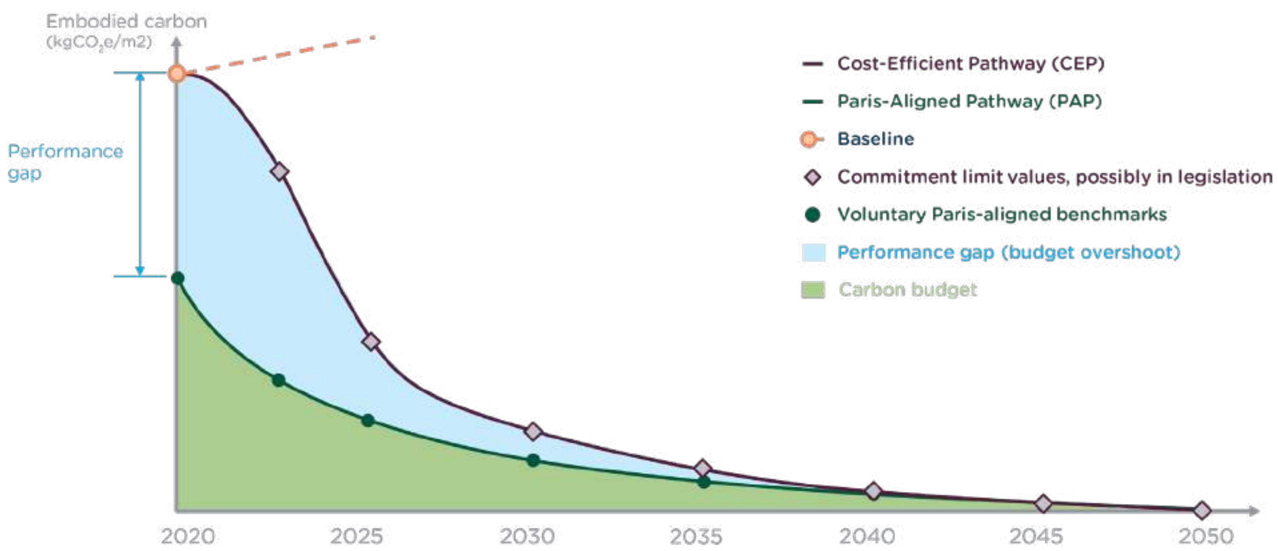
Performance system for embodied carbon	
Data foundation	
1. LCA method and metrics	• Nationally standardised LCA methods following the ISO and EN standards • Environmental data on building products and materials based on the EN standards. Data should be both industry and product specific. • Clearly defined 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
2. 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
3. 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	
4. 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
5. 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
6. 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 framework should include benchmarks or limit values that are set along pathways which 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. This pathway constitutes a realistic, but ambitious, scenario of embodied emission reduction based on available and economically-feasible reduction solutions, which the sector can commit to, while also considering social and technological parameters.

The resulting performance framework is illustrated in Figure 7. The Cost-Efficient Pathway should be ambitious so as to minimise, as much as possible, the overshoot of embodied emissions over the budget limit.

Figure 7: Embodied carbon performance framework



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.

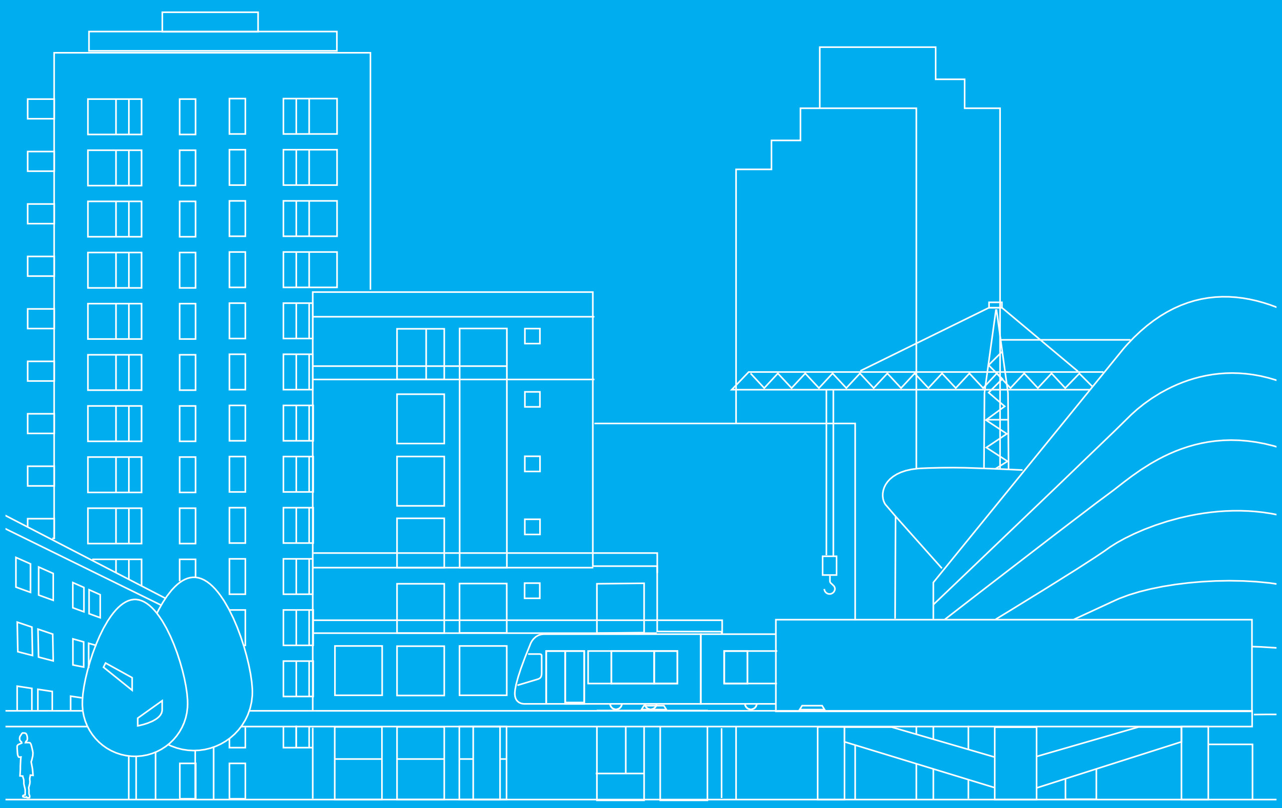
6. All stakeholders need to respond with urgency

Implementing this performance framework will require a combined effort from the whole value chain in the building industry, certification bodies, researchers, and policy makers. Definition and agreement on standardised methods for LCAs and the allocation of the carbon budget are the first essential steps needed to establish the performance framework. Additionally, all parts of the value chain must define and commit to the Cost-Efficient Pathway that ensures that effective reduction measures are used rapidly.

More specifically, the key recommendations from this study are:

- **Policymakers** need to define and promote standardised and centralised data collection methods for emissions life cycle analysis (LCA), and establish reference values – and wherever possible limit values – for the built environment, aligned with remaining science-based carbon budgets
- **Certification bodies** must require LCAs for all new buildings, share available data, and promote benchmarks aligned with the remaining carbon budgets
- **Investors** should require LCAs for all new buildings financed, and align their portfolios with the reference values if they wish to be Paris-aligned and anticipate regulatory risks
- **Designers** must design with these benchmarks in mind, advocating low-carbon solutions

A national approach is suggested in this study, 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.



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