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WHOLE-LIFE CARBON:

CHALLENGES AND SOLUTIONS FOR HIGHLY EFFICIENT AND CLIMATE-NEUTRAL BUILDINGS

BPIE

Authors
Zsolt Toth
Jonathan Volt

Reviewed by
Barney Jeffries
Caroline Milne
Hélène Sibileau
Maria Stambler
Sibyl Steuwer
Oliver Rapf
Mariangiola Fabbri

Graphic design:
Ine Baillieul

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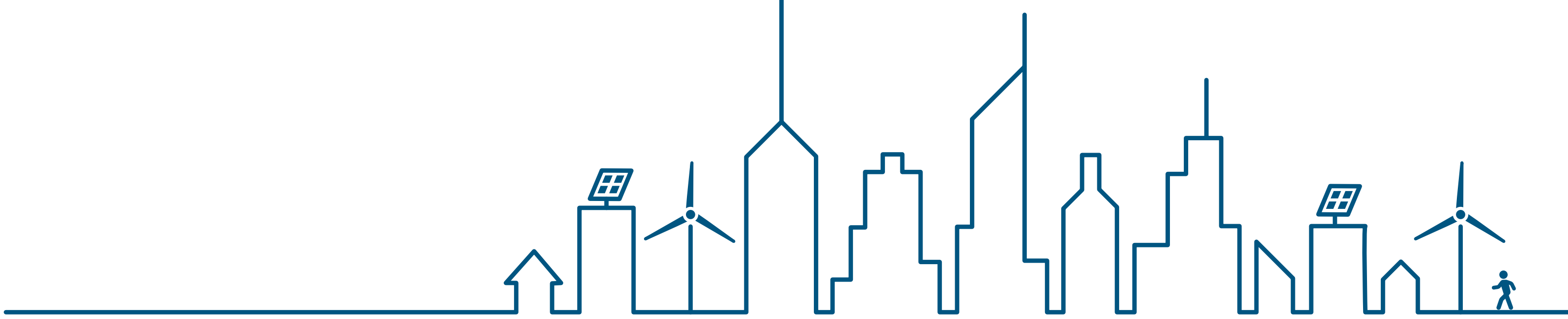
CONTENTS



INTRODUCTION

The European Union aims to be climate-neutral by 2050, requiring a fundamental transformation of the construction and building sectors. This decade is critical as direct building CO_2 emissions need to more than halve by 2030 to get on track for a net-zero carbon building stock by 2050. Emissions must be drastically cut throughout the whole lifecycle of buildings, encompassing all operational and embodied emissions. In the Renovation Wave strategy, the European Commission announced its intention to address "lifecycle thinking and circularity"; it is important that the intention is followed up by decisive action and integrated into regulatory proposals.

Reductions of embodied carbon emissions can be achieved by developing and implementing policies that tackle the lifecycle emissions of buildings, including those resulting from the production, installation, maintenance and disposal of building materials. This is a significant departure from existing policies, as most of the focus on reducing carbon emissions from the built environment has been on managing and reducing the energy consumption in the buildings' use phase, not addressing the significant mitigation potential of embodied emissions.

The ongoing review of key policy and legislative files, such as the Energy Performance of Buildings Directive (EPBD), the Energy Efficiency Directive (EED) and the Construction Products Regulation (CPR), provides a significant opportunity for the EU to begin consistently integrating "whole-life carbon" in the policy framework. Actions at the building level must also be well-coordinated and aligned with policy actions upstream on raw materials and construction products, as well as with end-of-life policies addressing waste and increasing circularity.

This summary report introduces basic concepts and key issues related to the integration of whole-life carbon considerations in building policies. It aims to be a conversation starter for policymakers and building sector stakeholders to engage on policy gaps and potential mitigation solutions for carbon lifecycle approaches for construction and buildings.

There is no overarching consensus over exactly how much emissions arising from the European buildings stock are attributable to embodied emissions. The reasons for the wide discrepancies in the reported figures include the relative novelty of the topic and the lack of large-scale reports, different assumptions and boundary conditions, emissions reported in different sectors and within different scope, and quality and availability of data. Equally, the importance of embodied carbon cannot be captured by a single figure given that the breakdown of operational and embodied carbon varies according to building type, the lifespan of the building, grid decarbonisation, national building standards and climatic conditions.

The lack of a robust evidence base is one of the main reasons why embodied carbon has seldom been considered in policymaking and that embodied footprint is generally considered insignificant in comparison to operational carbon.[1] Earlier studies have put embodied carbon content at around 10% of the overall lifetime emissions, which is within the uncertainty range of the energy demand forecast for building use and thus not considered relevant. More recent studies, however, are consistently demonstrating how carbon emissions are shifting from the operational stage to carbon released during other lifecycle stages of the building, which further raises the need for policymakers to consider whole-life carbon.

[1] Röck, M. et al. (2020) "Embodied GHG emissions of buildings – The hidden challenge for effective climate change mitigation", Applied Energy 258.

GLOSSARY: CARBON IN BUILDINGS

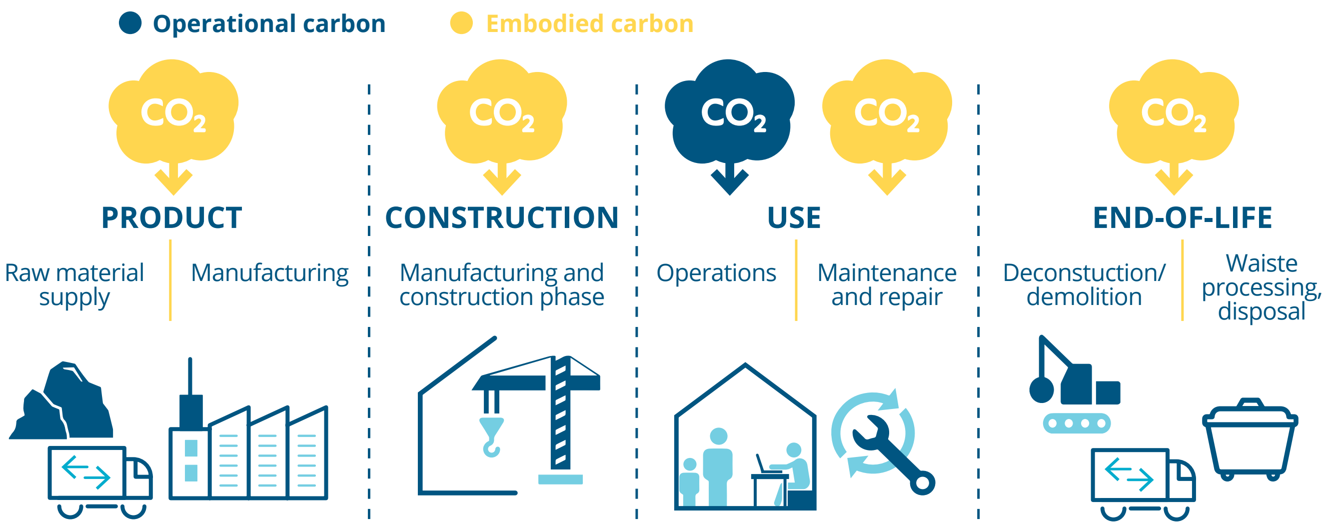
- **WHOLE-LIFE CARBON** emissions are the carbon emissions resulting from the materials, construction and use of a building over its entire life, including its demolition and disposal. Other terms used are *lifecycle carbon or cradle-to-grave carbon*.
- **EMBODIED CARBON** emissions are associated with energy consumption (embodied energy) and chemical processes during the extraction, manufacture, transportation, assembly, replacement and deconstruction.
- **OPERATIONAL** emissions are associated with energy consumption (operational energy) while the building is occupied, e.g. heating, cooling, lighting and appliances.
- **UPFRONT CARBON** emissions are released during the materials production and construction phases.
- **END-OF-LIFE CARBON** emissions are associated with deconstruction/ demolition, transport from site, waste processing and disposal of a building or infrastructure.
- **USE STAGE CARBON EMBODIED** emissions are associated with materials and processes needed to maintain the building or infrastructure during use, such as for refurbishments.

> **The importance of embodied emissions will increase dramatically as more buildings are constructed and renovated to higher energy efficiency standards, which will greatly reduce operational emissions.**

It is estimated that embodied carbon today typically contributes 10-20% of EU buildings' CO_2 footprint, depending on factors including building type, the carbon intensity of the grid, building regulations, etc.[2] However, the importance of embodied emissions will increase dramatically as more buildings are constructed and renovated to higher energy efficiency standards, which will greatly reduce operational emissions. An analysis of 60 new buildings in Denmark, a country with relatively ambitious building regulations, showed that embodied carbon emissions are 2-4 times greater than emissions associated with operational energy use.[3]

Over time, the legislative drive for more stringent operational performance requirements has increased embodied carbon emissions from buildings in both absolute and relative terms. This is explained by the fact that high-performance buildings require more materials and services. It is, however, already possible to achieve high in-use energy performance levels in buildings while also lowering the embodied emissions. An analysis of more than 650 global lifecycle assessment (LCA) case studies demonstrates the possibility to design buildings with low lifecycle emissions regardless of the building regulations they have to comply with.[4] In other words, it is technically possible to build high energy performance buildings with low embodied emissions.

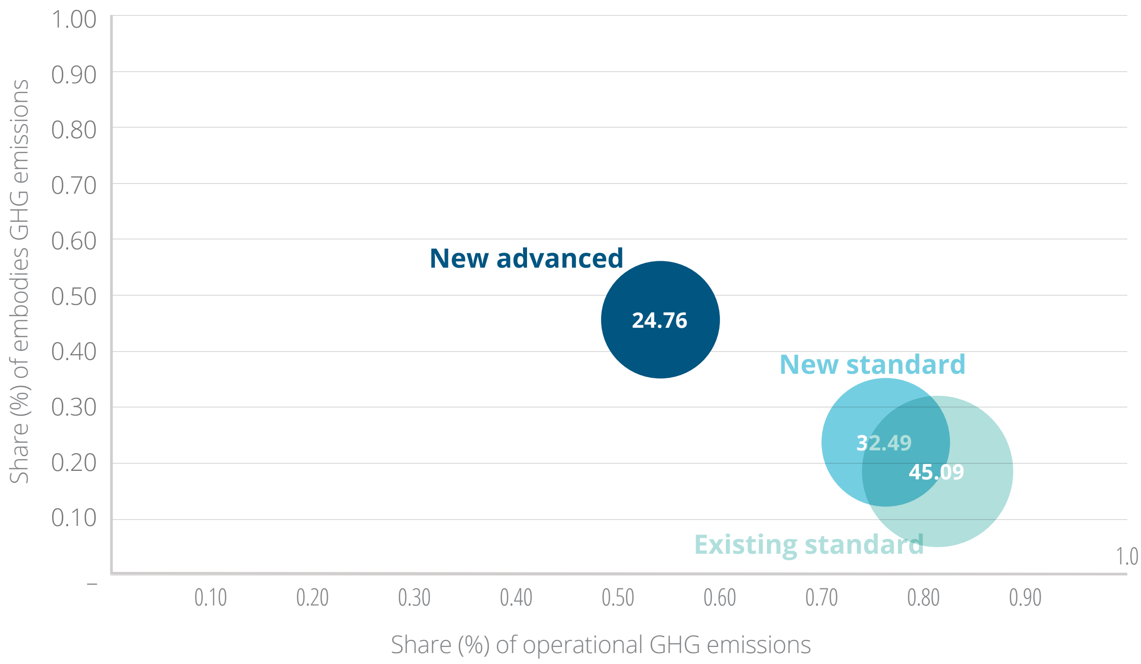
Figure 1: Embodied and operational carbon in a building's lifetime.



2 IEA (2020) Energy Technology Perspectives and IEA (2019) Material Efficiency in Clean Energy Transitions. International Energy Agency
3 Kjær Zimmermann, R. et al. (2020) Klimapåvirkning fra 60 Bygninger (in English: Climate impact of 60 buildings). Aalborg University. (Available: Online)
4 See results in Röck, M. et al. (2020)

The whole-life carbon emissions from buildings are declining but the relative importance of embodied carbon emissions is increasing, as illustrated in Figure 2. The three bubbles represent different classes of "building performance levels", while their size represents the whole-life carbon emission intensity of each class. The two axes show the relative weight of operational (horizontal axis) and embodied (vertical axis) emissions. The recently enforced nearly-zero energy building regulation for new buildings in the EU should be equivalent to the "new advanced" category. In this category, embodied carbon emissions amount to almost half of the emissions but the total whole-life carbon emissions have decreased substantially.

Figure 2: The growing importance of whole-life carbon in buildings.
Data from Röck et al (2020) based on a literature review of more than 650 global LCA studies of which about ¾ comes from Europe. Energy performance standards are represented by "new advanced": low energy buildings such as nearly zero energy buildings; "new standard": buildings complying with current/recent building regulations; "existing standard": constructed before any considerable tightening of building regulations. The authors divided the LCA cases into these three categories. The size of the bubbles shows the average total whole-life carbon emissions of the building categories in $KgCO_2/m^2/$ year, while the y-axis shows the share of embodied carbon and the x-axis operational carbon.



The financial aspects are also relevant as until recently, energy efficiency promised substantial operational emission reductions at comparatively low (or even negative) financial costs. While several countries still have a long way to go in terms of energy efficiency requirements, in others, many of the cost-effective measures to reduce operational emissions have been adopted and implemented already. This makes compliance with stricter energy efficiency standards increasingly expensive, whereas achieving embodied carbon reductions is often both simpler and cheaper than achieving operational carbon savings.

WHOLE-LIFE CARBON AND EFFICIENCY FIRST

“Energy and carbon metrics are complementary and both are required to decarbonise the building stock.”

Efficiency first is a key principle of the EU and one of its main approaches to reducing emissions from the building sector. Integrating whole-life carbon considerations, and tackling embodied emissions, will not impede the efficiency first principle but rather make sure the efficiency efforts are fully aligned with our carbon-neutrality goals. Energy and carbon metrics are complementary and both are required to decarbonise the building stock. Energy efficiency remains an important metric as it ensures that energy is not wasted. Minimum energy performance requirements will still have an important role to make sure the quality of buildings is improved and that easy substitutions, such as carbon offsetting, are avoided.

Undoubtedly, the deep renovation rate must increase in order to set the whole building stock on a net-zero emissions pathway.[5] Energy efficiency renovations, however, not only contribute to reducing operational carbon emissions but also to increasing embodied carbon by adding new materials and systems into the building. Without accounting for whole-life carbon, there is a risk that construction and renovation decisions ignore these hidden emissions.

Considering lifecycle carbon is equally relevant for both new construction and renovations, and can inform which materials and services should be used to achieve lower emissions over the entire lifecycle of the asset.

Choosing the right strategy and taking action early on is paramount as carbon emitted during the construction (and renovation) phase is both immediate and irrecoverable, whereas operational carbon is long term. Embodied carbon is emitted in a short burst during the construction phase and unlike operational carbon cannot be mitigated during the working life of the building. Policy and market actions should therefore target emissions savings in the building lifecycle early on as these are very quickly using up the remaining carbon budget left to limit global warming to 1.5°C. This is often referred to as the time value of carbon. It provides a compelling reason for policymakers to address both embodied and operational carbon.

Finally, when EU countries decide on decarbonisation pathways, the building sector must be treated as a priority. Choosing a “buildings first” approach focusing on both operational and embodied carbon reductions, ahead of grid decarbonisation, will ensure that the co-benefits of building renovation (improved indoor environmental quality, health, productivity, jobs) are realised, but also costly investments in energy infrastructure are avoided. The decarbonisation of the energy supply is bound to have some negative externalities or limitations, such as land requirements for biomass or specific materials for wind and solar power. To keep these negative externalities to a minimum, it is necessary to reduce the total final energy demand by increasing the efficiency level.

5 BPIE (2020) On the way to a climate-neutral Europe.

CURRENT STATE OF WHOLE-LIFE CARBON REGULATIONS

Current EU regulations mainly cover the operational energy performance of buildings, while the carbon footprint and buildings' climate impacts remain largely unregulated, despite the significant carbon reduction potential. The overview of existing policies reveals that:

1. **Some building lifecycle stages are not regulated or not fully regulated at EU level.**
2. **With the exception of Level(s) – which is an assessment and reporting framework rather than a policy of its own – existing policies are designed in silos and only target individual stages of the lifecycle with no coherent links between the stages.**
3. **Some national regulations (see next section) already go beyond EU-level legislation.**

Table 1 presents the main EU policy instruments, existing and proposed, and the corresponding lifecycle stages of buildings they address. The modules are based on the commonly used European standard (EN 15978) for the assessment of the environmental performance of buildings.

Table 1: Scope of various EU regulatory and non-regulatory measures against the building lifecycle.

Lifecycle stages	Modules	EU policy instruments							
		EPBD	EED	CPR[6]	Ecodesign	WFD[7]	ETS[8]	Level(s)[9]	Taxonomy[10]
PRODUCTION	A1 Raw material supply	-	-	(*)	•	-	•	••	(*)
	A2 Transport	-	-	-	-	-	(*)	••	(*)
	A3 Manufacturing	-	-	(*)	-	-	•	••	(*)
CONSTRUCTION	A4 Transport	-	-	-	-	-	(*)	••	(*)
	A5 Construction installation process	-	-	(*)	-	-	-	••	(*)
USE	B2 Maintenance	-	-	(*)	-	-	-	••	(*)
	B3 Repair	-	-	(*)	-	-	-	••	(*)
	B4 Replacement	-	-	(*)	-	-	-	••	(*)
	B5 Refurbishment	-	-	(*)	-	-	-	••	(*)
	B6 Operational energy use	••	••	-	•	-	(*)	••	••
END-OF-LIFE	C1 Deconstruction	-	-	(*)	-	•	-	••	(*)
	C2 Transport	-	-	-	-	-	(*)	••	(*)
	C3 Waste processing	-	-	-	-	••	-	••	(*)
	C4 Disposal	-	-	-	•	••	-	••	(*)
BEYOND LIFE	D Reuse/recycle	-	-	(*)	•	•	-	••	(*)

Partially covered | Fully covered | Under revision

6 The basic requirements for construction works set out in the Construction Products Regulation (CPR) include sustainable use of natural resources; however, the regulation does not impose minimum performance requirements for the whole product lifecycle, including embodied carbon. The ongoing revision could possibly introduce recycled content requirements for certain construction products (Circular Economy Action Plan).

7 Waste Framework Directive

8 The emissions trading scheme (ETS) covers the power sector and energy-intensive industries, such as concrete, which means that buildings are indirectly affected. The Commission's forthcoming June package of energy and climate laws may include a proposal to extend the ETS to sectors such as building and road transport.

9 Level(s) embraces a full lifecycle approach and the methodology to calculate the GHG emissions of the building follows the relevant global and EU standards for sustainable construction (ISO 14040/44, EN 15804 and EN 15978).

10 The current EU Taxonomy only recognises improvements to the energy and carbon performance of buildings during the use phase (climate change mitigation and adaptation efforts). In going forward, the eligibility criteria will also include the "do no significant harm" requirement in relation to four other environmental objectives – water, circular economy, pollution prevention and biodiversity – for which full taxonomy systems are yet to be developed.

NATIONAL BUILDING REGULATIONS TARGETING WHOLE-LIFE CARBON

The countries with the most progressive requirements for operational energy are also the ones looking into regulating embodied carbon emissions. These countries can no longer make significant carbon savings in new buildings by further tightening in-use energy performance standards. The very low operational energy requirements mean that embodied carbon becomes the most significant area of carbon emission over the lifetime of the building. Therefore, it makes sense to focus on untapped carbon savings and set targets for emissions from the manufacturing and construction processes.

The map below (Figure 4) displays the leading whole-life carbon regulations in Europe. Three countries have introduced CO_2 limits for a large share of new buildings, while two other countries have plans to do so. Three additional countries have LCA requirements for public buildings.

- Denmark's new regulation sets whole-life carbon emissions for new buildings, encompassing both operational and embodied emissions, based on LCA. Plans for the progressive tightening of CO_2 limits are depicted in Figure 3 below.
- The Netherlands has since 2017 required all new residential and office buildings whose surface exceeds 100m2 to account for and report their embodied impacts based on a simplified LCA using a national method. All impacts are converted into a monetary value, which since 2018 is used to set a "mandatory environmental impact cap" for new buildings.
- Finland and Sweden have developed simplified LCA methodologies and whole-life carbon databases, intending to facilitate whole-life carbon accounting and regulation in the future. Finland plans to introduce CO_2 limits for new buildings by 2025 and Sweden by 2027.
- France's pending new building regulation (RE2020) aims to reduce the climate impact of new buildings by integrating enforced energy efficiency requirements and whole-life carbon considerations. This is supported by the Énergie Positive & Réduction Carbone (E+C-) label, whose simplified LCA methodology has been developed together with the industry and features both energy and whole-life carbon emissions.
- Germany, Switzerland and the UK have all introduced LCA requirements for public buildings/projects.

Figure 3: Denmark regulates whole-life carbon from 2023 in their national building regulations. Information derived from the Danish agreement on sustainable construction [05/03/2020]. The carbon impact comprises both embodied and operational carbon emission based on LCA. Ministry of the Interior and Housing (2021) National strategy for sustainable construction (Available in Danish: Online).

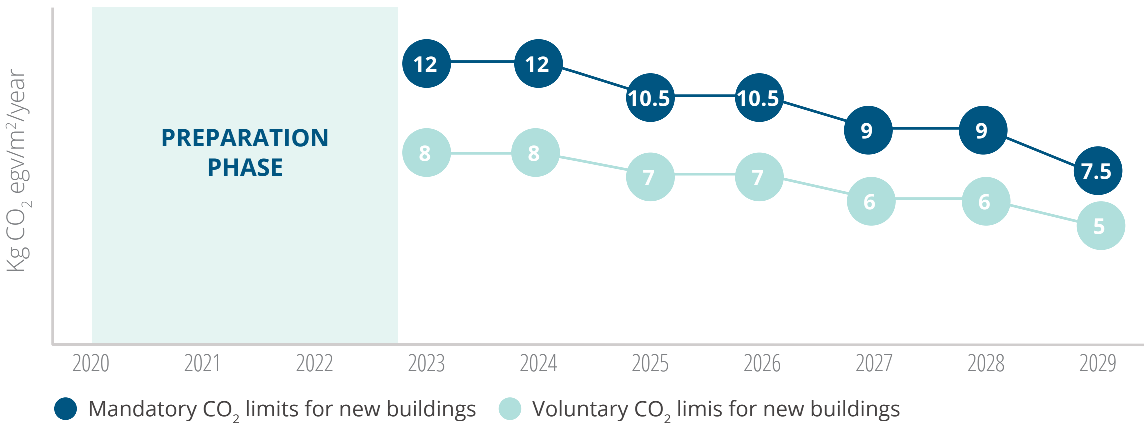
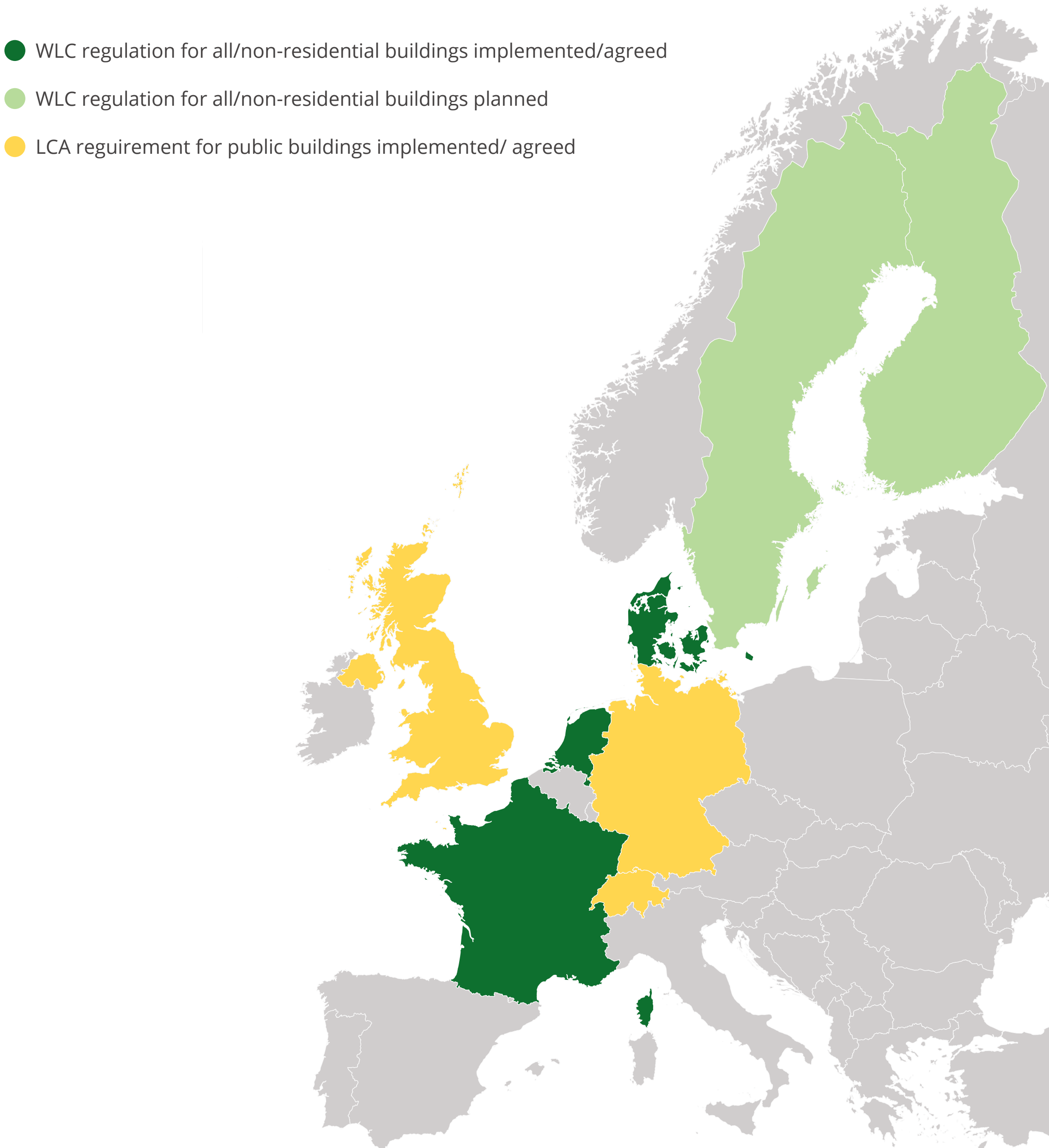


Figure 4: Map of the leading whole-life carbon regulations in Europe. Map design: Showeet.



The bold and swift actions taken by the selected national authorities highlight that a common European policy is worthwhile pursuing. This would lead to greater transparency, comparability and monitoring of progress across borders and industries, in particular for construction materials and services but also for cross border real estate investments. It would also lead to a faster take up of whole-life carbon considerations in all Member States in a more consistent way, which is essential to reach climate targets by 2030 and beyond.

METHODS FOR ASSESSING THE WHOLE-LIFE CARBON OF BUILDINGS

An LCA is typically used to calculate the whole-life carbon of a building. It is a well-established methodology to assess environmental impacts and resource consumption at each stage of the building's lifecycle, from material extraction to construction and use, to the demolishing of the building. The LCA can also include an assessment of the potential benefits from the reuse or recycling of components after the end of a building's useful life. The LCA enables the developer and the design team of new construction or renovation projects to compare, prioritise and optimise the allocation of resources. LCA is the approach embraced by the Construction Products Regulation (CPR), Level(s) and the majority of voluntary certification schemes for sustainable building.

Increasingly, manufacturers of construction products publish LCA data for their products using environmental product declarations (EPDs). Storing this information in a digital repository, such as a digital building logbook, material passport or building information modelling (BIM) could greatly contribute to more accessible and reliable LCA data.

The EU Commission has developed the Level(s) tool to assess and report on sustainability aspects throughout the lifetime of buildings. The objective is to provide a common language on sustainability and circularity for buildings targeting the mainstream market. It has been designed as an easy entry point to sustainability assessment. Level(s) is essentially a tiered approach to LCA in buildings with a focus on enabling comparability, data availability and benchmarking. The Level(s) framework can be used to enable benchmarking of the whole-life carbon performance and, eventually, the introduction of regulations, as is intended in Sweden[11] and Finland[12]. At the EU level, the most likely policy initiatives to integrate Level(s) are the green public procurement criteria and the EU taxonomy for sustainable finance.

Despite these efforts, most of the existing whole-life carbon accounting standards are still considered too high-level and lack a uniform interpretation by building professionals. Public authorities and professional organisations[13] are therefore developing practical guidelines and methodologies to help the implementation and boost the credibility and accuracy of whole-life carbon data. The review of existing whole-life carbon regulations shows that in the interest of practical implementation, countries (e.g. Sweden, Finland and the Netherlands) develop their own (simplified) LCA methodologies based on common standards (see box below).

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[11] Boverket (2020) Regulation on climate declarations for buildings
[12] Kuittinen, M. (2019) Method for the whole-life carbon assessment of buildings. Publications of the Ministry of the Environment.
[13] RICS (2017) RICS professional statement: Whole life carbon assessment for the built environment

Multiple standards already exist outlining how to measure whole-life carbon emissions. In Europe, the most relevant ones are:

- **EN 15978** presents the general structure and definition of stages in the life cycle of buildings according to the European standard for the sustainability of construction works, assessment of the environmental performance of buildings.
- **EN 15804** defines how companies should go about creating Environmental Product Declarations, which are a crucial component in enabling whole-life carbon reporting.
- **EN 15643-5** outlines how to assess the sustainability of buildings and civil engineering works.

SUMMARY OF BARRIERS, ENABLERS AND POLICY SOLUTIONS

Managing embodied carbon is a novel skill. It is acknowledged that regulating embodied carbon is a complex and data-intense undertaking. Best practices exist and can be useful for preparing the market for large-scale roll-out of carbon accounting and reporting as part of building regulations. As seen in the frontrunner countries, trade-offs between simplicity and accuracy, as well as data quality and granularity, will need to be carefully weighed. Carbon accounting and management should be made more accessible to building sector stakeholders. The aim is to regulate embodied carbon in the same way as energy performance is currently mandated, including highly standardised calculation methods as well as cost-efficient and robust processes.

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The table on page 14 summarises the key stakeholders, barriers, mitigation and policy potential across the different stages of the building lifecycle. Better and more accessible whole-life carbon data, as well as alignment of the construction value chain, are the most important enablers. The actions taken in the recent past in the Nordics, the Netherlands and France demonstrate that it is possible to overcome existing barriers. Building sector stakeholders and financial institutions which start to include embodied carbon quantification and mitigation in their projects are doing so mostly for risk management and competitive reasons, as part of their corporate social responsibilities, but also increasingly as part of compliance with regulatory requirements. In going forward, all these actors will need to play their part more consistently by designing, building and renovating according to whole-life carbon principles.

	PLANNING	DESIGN	CONSTRUCTION & RENOVATION	USE	END-OF-LIFE
KEY STAKEHOLDERS	• Local authorities • Architects • Developers • Financing institutions	• Architects • Developers • Designers • Engineers • Sustainability consultants	• Developers • Contractors • Material & equipment suppliers • Owners • Financing institutions	• Owners • Real estate managers • Facility managers • Tenants • Utility companies	• Demolition contractors • Recycling and waste managers
BARRIERS	• Lack of policy requirements • No clear incentives or penalties • Financial risk • Disregard for lifecycle costing • Awareness gap	• Lack of incentives • No reliable benchmarks • Technology risks • Lack of communication and leadership	• Value-chain fragmentation • Liabilities • Lack of information sharing & coordination	• Split incentives • Lease structures • Lack of information sharing & coordination	• Lack of knowledge about what can be recycled • Not enough incentives to use re-used components • Lack of information on where building materials are stored
MITIGATION POTENTIAL	• Set low embodied carbon goals and monitoring/ verification protocols • Preferential financing Taxonomy eligibility • Increase awareness and demand for low-carbon buildings	• Use of LCA & • BIM • Avoiding over-specifications • Design for flexibility in use, resilience and long lifespan • Neighbourhood integration and optimisation • Enable rapid installations • Request EPDs from suppliers • Educate and engage clients on whole-life carbon	• Low material consumption and low CO_2 intensity • Use materials and solutions that enable reuse and recycling • Off-site construction and design for less waste on-site • Locally sourced materials • Rapid installations • Clean transport solutions • Clarify responsibility of carbon data management	• Optimise envelope, system performance and • renewable energy integrations • Proactive maintenance, servicing and repair strategy • Green leases and data sharing • Smart building, storage and energy flexibility	• Divert waste materials from landfills • Create secondary market for demolition/ recycled materials • Incentivise urban mining
POLICY POTENTIAL	• Mandatory LCA in building permitting • Green public procurement • Whole-life carbon targets and caps • Sustainable finance taxonomy • ETS, carbon tax	• Whole-life carbon cap • BIM to test and optimise design options • Whole-life carbon database for products and materials	• Encourage lean construction Encourage the use of digital building logbook, material passports and BIM	• Assess and report as built carbon performance • Real-time energy and carbon data • Demand response	• Digital building logbook, material passports or BIM • Construction and demolition waste protocol

Key messages

Reaching carbon-neutrality targets is not possible without improving energy efficiency. Focusing on energy efficiency will deliver significant carbon emissions reduction but not necessarily up to zero emissions.

Both energy and carbon metrics, as well as policies targeting both embodied and operational emissions, are needed. In driving more ambitious building regulations, attention should be paid to the right balance and break-even points between embodied carbon and operational carbon.

Reducing whole-life carbon emissions simultaneously contributes to limiting resource depletion and reducing pollution. The principles and action to mitigate whole-life emissions are the same as improving circularity (e.g. reuse, reduce, avoid over-specifications, consider local aspects and passive solutions, improve building resilience, flexibility and adaptability, extend the lifespan of buildings and components, improve recyclability).

Applying whole-life carbon considerations in the construction sector does not only apply to materials but equally to processes, including improving material flows, enhancing productivity, eliminating waste and reducing delays, which are all important factors to increase the competitiveness and environmental performance of the sector.

Early actions taken by a few Member States demonstrate that whole-life carbon policies are possible and desirable. A common EU-level approach could yield additional benefits in terms of greater transparency, comparability and monitoring of progress across borders and industries.

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INSTITUTE EUROPE

Rue de la Science 23
B-1040 Brussels Belgium

Sebastianstraße 21
D-10179 Berlin Germany

www.bpie.eu