

# ESTIMATING THE CARBON FOOTPRINT OF BUILDINGS

WHOLE LIFE CARBON ROADMAP  
FOR POLAND 2050

#BUILDING  
**LIFE**



**PLGBC**  
Polish Green Building Council



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**#BUILDINGLIFE**



IKEA Foundation

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## Information about PLGBC

The Polish Green Building Council ([PLGBC](#)) is a non-governmental organisation which since 2008 has been working for the transformation of buildings, cities and their surroundings in such a way that the way they are planned, designed, constructed, used, modernised, demolished and processed is as sustainable as possible.

The organisation supports the creation of sustainable buildings for all by:

- activities related to climate change mitigation and adaptation,
- applying the principles of the circular economy,
- enhancing well-being, quality of life and the health of society,
- enhancing biodiversity.

The PLGBC is part of a global community of more than 70 green building councils organisations brought together under the [World Green Building Council](#).

The English version of this report is a shorter, translated version of Polish full report, which can be found [here](#).

The Polish version is the superior, original version of this report and any possible ambiguities should be compared with the original.

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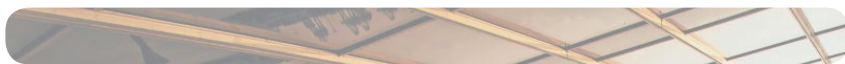
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SUMMARY



**#BuildingLife** is a project led by the World Green Building Council and ten European green building councils with aim to develop and publish national roadmaps for decarbonising the building sector by 2050, based on the total net carbon footprint over the entire lifecycle of buildings. Running until the end of 2022, the project supports the ambitions of the European Green Deal strategy and stimulates climate action through national and regional decarbonisation plans that will address the environmental impact of the entire lifecycle of buildings.

Building partnerships and supporting initiatives created by international communities, such as WorldGBC, is key on the road to decarbonisation. Decarbonization process requires significant effort and resource allocation across the fragmented value chain, particularly in less developed markets.

**#BuildingLife** emphasises the need to focus not only on the operational emissions of buildings, but also on the importance of the embodied carbon and its environmental impact during the production phase of building materials and technologies, transportation, construction and end-of-life of the building and its components. Reducing these emissions is essential in order to consider the total impact of buildings and the construction sector and to progress towards Europe's climate strategy of becoming climate neutral by 2050.

**#BuildingLife** is a project that aims to accelerate decarbonisation in the building sector through private sector action and appropriate public sector policies. Building a coalition to support a shared vision for zero-carbon buildings in Europe is the overarching goal of the project.

European green building councils taking part in the project are: Croatia, Finland, France, Germany, Ireland, Italy, the Netherlands, Poland, Spain and the United Kingdom.

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# #

# BUILDING LIFE



# INTRODUCTION



Adopted in 2015 at the COP21 climate summit, the Paris Agreement, to which Poland is a signatory, has as its main objective to limit the average global temperature increase below 2°C, preferably to 1.5°C above pre-industrial levels. Meeting this goal requires that global net anthropogenic greenhouse gas emissions reach zero by around 2050, meaning that no additional emissions will enter the atmosphere.

The importance of the building stock in achieving climate neutrality is indisputable. The most recent data show that buildings are responsible for approximately 38%<sup>4</sup> of global CO<sub>2</sub> emissions, with 28% coming from the operation of buildings and the remaining 10% is due to the energy consumption required to produce the materials and technologies used in construction (the embodied carbon).

So far, all efforts have mainly focused on reducing the operational carbon, i.e. CO<sub>2</sub> emissions caused by the use of buildings - heating, cooling, hot water preparation, use of appliances, computers, lifts, installations, etc. The analysis of the total carbon footprint is based on a more integrated approach, so the sustainability challenge in the area of buildings goes far beyond the reduction of CO<sub>2</sub> in the use phase of buildings. The construction process and the use of materials in the construction and use phase also produce CO<sub>2</sub>.

As technologies develop to reduce the energy intensity of buildings during their operation, the importance of the embodied carbon, which is currently often marginalised, will grow. Assessing the carbon footprint of construction processes requires a new look at how the building sector can become more sustainable. Addressing this rationale is possible by assessing the CO<sub>2</sub> emissions over the entire life cycle of a building.



# HOW TO DECARBONISE THE BUILT ENVIRONMENT BY 2050. WHOLE LIFE CARBON ROADMAP FOR POLAND

JUNE 2021

The PLGBC's response to these challenges was the report published in June 2021 titled **How to Decarbonise the Built Environment by 2050. Whole Life Carbon Roadmap for Poland**. This was the first such publication produced by a green building council in the CEE region, with financial support from the European Bank for Reconstruction and Development (EBRD). The report emphasises that achieving a whole life net zero carbon footprint of buildings by 2050 is a very ambitious but achievable goal. However, this requires a transformation of both buildings and the building sector as a whole. A key prerequisite is the involvement of all stakeholders with an impact on emissions: manufacturers, engineers, architects, developers, investors, property owners and consultants. Equally important is clear and decisive action by authorities at various levels to drive change in the construction market, through the

introduction of appropriate legislation, in order to achieve decarbonisation of the building stock.

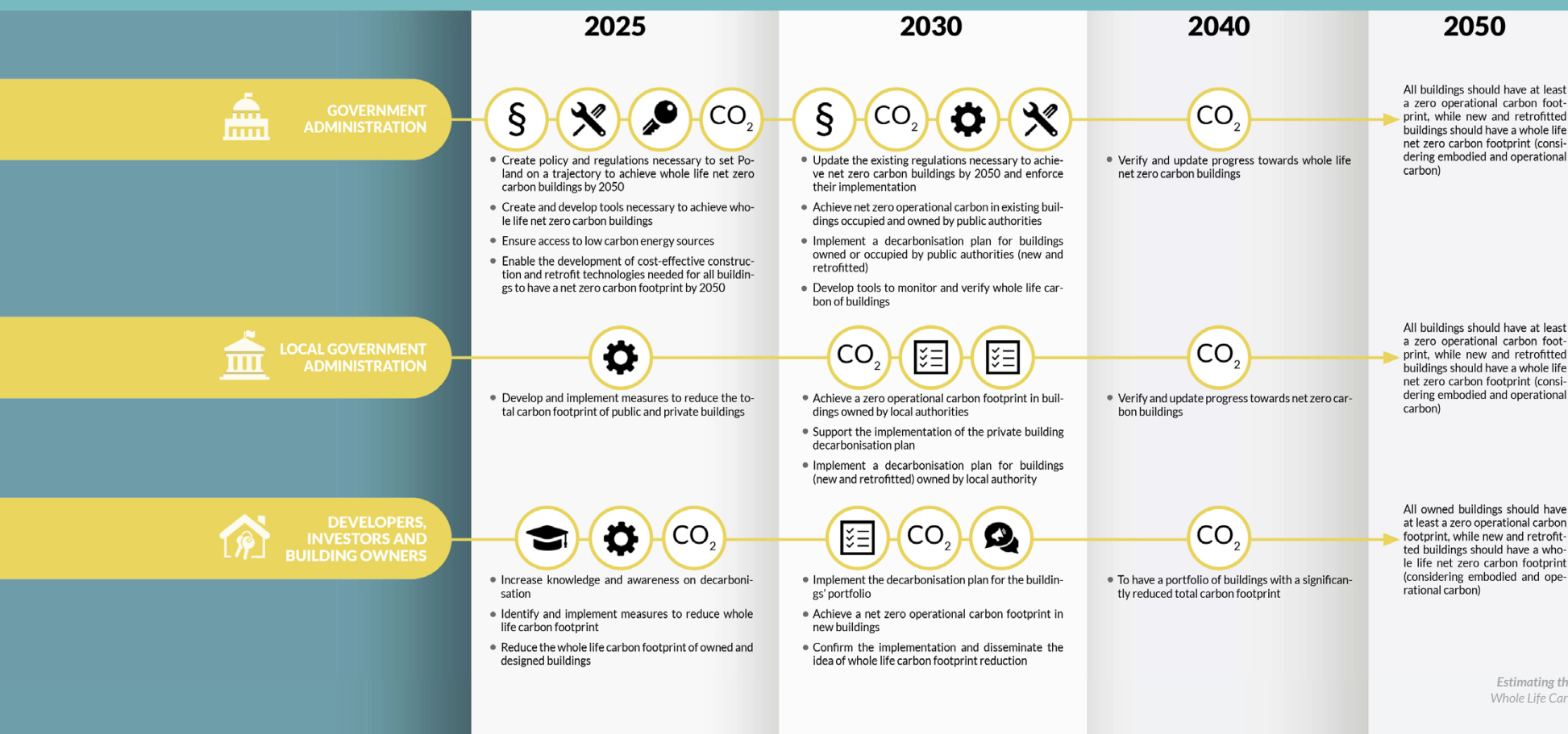
It is important to emphasise that the 2021 report **outlines the actions** that all stakeholders involved in the construction sector **should implement by 2050** to achieve the vision contained in the document:

**All buildings should have at least a zero operational carbon footprint, while new and retrofitted buildings should have a whole life net zero carbon footprint (considering embodied and operational carbon).**

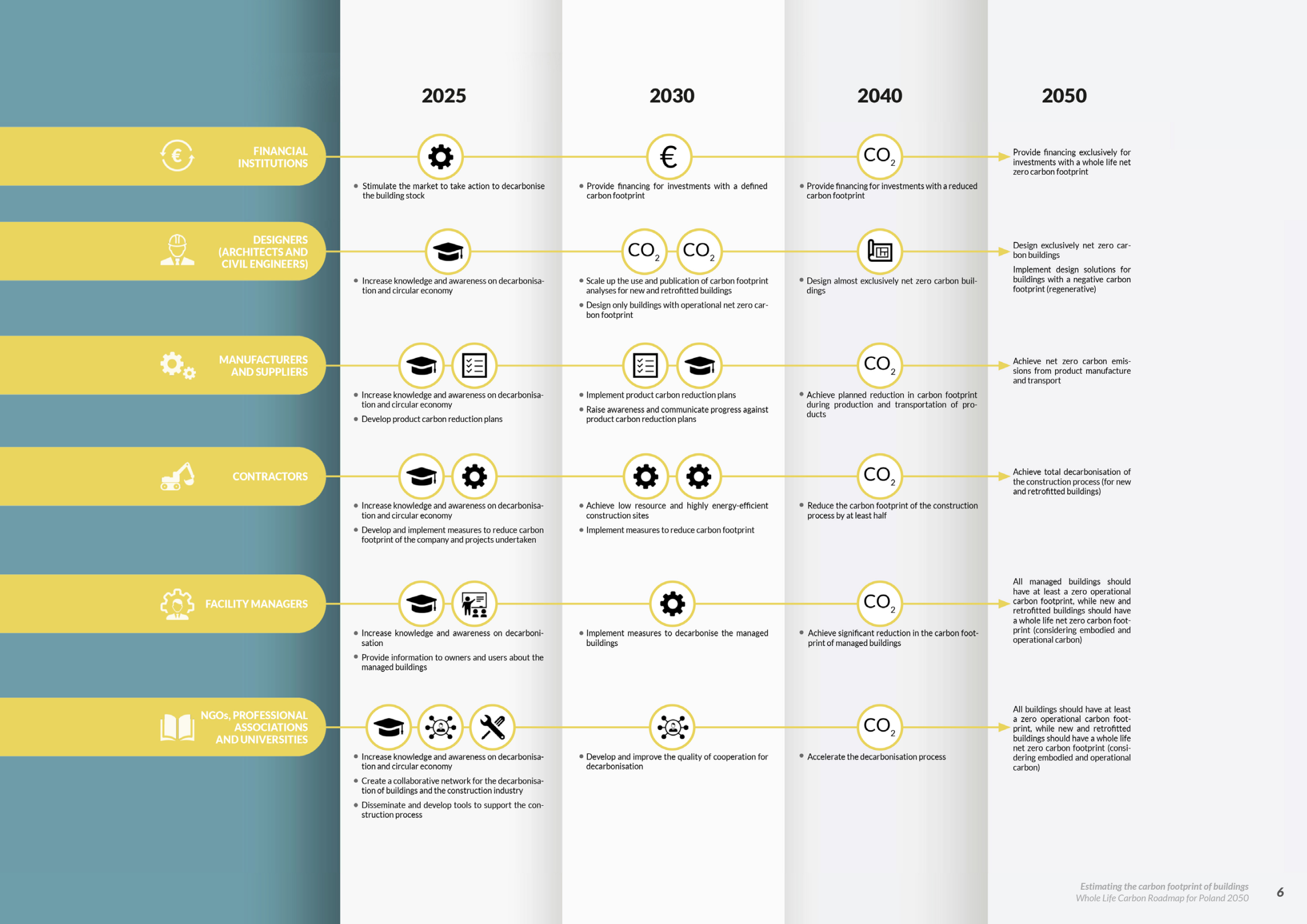
The presented decarbonisation roadmap provides a guide for planning and strategy development by nine identified stakeholder groups. Intersectoral collaboration is an important prerequisite for achieving climate neutrality, so the roadmap is designed to facilitate the implementation of relevant actions by the different groups in specific time frames. These actions have been aligned to help facilitate the radical collaboration across the whole value chain that is needed to drive lasting change.

The implementation of the concrete measures presented below by all stakeholders in the construction sector within an appropriate timeframe is a condition for achieving climate neutrality in the construction sector.

Figure 1. Roadmap for decarbonising the construction industry by 2050.









## OCTOBER 2022

The realisation of the vision presented in the 2021 report depends on a number of changes that need to take place in the Polish construction sector with regard to the production of materials, design, construction process, energy sources and circular economy solutions. As part of the public presentations of the report *How to decarbonise the built environment by 2050. Whole life carbon roadmap for Poland* the important takeaway was the highly emphasised lack of adequate legislation at national level related to the obligation to calculate the total carbon footprint of buildings. Therefore, the basis for actions to be taken must be changes in legislation that will enable the implementation of actions and verification of the CO<sub>2</sub> emissions from buildings. Solutions that allow the construction of buildings with a zero carbon footprint already exist - they need to be promoted and supported appropriately, both legislatively and financially. In addition, the involvement of the financial sector, through the active participation of commercial banks and international financial institutions in the implementation of appropriate instruments to support decarbonisation in Poland is equally important.

The vision of completely decarbonised building stock in 2050 goes beyond the issue of operational GHG emissions, which has been the focus to date. It is important to bear in mind that buildings are an important bank of materials in which resources are stored over many decades, and the way they are designed has a major impact on lifecycle emissions in both new and refurbished buildings. It is therefore necessary to progressively take into account the whole life cycle emissions from buildings, starting with new constructions where it is easier to take into account the embodied carbon at the design stage. Life cycle assessment of buildings should also be taken into account in retrofitted buildings, as part of a whole life cycle GHG reduction policy. Minimising GHG emissions over such a long period requires saving resources and implementing the principles of circular economy. The life cycle global warming potential indicates the overall contribution of a building to emissions leading to climate change. It expresses both the carbon emissions embodied in the building materials and the direct and indirect carbon emissions during the use phase.

**The requirement to calculate the global warming potential over the life cycle of new buildings is therefore the first step** towards a more reliable consideration of the whole life cycle characteristics of buildings and the circular economy.

The most popular technique for assessing a building's complex environmental impact is the Life Cycle Assessment (LCA) method, based on EN 15978 Sustainable construction, and which has the unquestionable advantage of taking a holistic approach, taking into account the entire life cycle of a building. It is also important to take into account the most relevant ecosystems and pollution processes. The norm presents a calculation method based on life cycle assessment for evaluating the environmental performance of a building and provides means of communicating the results of the assessment, resulting in the definition of several indicators that show the environmental impact of a building. For the time being, however, the norm leaves a large margin of uncertainty in the results obtained, related to the assumptions made in the different phases of the life cycle of buildings and the interpretation of the results, leading to limited readability of the LCA analyses presented, as well as a lack of comparability.

**A uniform approach to the scope and methodology for determining the total carbon footprint taking into account the different types of buildings should therefore be developed in order to obtain transparent results and make them comparable.**

Despite these reservations, LCA analysis is today the most objective and precise tool for the environmental assessment of buildings, and its results can be used to optimise design solutions and thus reduce construction and future operating costs.

At present, LCA analysis of the building is not required by Polish regulations and therefore not performed as standard by investors or designers, and is mostly drawn up for the purposes of multi-criteria certifications (e.g. BREEAM, LEED, Zielony Dom, etc.). As a rule, LCA is carried out by specialised offices, usually based on projects, while the greatest potential for optimisation/reduction of CO<sub>2</sub> is in the conceptual phase. In contrast, a reliable result of the environmental impact of a construction project is presented by LCA analysis based on the carbon performance of the building materials and installations used in the building. Another difficulty in popularising LCA analysis is the lack of a uniform and consistent methodology for calculating the carbon footprint of buildings.

Guided by the above rationale PLGBC, as part of the #Building Life project, has developed a methodology for estimating the carbon footprint of buildings presented in this report, a supplement to the 2021 publication *How to decarbonise the built environment by 2050. Whole life carbon roadmap for Poland*.<sup>22</sup>



An aerial photograph of Budapest, Hungary, featuring the Danube River, the Chain Bridge, and the prominent dome of St. Stephen's Basilica. The city is nestled between hills, with residential areas visible in the background. A semi-transparent blue geometric pattern is overlaid on the right side of the image.

# CHAPTER 1

## CARBON FOOTPRINT FRAMEWORK

# LCA ANALYSIS - LIFE CYCLE ASSESSMENT

Life cycle assessment (LCA) has been, since the 1990s, one of the most evolving methods used in the assessment of technologies, products or services and their environmental impact.

It provides a basis for identifying, prioritising and establishing ways to improve environmental quality. In the context of buildings and building products, the most relevant standards are: EN 15978<sup>51</sup> related to the environmental assessment method for buildings and EN 15804<sup>50</sup> related to the environmental assessment method for construction products.

LCA is a technique that examines the environmental aspects and impacts of a product throughout its life cycle, reflecting the risks that arise from poorly managed processes in the production of materials, construction and operation of buildings. LCA takes into account all ecosystems and their components, so that the environmental impact of a product can be fully assessed, as well as the consumption of individual environmental resources. The analysis is carried out from the acquisition of the raw material, through the production and use stages, to the end of life. Thanks to this approach, no stage of the product's life is overlooked, making it possible to carry out full analyses of the risks that production off construction materials ay pose to the environment.

The following figure shows the life cycle of a building according to EN 15978, and the guidelines and scope of the calculations adopted in the methodology for estimating a building's life cycle footprint are described in details in Chapter 2.

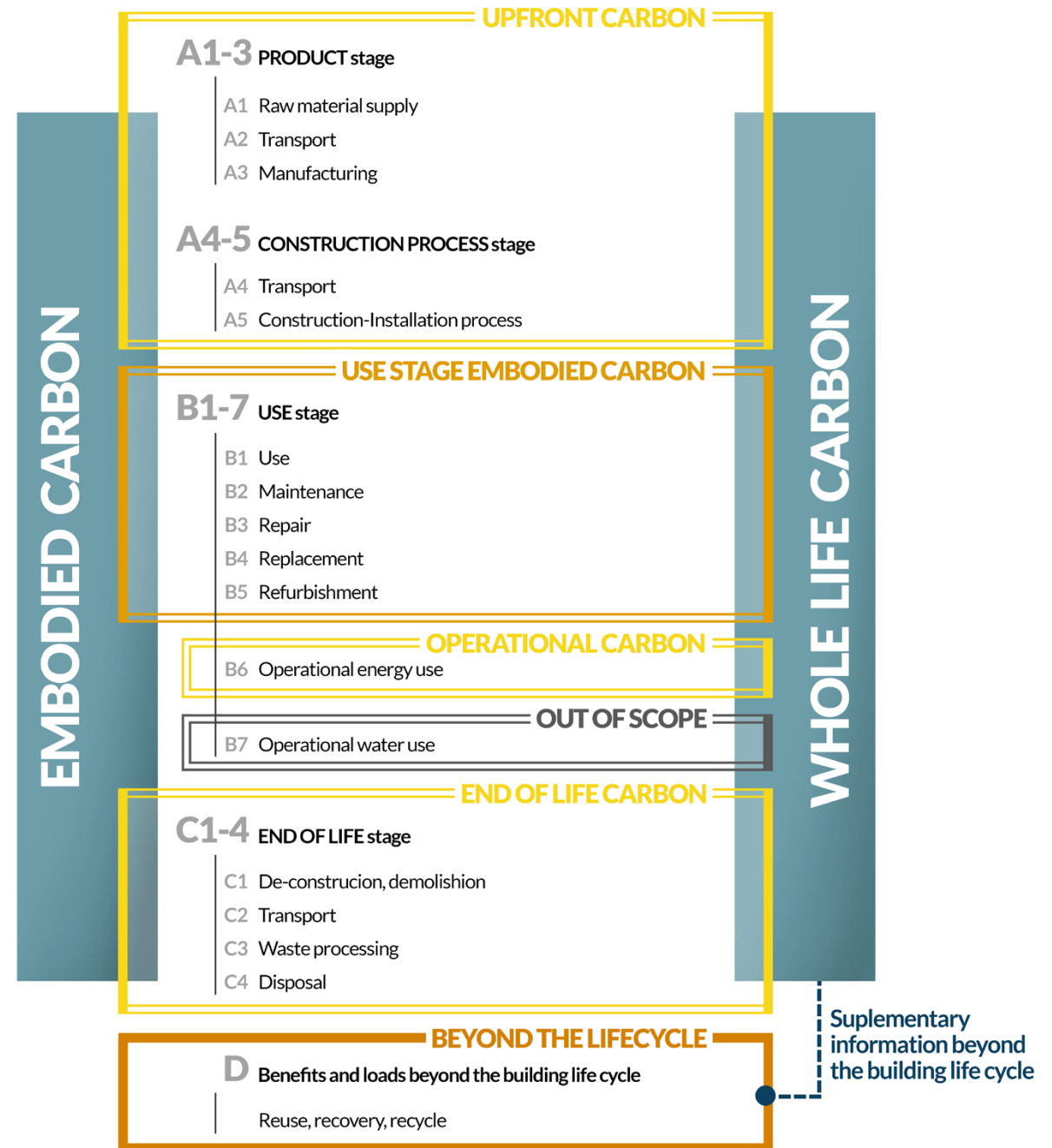


Figure 2: Life cycle of a building according to EN 15978



# NET ZERO CARBON BUILDING

**Net Zero Carbon Building\*** (NZCB) is a building whose operational and embodied carbon balance, over its entire life cycle, is zero.

## It is a building:

1. That has a comprehensive inventory of all emission sources throughout the life cycle, with detailed embodied and operational carbon.
2. With minimised energy demand and thereby reduced operational carbon footprint, with appropriate materials and technologies for construction selected in order to reduce the embodied carbon.
3. Optimised to reduce the carbon footprint throughout its life cycle - taking into account both embodied and operational carbon.
4. Whose operational energy needs are met by on-site (where possible) or off-site renewables.
5. Whose embodied carbon is reduced during the maintenance, modernization and deconstruction stages.
6. In which if the previous steps have been made and the building has not yet reached net zero carbon across the life cycle, the use of offsets is allowed, but only from certified programmes.

The design and construction of net zero carbon buildings should be based on a series of good practices that rely heavily on the introduction of circular economy principles. These include:



### Design for disassembly

designing the building in a way that allows construction from components that can be dismantled and reused, so that the whole building can be easily adapted for other purposes in future. This way, a building that has completed its life cycle in its current form can be a source of materials for the next investment. This concept of a building as a bank of materials is now increasingly popular<sup>25</sup>.



### Building reuse

finding a use for an existing building that requires little or no renovation or adaptation. This can significantly minimise the carbon footprint from the construction and conversion process.



### Life cycle carbon footprint optimisation

looking at the effects of decisions at the design stage from a whole building life cycle perspective. Taking the thickness of a building's insulation as an example: thicker insulation translates into less heat loss, resulting in lower energy consumption, which in turn translates into a lower operational carbon footprint. However, it must be taken into account that the thicker the insulation, the greater the amount of energy and material required to produce it, which results in a higher embodied carbon (if no biogenic materials are used). The key is to determine the optimal solution for which the overall carbon footprint will be the lowest.



### Natural materials

using natural, renewable materials also reduces the carbon footprint of buildings. Examples include wood (sustainably grown, such as FSC certified), hemp, flax or bamboo. Such materials are made from plants that sequester carbon dioxide from the atmosphere, further reducing the carbon footprint of products made from them. This even allows for a negative carbon footprint.

\* The definition of a building adopted in the report published by PLGBC *How to Decarbonise the Built Environment by 2050. Whole Life Carbon Roadmap for Poland*<sup>22</sup>

## EMBODIED CARBON OF THE BUILDING

The importance of the embodied carbon is repeatedly highlighted throughout this report. The reason for that is the operational carbon footprint of buildings is already a widely accepted concept and the need to reduce it is well understood and increasingly implemented. However, it is worth noting that as the operational carbon footprint decreases, the importance of the embodied carbon will increase and without taking appropriate actions to reduce it, it will not be possible to decarbonise the building stock by 2050 in Poland.

In many studies, the decarbonisation pathway for buildings focuses on zero emissions only in the context of a building's use, i.e. improving the energy efficiency of existing buildings through thermal upgrades, energy management and switching to low or zero carbon heating sources, and in the case of new buildings, constructing them to nearly zero energy building standards. However, we must continue our efforts to emphasise the importance of the environmental impact of a building throughout its life cycle, including the materials used to construct it, the construction process itself, refurbishment, and finally, demolition.

Sustainable construction is not simply choosing a material or building component with a lower carbon footprint, but looking at how a product will perform in the long term. For example, elements that are highly resilient, have a high coefficient of strength and are easier to adapt and reuse, are a greener choice than products with a lower carbon footprint, but which are less durable, impossible to recycle or reuse. Only such a holistic approach will allow for the complete decarbonisation of the construction sector.

Estimations of CO<sub>2</sub> emissions from buildings vary widely, showing that the embodied carbon footprint accounts for 10 to 50% of total lifecycle emissions<sup>23</sup>. In contrast, a report from One Click<sup>20</sup> states that, depending on building type and location, the embodied carbon footprint is around 450 kgCO<sub>2</sub>e/m<sup>2</sup>. These figures confirm analyses published by DGNB<sup>4</sup>, where the average embodied carbon of a building

is 435 kgCO<sub>2</sub>e/m<sup>2</sup>, assuming a 50-year life cycle. Further analyses by Ramboll<sup>48</sup>, report the embodied carbon of 600 kgCO<sub>2</sub>e/m<sup>2</sup> and highlight that 70% of this value are upfront emissions.

Carbon emissions vary depending on the type of building - this is related to the specific use and requirements of a building, i.e. structure, technical equipment, volume, location, etc. *The Embodied Carbon Primer*<sup>42</sup>, produced by LETI (London Energy Transformation Initiative), shows the results of a whole life carbon footprint analysis, broken down by phase emissions, for an office building, a school building and a residential building. In the Figure 3, the graphic on the left shows the total carbon footprint for buildings built to current building standards, where the operational carbon footprint is dominant over the lifetime. The graphic on the right shows the emissions structure for buildings built to high energy standards, with low energy demand, supplied in addition by heat pumps. In these cases, modules A1-A3 assigned to the embodied carbon are responsible for the largest emissions.

It should be stressed that the data presented cannot be a clear benchmark or comparative values due to the adoption of different calculation methodologies and too little data. This highlights the need for an effort to collect robust data from different stages of the building life cycle, different building types and their components in order to develop useful, aggregated carbon indicators.

To eliminate inconsistencies, reliable data on the operational emissions generated by buildings and the embodied carbon need to be collected, both during the construction and the use phase. In order to achieve this, **regulations in individual European countries need to clearly define the methodology for calculating the total carbon footprint over the entire life cycle of a building, impose reporting, benchmarking and, as a result, introduce emission limits within the relevant modules of the EN 15978 standard**<sup>51</sup>.

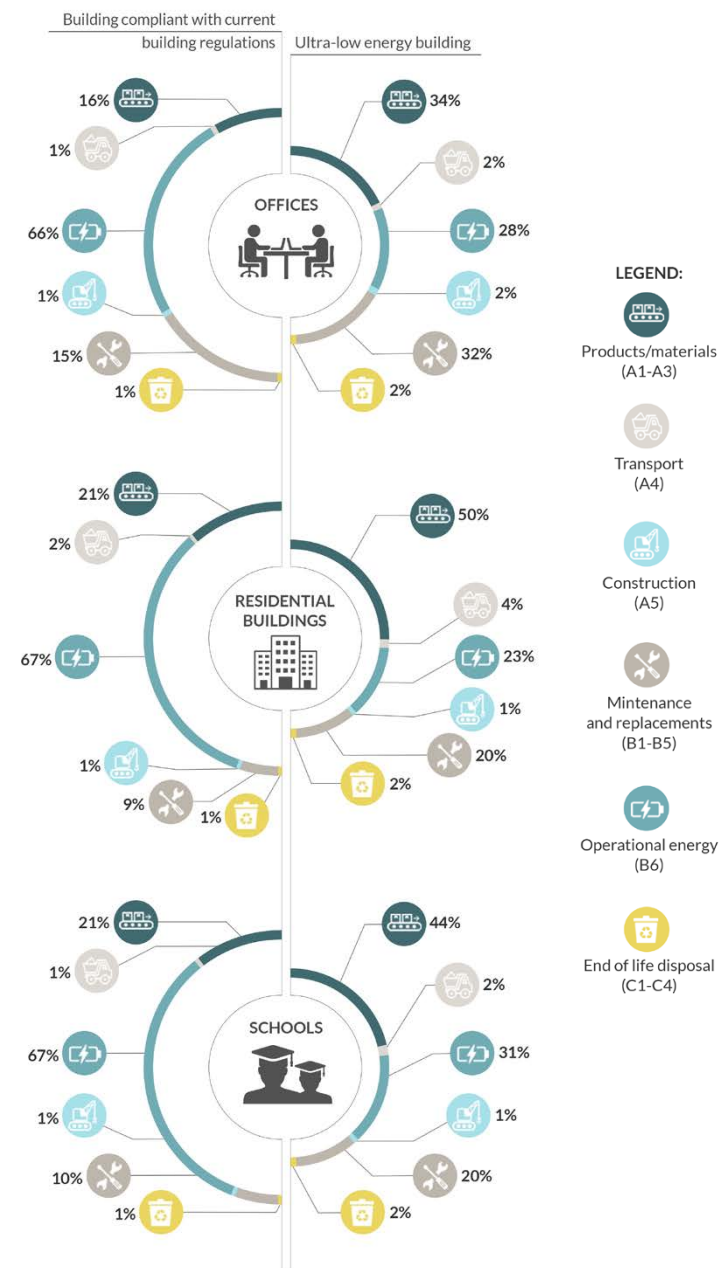
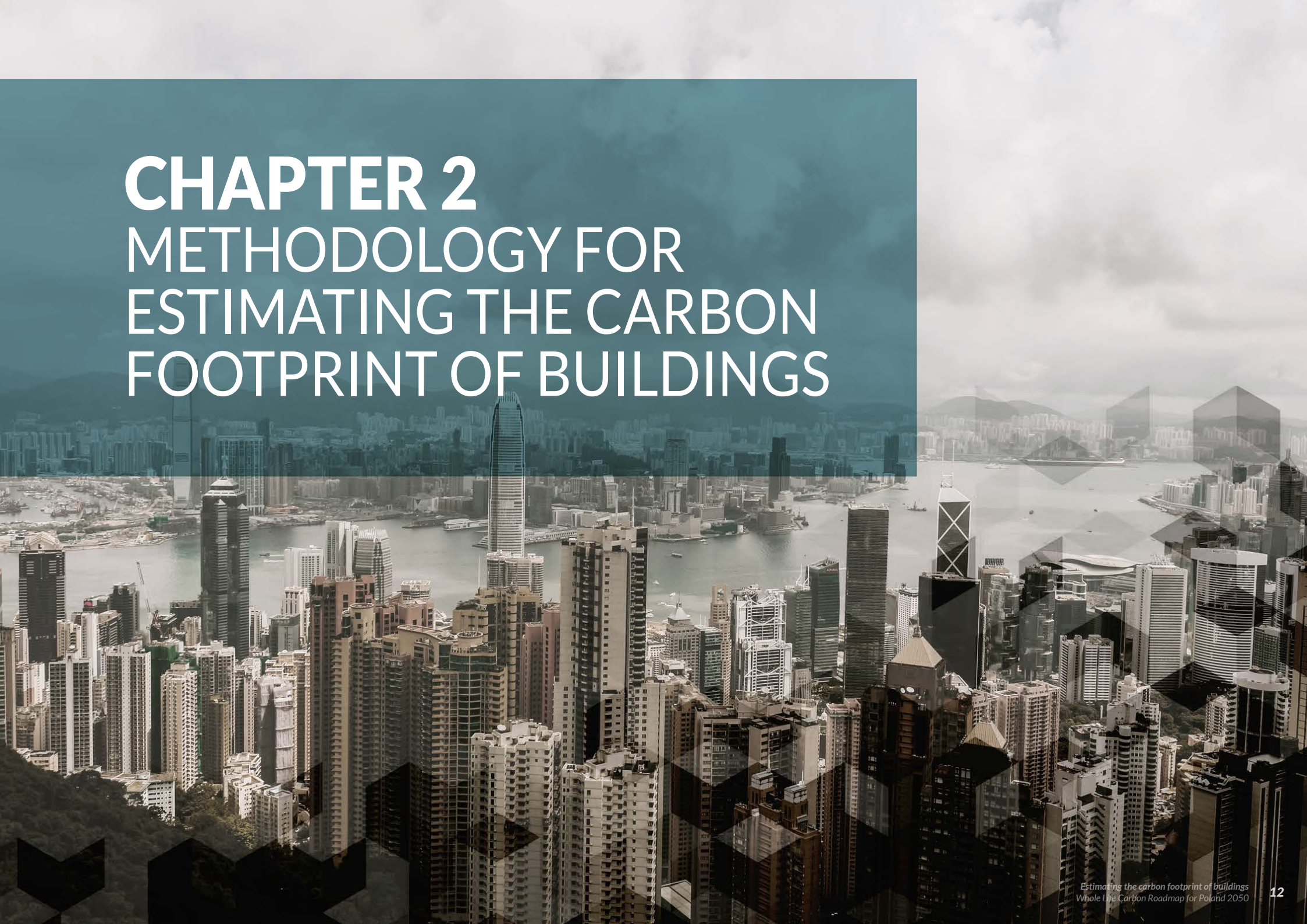


Figure 3: CO<sub>2</sub> emission structure<sub>2</sub> in the different phases of the LCA analysis for different building types - based on Embodied Carbon Primer<sup>42</sup>





# CHAPTER 2






## METHODOLOGY FOR ESTIMATING THE CARBON FOOTPRINT OF BUILDINGS

# ESTIMATING THE CARBON FOOTPRINT - A VITAL PART OF BUILDING DECARBONISATION EFFORTS

This section of the report will present a methodology for development of a multilevel analysis of environmental impact of a building throughout its entire life cycle, based on the value of its carbon footprint. The methodology presented applies to newly designed buildings.

The carbon footprint of a building is the sum of all greenhouse gas emissions associated with processes occurring during its life cycle. The value of the carbon footprint is directly linked to the Global Warming Potential (GWP) indicator expressed in kilograms of CO<sub>2</sub> equivalent (kgCO<sub>2</sub>e). The carbon dioxide equivalent includes the impact of emissions of various greenhouse gases, not just CO<sub>2</sub>, but it is commonly referred to as carbon dioxide emissions, which should be taken as a simplifying abbreviation.

**Table 1:** GWP values according to Intergovernmental Panel on Climate Change (IPCC)

	SUBSTANCE	ATMOSPHERIC LIFETIME (YEARS)	GWP <sub>100</sub> (kg CO <sub>2</sub> e)
	Carbon dioxide (CO <sub>2</sub> )	-	1
	Methane (CH <sub>4</sub> )	12 (decomposition leaves CO <sub>2</sub> in the atmosphere)	23
	Nitrous oxide (N <sub>2</sub> O)	144	296
	Sulphur hexafluoride (SF <sub>6</sub> )	3 200	22 200
	Carbon tetrafluoride (CF <sub>4</sub> )	50 000	5700

LCA is a technique that can be used to examine the impact of a building over its entire life cycle, from the acquisition or manufacture of building materials from raw materials and natural resources, through production, use, to demolition. It is used in the estimation of a building's carbon footprint, but can also be used to determine other indicators, such as Ozone Depletion Potential (ODP). The calculation procedures for the other indicators are analogous to those for the carbon footprint. The scope of life cycle assessment and the type of indicators determined by it can be influenced by local regulations, industry guidelines and the requirements of multi-criteria rating systems for buildings.

According to Level(s) guidelines, reporting of the global warming potential expressed in kgCO<sub>2</sub>e should take into account its origin from fossil sources, biogenic sources, and from land use and land use change. GWP-luluc (land use and land use change) takes into account all emissions associated with the release of biogenic carbon dioxide due to land use change, e.g. conversion of forest land to housing. According to the methodology for EPD development, as outlined in PN EN 15804 standard, the GWP-luluc value can be disregarded if its contribution to the total GWP value (consisting of GWP-fossil, GWP-biogenic and GWP-luluc), for all LCA modules except Phase D, does not exceed 5%. In practice, the GWP-luluc value is not declared in EPDs.

The methodology presented in this study concerns the estimation of the carbon footprint of a building, excluding the effects of the change of use of the investment parcel. Therefore, the **GWP-luluc indicator will not be included in the methodology. The authors of this study recommend that GWP-luluc is determined and taken into account at the stage of issuing environmental decisions, where the impact of the entire development is considered in the context of its location and influence on its surroundings.**

Guidance for the calculation of GWP-luluc due to forest land conversion is provided in the European Commission's publication Product Environmental Footprint Guide (PEF)<sup>39</sup> and the standards PAS 2050:2011 (BSI 2011) and Annex PAS2050-1:2012 (BSI 2012)<sup>49</sup>.

This report describes the methodology for estimating building's carbon footprint developed to meet the objectives outlined in the publication *How to decarbonise the built environment by 2050. Whole life carbon roadmap for Poland* (PLGBC, June 2021). The methodology is based, among others, on:

- PN EN 15978:2012 standard,
- EU Level(s) system,
- "Whole life carbon assessment for the built environment" (RICS professional statement, UK, 1st edition, November 2017),
- "How to calculate embodied carbon" (The Institute of Structural Engineers, second edition).

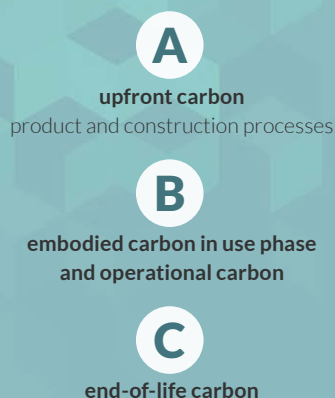
The methodology developed is based on the general guidelines and calculation principles presented in the above publications, as well as on recommendations presented in industry studies, such as the "LETI Embodied Carbon Primer", and on the authors' experience from life cycle assessments of buildings.



# LIFE CYCLE ASSESSMENT (LCA)

## BUILDING LIFE CYCLE STAGES - INTRODUCTION

The entire building life cycle is made up of 15 modules assigned to the three main stages of the cycle:



The product stage includes modules A1 (raw materials supply), A2 (transport) and A3 (manufacturing). Further modules related strictly to the construction process are A4 (transport of products to the construction site) and A5 (construction process).

Within the use stage, life cycle modules related to the permanent components of the building such as B1 (use), B2 (maintenance), B3 (repair), B4 (replacement), B5 (refurbishment) and modules related to the utilities supplied to the building, namely B6 (energy consumption) and B7 (water consumption), have been identified.

The four modules associated with the end-of-life stage are C1 (de-construction/demolition), C2 (transport of debris and waste), C3 (waste processing) and C4 (waste disposal or storage). The analysis may also include module D, which considers any greenhouse gas emissions (or reductions) that occur outside the life cycle of the building under consideration, which can be linked to the possibility of reusing building components in a new facility, or recycling them.

## The carbon footprint of a building can be determined for different life cycle ranges:

- *From cradle to gate*, which covers **modules A1 to A3** - only emissions associated with the manufacture of products from which the building is or will be constructed are considered.
- *From cradle to completion* takes into account **modules A1 to A5** - it additionally includes emissions caused by the transport of products to the construction site and by the construction process itself. The carbon footprint estimated for this range is called upfront carbon.
- *From cradle to grave*, where the entire life cycle of the building should be taken into account, thus **modules A1-A5, B1-B7 and C1-C4**. The results of this assess-

ment give the figure of the total carbon footprint. However, it is worth noting that within the total carbon footprint there is additionally a distinction between the operational carbon, associated with modules B6 and B7, and the embodied carbon, associated with the other life cycle modules.

- As work on the transition to a **circular economy progresses**, also cradle-to-cradle assessments, that additionally take into account the environmental benefits and loads of **module D** are also gaining importance, thus they can be considered optionally.

**Table 2:** Building life cycle phases by module according to EN 15978 2012

	A1-A3	A4-A5	B1-B3	B4-B5	B6-B7	C1-C4	D
LCA modules	Extraction and transport of raw materials and production	Product transport and construction	Operation, maintenance and repair	Replacement and refurbishment	Energy and water consumption	Demolition and transport of waste and its disposal or treatment	Benefits and loads beyond the building life cycle
LCA stages	Product stage	Construction process stage	Use stage			End-of-life stage	
Embodied carbon							
Operational carbon							
Total carbon							

# COMMENTS AND RECOMMENDATIONS



## BUILDING LIFESPAN

When defining the scope of LCA analyses, it is worth noting that the lifespan of buildings is usually expressed in decades, and can be centuries for some monumental buildings. For the **purpose of the current carbon footprint estimates, buildings are generally assumed to have a lifespan of 50 or 60 years.** This means that when carrying out a life cycle assessment to estimate the embodied carbon of a proposed building, it is possible to rely on current production data for the components used for construction, however it is necessary to make a number of assumptions about the use of the building over the following decades and assume an end-of-life scenario that could be appropriate to the reality of the second half of the XXI century.

**The assumed lifespan of the building, considered in the LCA analysis, has a fundamental impact on the results of building's total carbon footprint.**

## SCOPE OF THE BUILDING LIFE CYCLE

By limiting the scope of the LCA to modules A1-A3 (product stage) and A4-A5 (construction stage), the lifespan taken into account in the analysis is shortened and thus the number of assumptions needed is significantly lower. This means that the estimation of the upfront carbon alone can be much more precise than the estimation of the embodied carbon (during the use of the building) and the total carbon. The Figure 4 illustrates how the range of building lifespan analysed affects the uncertainty of the results in the different life cycle assessment modules. The issues of how assumptions affect the uncertainty of the assessment results are discussed in more detail later in the document, as part of the case study analysis. The following sections present recommendations with proposed assumptions for estimating the total carbon footprint for buildings located in Poland.

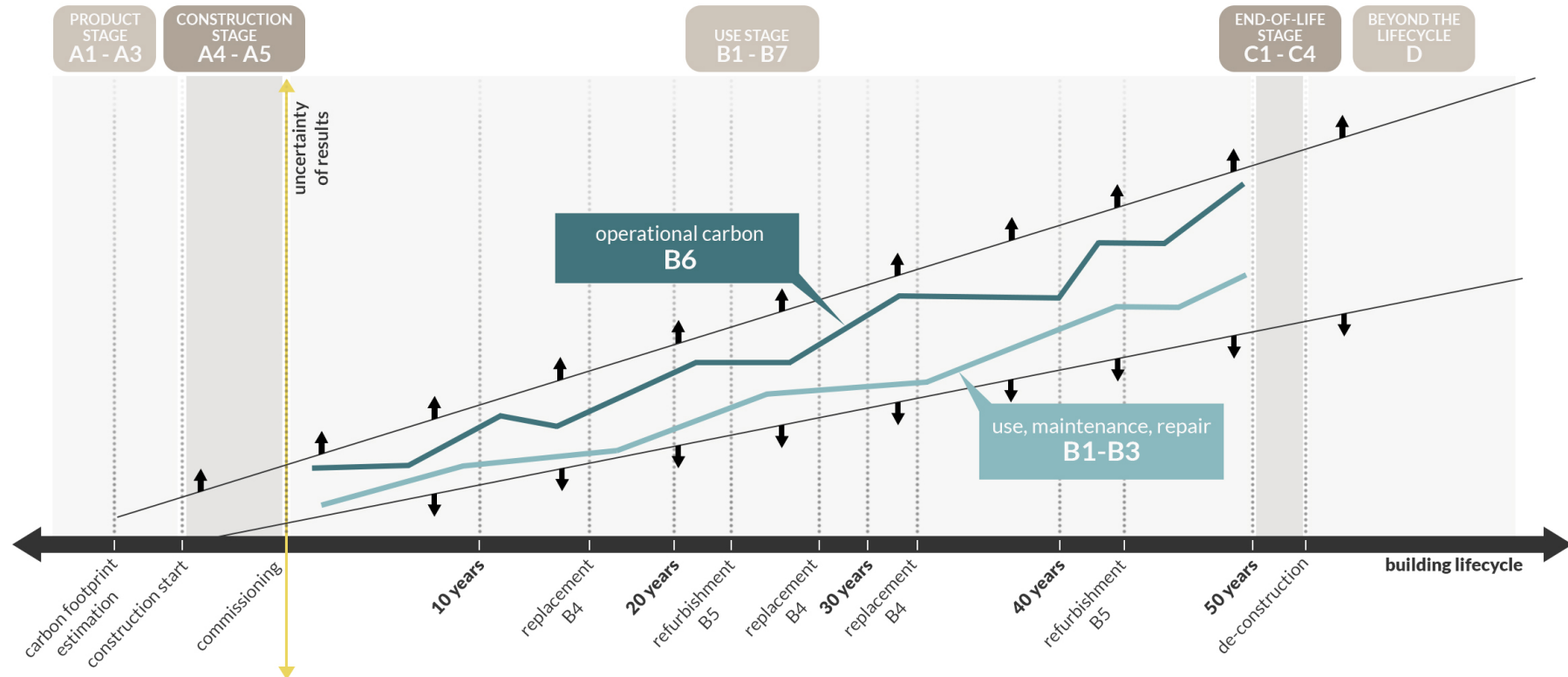


Figure 4: Building lifespan vs. uncertainty of assessment results - own study



## ASSESSMENT OF THE CARBON FOOTPRINT OF A BUILDING IN THE INVESTMENT PROCESS

The EU Level(s) framework for sustainable buildings, which is one of the bases for this study, distinguishes three levels of life cycle assessment suitable for different stages of the investment process:

- Level 1: conceptual design of the construction project - the most basic level, which includes early qualitative assessments based on the conceptual design and reporting on the concepts to be used or planned,
- Level 2: detailed design and construction efficiency - an intermediate level involving quantitative evaluation of designed efficiency and construction monitoring using standardised units and methods,
- Level 3: post-construction and building performance after completion of construction and handover of the building to the client - this is the most advanced level, as it involves the monitoring and investigation of activities on the construction site, as well as the completed building and its subsequent use.

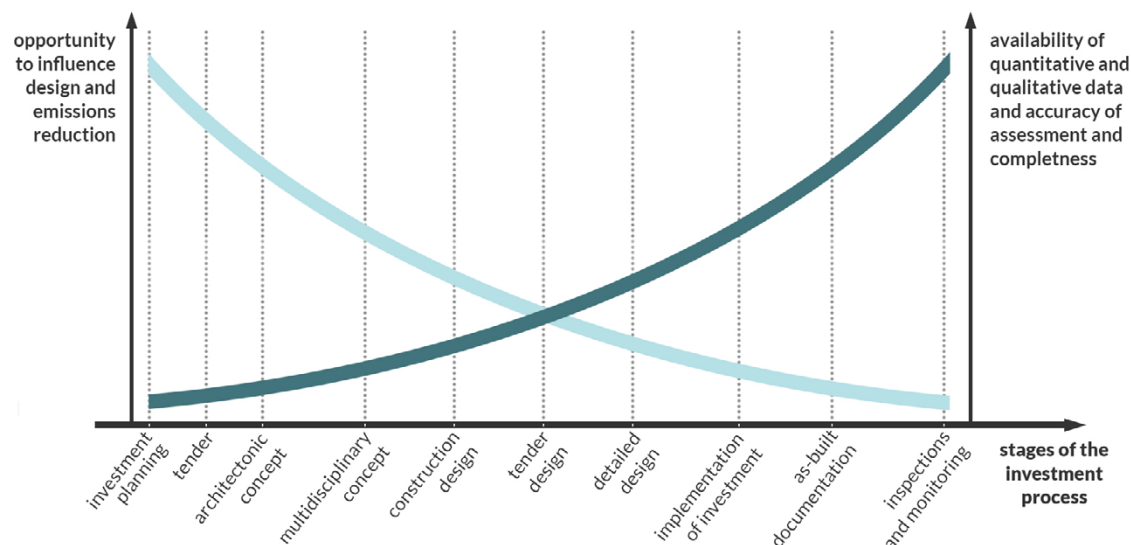


Figure 5: Opportunity to influence design and emissions reduction vs. availability of building data at different stages of the investment process - own development

Analogous stages can be distinguished in case of assessing the carbon footprint of a building. Depending on the stage of the investment process, the analysis will serve different purposes and will be characterised by a different degree of accuracy, appropriate to the phase of the project or implementation (Figure 5). It is recommended that the investment process considers the possibility of estimating the carbon footprint at each of the three stages of the construction project.

Depending on the stage of the project, life cycle assessment will serve different purposes.

### STAGE 1 - recommended

#### Conceptual design

this is the least accurate level of assessment as it mainly covers quality parameters at an early stage of implementation. The life cycle assessment of a building carried out at this stage aims to present alternatives to the conceptual design and to identify the building elements that contribute most to GHG emissions. The results of the life cycle assessment carried out at this stage should be the basis for the formulation of guidelines for further phases of the project. In this way, a building life cycle assessment carried out at this early stage **can make the greatest contribution to minimising the carbon footprint of the project.**

### STAGE 2 - compulsory

#### Technical (construction) or tender design

a life cycle assessment is performed at this stage based on the complete multidisciplinary documentation developed for the project and often detailed BIM models. This stage allows a fairly precise quantitative assessment of the designed solutions and the adoption of realistic scenarios regarding the implementation process. The results of the building life cycle assessment obtained at this stage can, for example, help to define additional selection criteria for the materials specified in the design.

### STAGE 3 - recommended

#### Construction and as-built stage

at this stage it is possible to take into account the exact quantity, origin and type of materials used on the basis of the detailed design and the measurements and records kept by the general contractor. The calculation of the upfront carbon at this stage can be a verification of the assumptions made for the life cycle assessment carried out at an earlier stage. In view of its usefulness for future developments, **it is recommended that, wherever possible, the calculation of a building's embodied carbon emissions should be a mandatory part of the work commissioned from the general contractor.**

Special applications developed for this purpose, such as <https://qualisflow.com/>, can be helpful in tracking the flow of materials during the construction.

Given the importance of the construction project and its regulation in the Building Act, the recommendations presented in the following section mainly relate to life cycle assessment of a building carried out precisely at **construction project stage - Stage 2 according to the Level(s) framework nomenclature**.

### However, it is worth noting that:

- assessing the carbon footprint at the earliest possible stage of the project is extremely valuable from the point of view of decarbonising the investment and can be further rewarded by various multi-criteria building certification systems,
- the estimation of the carbon footprint during the construction phase, due to the greatest availability of information on the process flow and the solutions finally applied, has the greatest research value and can thus indirectly contribute to lowering the carbon footprint of subsequent investments.

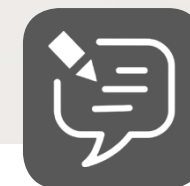
## Data sources for materials

In order to ensure the comparability of the results of the life cycle assessments of buildings in the calculations carried out from **the building design stage onwards**, EPDs, in accordance with standard PN EN 15804, and verified averaged (generic) data should be used. EPDs provide information on materials, construction products and appliances in terms of their environmental impact. However, it is important to ensure that the declarations are up-to-date: both verification and expiry dates of the document should appear on the first page. Declarations are usually valid for five years. Generic data are also produced based on the information from EPDs.

While the specific product that will be used in the development is known at the design stage, it is useful to use product-specific carbon emission data. EPDs provide detailed information on the environmental impact of materials or products, including information on carbon emission factors for modules A1-A3. EPD information can also be used to determine which products should be used to meet expected targets. EPDs can be found on the websites of product manufacturers and product development and dissemination bodies, such as:

- [Building Research Institute](#)
- [ECO Platform](#)
- [ÖKOBAUDAT](#)
- [Environdec](#)
- [Institut Bauen und Umwelt](#)
- [BRE Green Book Live](#)
- [Transparency Catalog](#)
- [Climate Earth](#)
- [EPD Ireland](#)
- [Carbon Leadership Forum](#)





## COMMENTS AND RECOMMENDATIONS

- It should be noted that the above cited websites contain EPDs developed for products manufactured in different countries. The place of manufacture of a product can have a significant impact on carbon emission values.
- EPDs often only contain modules A1-A3, so care should be taken when combining data from EPDs with other sources that may contain additional modules, e.g. A-C. In order to compare such data with each other, it will be necessary to fill in the gaps (or at least draw attention to them).
- EN 15804 standard now requires EPDs for building products and materials to include modules A1-A3, C1-C4 and D. This will increase the availability of data for modules C and D and can be incorporated into lifespan carbon calculations, provided that all materials and products are considered in the same way.

The sources of data used in LCA depend largely on the stage at which the building assessment is carried out. The information needed for the assessment can be divided into the following categories (Table 4):

- **General data** (indicators) - typical for the type of building and construction materials used. These are values determined on the basis of previous, more detailed analyses carried out for reference buildings.
- **Aggregated data** for the main building elements - these may refer, for example, to selected building elements such as its structure, envelope, internal partitions, building installations, etc. These data can be derived from the analysis of a selected representative part of the building and be used to extrapolate results for the whole building. This data is particularly useful at the concept stage when comparing different design options.

- **Generic data** - averaged information collected for one product or building element, based on information from different manufacturers. They are useful at any project stage.
- **Details** - mostly used at advanced stages of the design process or during construction. They are mostly contained in EPD sheets (they concern for example bricks, gypsum, insulation, flooring, windows, finishes).
- **Measured data** - the most accurate category of data, derived directly from the measurement of energy or material consumption during the course of construction work or the use stage of a building.



**Table 3:** Summary of preferred data to be used at each stage of building assessment

DATA CATEGORY	THE STAGE AT WHICH A BUILDING'S CARBON FOOTPRINT CAN BE CALCULATED			
	CONCEPT	CONSTRUCTION, TENDER AND DETAILED DESIGN	UNDER CONSTRUCTION	BUILDING USE OR DEMOLITION
General data (indicators)	✓			
Aggregated data for building elements	✓	✓		
Generic data for products		✓	✓	
Details of materials and products (EPDs)		✓	✓	✓
Measurement data			✓	✓

## COMMENTS AND RECOMMENDATIONS

At stage 1 of the project, rather than limiting the scope of the LCA, it is advisable to include all building elements and life cycle modules, even if the project lacks information on them. It is then recommended to use generic data (indicators) or aggregated data. In this way, the final results of the carbon footprint assessment can be compared between projects regardless of the stage of the project. In addition, the values obtained in the early phases of the project can be verified in the later phases of the project.

## Data sources on buildings

In order to carry out the LCA of a building, up-to-date design documentation is essential. BIM models or work estimates can provide additional support. For existing buildings, renovation projects and post-construction documentation should be a source of data.

Irrespective of the stage at which the carbon footprint assessment is carried out, the sources of data serving as a basis for the assessment should be indicated and any exclusions from the scope should be listed. It is also standard practice to exclude from the LCA building components whose mass contribution does not exceed 1% of the total mass of the building, provided that the total contribution of all exclusions does not exceed 5% of the total building mass.

## LCA tools

Dedicated software developed for building LCA can be a great help in calculating the carbon footprint. They can facilitate the access to multiple databases and include formulas implemented for calculating LCA modules - e.g. A4, based on the location of construction and the means of transport adopted for the product. The software can also facilitate the extraction of building information from a BIM model and the presentation of the results. However, it is important to note that particular skills are needed to operate the tools, to use them knowledgeably and to subject the results obtained to verification. The Figure 6 shows the names of exemplary LCA programmes and tools, together with information on LCA modules they cover, and in which part of the world they are mainly used.





REGION	SOFTWARE NAME	SCOPE OF THE ASSESSMENT
 <b>GLOBAL</b>	OneClick LCA Planetary	A1 - A3
	The Structural Carbon Tool	A1 - A3
	eTool „open use“ subscription	A - D
	eTool (paid version)	A - D
	OneClick LCA	A - D
 <b>UNITED KINGDOM</b>	Environment Agency - ERIC	A1 - A5
	Hawkins/Brown Emission Reduction Toolkit (H/BERT)	A - D
	ECCOlab	A - D
 <b>USA</b>	Beacon	A1 - A3
	EC3	A1 - A3
	Tally	A - D
 <b>USA &amp; CANADA</b>	Athena	A1 - A5, B4, B6, C1, C2, C4, D

Figure 6: Examples of carbon footprint calculation tools





# ASSESSING THE CARBON FOOTPRINT OF A BUILDING

## LCA SCOPE

Before assessing the carbon footprint, it is necessary to define the scope of the building life cycle assessment, that is, the limits of the investment in terms of the building components and the length of the analysed period and the LCA modules considered in the evaluation. The results of carbon footprint estimations carried out for different facilities, by different assessment bodies, can only be comparable with each other

if the LCA is carried out for an identical scope. The minimum scope of analyses for a building presented hereafter has been determined based on industry guidelines and recommendations operating in other European countries and taking into account the availability of data and the state of knowledge on the carbon footprint in Poland.

## COMMENTS AND RECOMMENDATIONS

The authors of this study suggest that for typical buildings the LCA should be carried out assuming a 50-year building lifespan. Such an assumption is consistent with the reference lifespan set out in the EU Level(s) system.

## LCA analysis modules

The authors of this study recommend that the embodied and operational carbon should be estimated as part of the building's LCA. The embodied carbon should include the emissions resulting **from modules A1-A5, B1-B5 and C1-C4**. The exclusion of module B6 (*operational carbon*) is justified as follows:









The energy efficiency of buildings is already legally regulated, and there are requirements in the legislation for the PE (Primary Energy) indicator expressed in kWh (per year and per unit of usable floor area of the building). This contributes to improving the energy efficiency of buildings, i.e. reducing the operational carbon.

Another factor that, in addition to energy efficiency, has an impact on the operational carbon emissions is the level of decarbonisation of the grid in Poland, referred to as the energy mix. Participants in the investment process can influence the energy mix to some extent, e.g. by deciding to produce electricity or heat on site, which is also already reflected in the PE indicator.

There are many projections as to the share of individual sources of electricity and heat in Poland, but at present, their time horizon mostly ends in 2040, while building life cycle assessments require assumptions reaching into the eighth decade of the 21st century. Achieving climate neutrality by 2050, in line with the goals of the Paris Agreement, would mean a complete shift away from fossil fuels, although despite various efforts and initiatives, such a scenario is unlikely.

The contribution of the operational carbon to the total carbon footprint of a building, depending on the type of building and the assumptions made regarding the decarbonisation of the grid, can range from 20% to 80%. Including such a large component of emissions in the assessment, which is at the same time very uncertain, would make life cycle assessments related to the total carbon footprint of a building lose their value as a tool for comparing buildings with one other. This issue is discussed in the case study developed as part of this report.

Module B5 covers the processes of building's renovation, which may involve changing the building external and internal envelope, room designation and installations in the building. As a consequence of the interventions in the building envelope, the operational carbon may also change. In the absence of specifically defined renovation plans in the indefinite future, attempting to quantify them runs the risk of a large over- or underestimation.

LCA MODULE	SOURCE OF EMISSIONS	SUGGESTED DATA TYPE
 <b>A1</b>	SOURCE OF EMISSIONS	Averaged data for products (generic), or <b>detailed data</b> for products (from EPDs)
 <b>A2</b>	EXTRACTION AND SUPPLY OF RAW MATERIALS	
 <b>A3</b>	MANUFACTURING OF THE PRODUCT	
 <b>A4</b>	TRANSPORT TO SITE	General data based on estimates for road transport
 <b>A5</b>	CONSTRUCTION AND INSTALLATION PROCESS	Overall data based on average emissions from reference sites
 <b>B1</b>	USE	General data based on estimated values for reference object types
 <b>B2</b>	MAINTENANCE	
 <b>B3</b>	REPAIR	










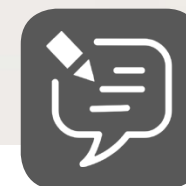
LCA MODULE	SOURCE OF EMISSIONS	SUGGESTED DATA TYPE
 <b>B4</b>	REPLACEMENT	Averaged data for products (generic), or <b>detailed data</b> for products (from EPDs) related to the expected lifetime of the product
 <b>B5</b>	REFURBISHMENT	
 <b>B6</b>	ENERGY CONSUMPTION	Outside the scope of the embodied carbon
 <b>B7</b>	WATER CONSUMPTION	
 <b>C1</b>	DE-CONSTRUCTION/DEMOLITION	Averaged data for products (generic), or <b>detailed data</b> for products (from EPDs)
 <b>C2</b>	TRANSPORT TO DISPOSAL FACILITY	
 <b>C3</b>	WASTE PROCESSING	
 <b>C4</b>	DISPOSAL	
 <b>D</b>	POTENTIAL FOR REUSE/RECYCLING	

Figure 7: LCA modules vs. preferred data type for carbon footprint assessment



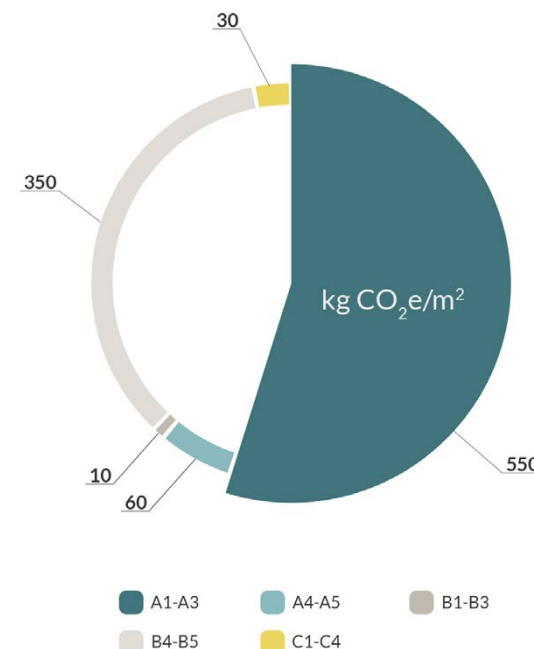
# COMMENTS AND RECOMMENDATIONS



- The largest share of the building's embodied carbon is accounted for by the modules related to the product stages **A1-A3**. Their share usually **exceeds 50%**.
- The modules that make up the construction stage **A4 and A5**, on average contribute **no more than 5% of the embodied carbon**, of which road transport of materials within the country accounts for about 1%. For sites requiring very extensive earthworks and temporary works, the values set for the A5 module will be higher. This topic is described in more detail later in the study.
- It can be assumed that in typical buildings, **the upfront carbon (modules A1-A5) represents around 60% of the embodied carbon**. This value will be lower for buildings of lightweight construction, where a larger share will be represented by elements to be replaced over the considered lifetime of the building, such as finishes and equipment, fixtures and fittings or the facade.
- For modules **B1-B3**, related to use, maintenance and repair, there are not many data and studies, but their **contribution to the whole building** is mostly estimated at 0.5-1%. Modules B1-B3 in the building life cycle have the largest share within the building installations group, due to leakage of refrigerants from the installations and maintenance or repair of equipment.
- Modules **B4 and B5**, i.e. replacement and refurbishment, account for a **large share of** the embodied carbon, as much as **35-40%**. In practice, module B5 can be considered the same as B4, which is also discussed in more detail later in the document.

- The end-of-life stage of the building, i.e. modules **C1-C4**, mostly contributes to the embodied carbon footprint at half the values specified for modules associated with the construction phase (A4-A5). This means that, in typical buildings, their total contribution can be taken as **2%**.
- In module **D**, additional benefits from the use of certain technologies or materials are sometimes identified, so that **negative values may appear in this module**. It is recommended that the values for module D are always **reported separately**, due to the high **uncertainty of accepted end-of-life scenarios**. Most often, the benefits relate to modular elements that can be used in new facilities without having to be recycled or due to the biogenic carbon content of the wood elements (unless CO<sub>2</sub> sequestration has previously been counted towards the product phase). This issue is discussed deeply later in the paper.

**To summarize the above approximations, the following (Figure 8) are the results for the various life cycle stages determined for a typical building with an embodied carbon footprint of 1,000 kgCO<sub>2</sub>e/m<sup>2</sup> of total floor area are shown below.**

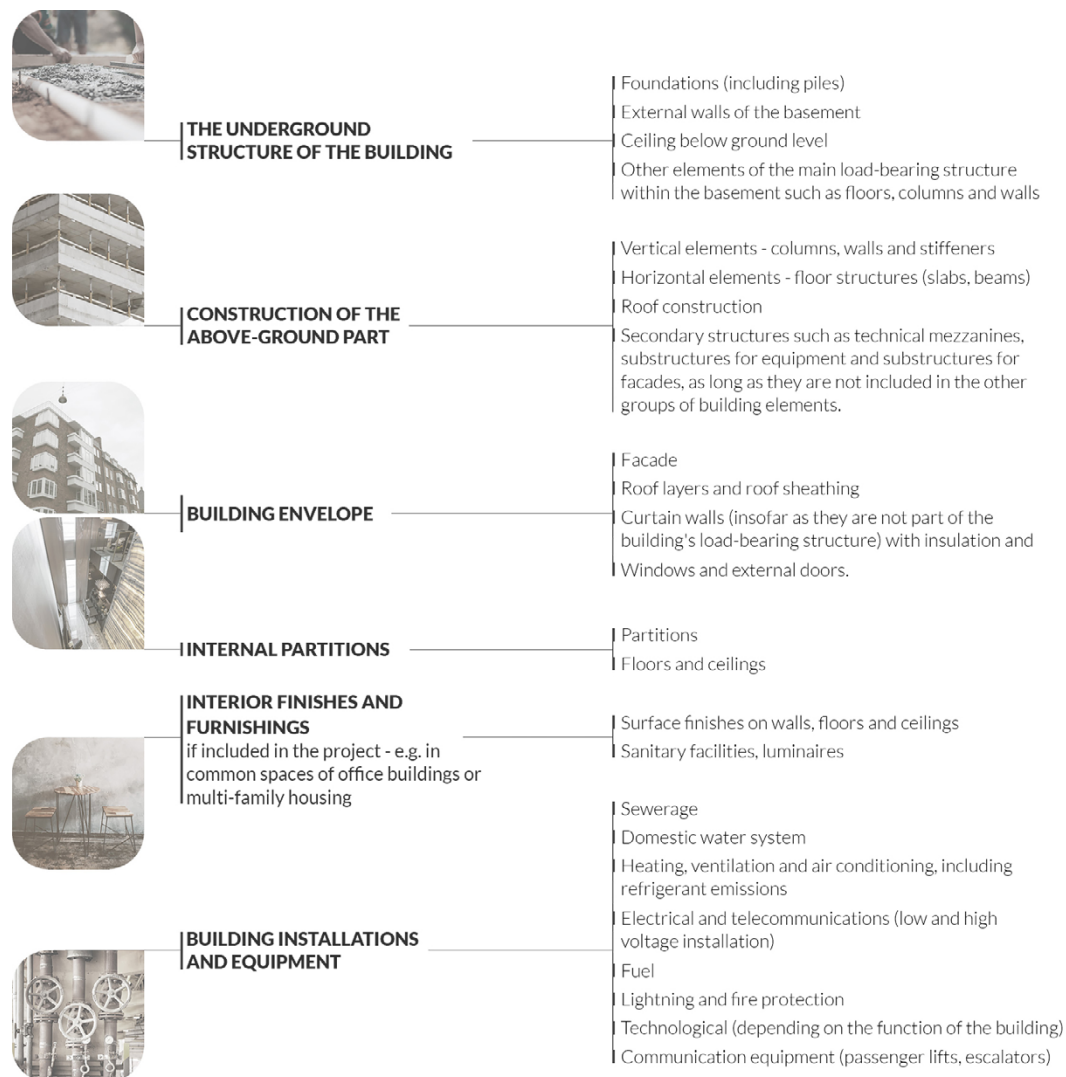


**Figure 8:** Various life cycle stages for a typical building (approximate results)

## Building elements

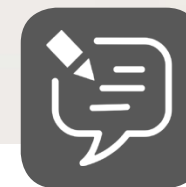
In the estimation of a building's total carbon footprint, it is necessary to take into account all building elements included in the analysed project that contribute significantly to the embodied carbon footprint. As a significance criterion, the mass can be taken as described earlier.

The building elements included in the LCA for the purpose of assessment of the carbon footprint should be:



An example of the contribution of individual groups to the carbon footprint of an entire building is illustrated in more detail within the case study.





# COMMENTS AND RECOMMENDATIONS

- An additional category of elements that may fall within the scope of a building lifecycle assessment are landscaping elements and external works, e.g.:
  - landscaping (paving, fencing, lighting, planting),
  - ancillary facilities (sheds, surface car parks),
  - external networks (connections, site drainage).

**If the carbon footprint of the works listed above is estimated, it is recommended that these results are presented separately from the results of the assessment of the building.**

- The carbon footprint associated with the temporary works listed below should be included in module A5 of the LCA.
  - site preparation (demolition of existing structures, levelling works, waste disposal),
  - specialised earthworks (excavation protection elements, soil reinforcement, excavation dewatering),
  - temporary structures erected solely for the purpose of constructing the facility and which cannot be reused after dismantling (e.g. reinforced concrete foundations for cranes).

Detailed data related to the technology of performing the construction, needed to assess the above scope, are mostly available only at the stage of implementation. At earlier stages of the project, these values can be estimated using general or aggregated data. Conducting accurate carbon footprint calculations at the construction stage, based on measured data, can be the basis for developing new, more precise calculation methods, so estimating the carbon footprint during or after construction can also contribute to decarbonising future developments.

## GUIDELINES FOR ASSESSMENT OF THE CARBON FOOTPRINT

The following section of the study provides detailed guidance for the carbon footprint calculations with a summary of the assumptions for each of the LCA modules.

### Product stage A1-A3

The product stage, comprising LCA modules A1-A3, is the most significant component of the building's LCA. The correct assessment of the values for this phase is crucial for the correctness of the whole life embodied carbon results. The idea of estimating the carbon footprint for these stages is very simple and comes down to adding up the emissions for each of the building's elements included in the analysis. The calculation procedure is shown in the figure below.

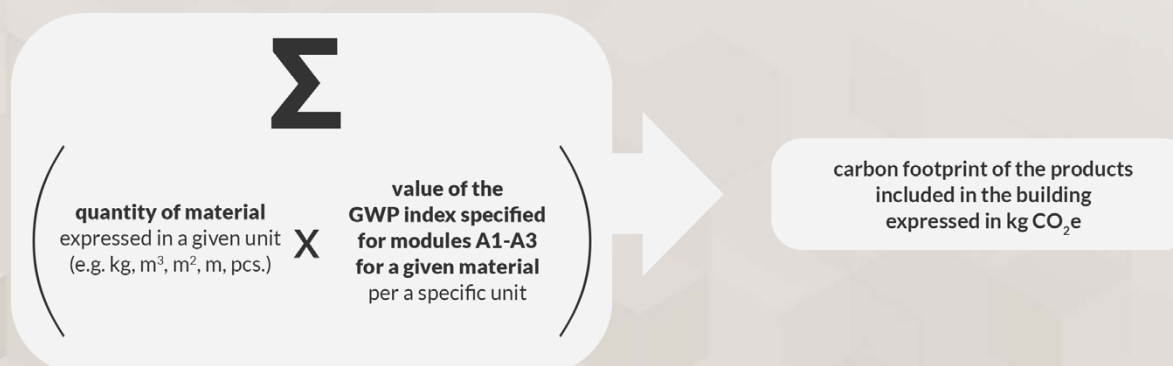
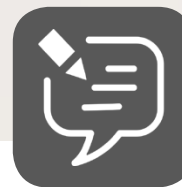


Figure 9: Emission calculation procedure for each building element

# COMMENTS AND RECOMMENDATIONS



- It is worth noting that the final result will be determined by the **correctness and completeness of the quantitative data** and the appropriate selection of generic values or EPDs for specific building components.
- In order to estimate the carbon footprint, data on products commonly available in the area where the construction will be located should be selected. Even so, the final origin of the product, unless it is derived from the design specification, may be different from the one assumed. Similar products differ in their carbon footprint values due to the origin of the raw materials, the technological processes used in their manufacture and the location of the factory and thus the energy mix that serves to power it.
- If material specifications do not impose restrictions on the GWP value of a product, it is recommended that materials with higher GWP values are selected. If no detailed data (from EPDs) for a given region for a product is available, nor generic data, the values determined for similar groups of products from other regions of the world may be used, but the differences in the technological process and product composition have to be taken into account. Any simplifications, approximations and calibrations of parameters used in the LCA should be described in the report and presented in a transparent manner.
- When developing the results for modules A1-A3, consideration should be given to whether the products used in the project contain biogenic carbon. The new EPDs, developed in accordance with EN 15804:2012+A2:2020, should distinguish the CO<sub>2</sub>e value associated with the biogenic carbon stored in the product, but older studies or some aggregated data may not contain this information. In the absence of specific data, it can be assumed that **1 kg of wood stores approximately 1.64 kgCO<sub>2</sub>e**. This value is based on EN 16449, assuming that 50% of the biomass is used for wood production and the rest is waste (roots, crown of the tree).
- When calculating the carbon footprint, if CO<sub>2</sub> sequestration is taken into account, the value of stored carbon should be distinguished in the results for modules A1-A5. In this case, modules C1-C4 should take into account the emissions associated with the release of previously stored carbon dioxide into the atmosphere. The figure below shows the phenomenon of carbon sequestration over the life cycle of a building.
- It is worth noting that timber, by taking sequestration into account, can have a negative carbon footprint over the life cycle of a building, but the final outcome is determined by the adopted end-of-life scenario of the element.

## Construction process stage A4-A5

Module A4 deals with the carbon emissions associated with transporting materials from the factory to the construction site.

The determination of transport-related carbon emissions (module A4 covers all transport stages from the last production site to the construction site, also taking into account stops at warehouses or distribution centres) requires the availability of the following data:

- the distance between the factory and the construction site (including handling and temporary storage areas),
- mode of transport with emission factor (kgCO<sub>2</sub>/kg/km),
- the weight of the material to be transported and the degree of filling of the means of transport.

At the project stage, the above-mentioned specific data is mostly not available and general data, defined for typical distances and means of transport used in the region under consideration, must be used. In the absence of more detailed data, the transport scenarios presented next can be adopted.

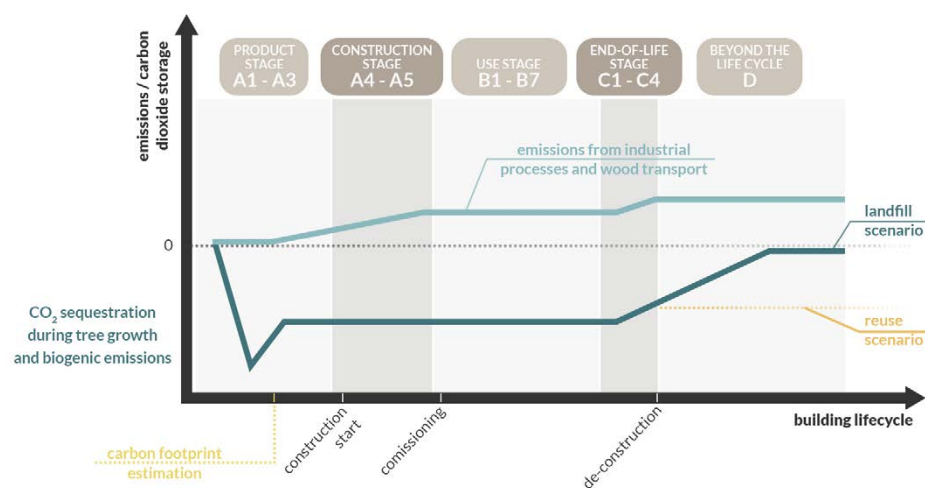


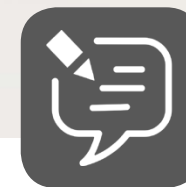
Figure 10: Carbon sequestration over the lifecycle of a building

PRODUCT TYPE	EXAMPLES OF PRODUCTS	MEAN OF TRANSPORT 1	DYSTANS (KM)	MEAN OF TRANSPORT 2	DISTANCE (KM)
LOCAL	Concrete mix, mortar	Road transport - motor vehicles of various types, e.g. concrete mixer truck up to 8m <sup>3</sup> , TIR with trailers up to 40t, van up to 9t.	60-110	-	-
NATIONAL	Blocks, reinforcement, prefabricated elements		110-560	-	-
EUROPEAN	Appliances, finishes, installations		560-1000	-	-
GLOBAL	Specialised equipment or unusual cladding requiring import from another continent		110-560	Transport by sea (e.g. container ship) or by air	10 000

Table 5: Adopted means of transport and distance for typical products and materials



# COMMENTS AND RECOMMENDATIONS



- Usually the A4 module does not contribute much to the embodied carbon - it can be estimated at 1%.
- Software dedicated to development of LCA of buildings, which has formulas for estimating the impact of transport based on the location of construction, can be helpful.
- Carbon emissions arising from the construction process should be included in the A5 module. Mostly, the emissions associated with the A5 module make a moderate but noticeable contribution to the overall balance for the embodied carbon, at 4-5%.
- Energy consumption for landscaping, construction work and the treatment and disposal of waste during the construction process should be taken into account. Using the information available in the EPDs, it is necessary to make sure that the assumptions about the installation method set out in the declaration coincide with the design.
- Module A5 should take into account the percentage of wasted products on site that generate waste and are not reusable. Based on the available publications, the following waste allowance values are proposed for the following materials (Table 6).
- Any temporary works, including facilities erected during construction, such as work platforms or trench shoring, should also be included in the emissions associated with module A5. If accurate data on temporary facilities are available at the design stage, the emissions associated with them should be counted in the same way as the emissions associated with the construction of the target facility for modules A1-A4. Temporary items that can be recovered and reused on other construction sites, such as some trench shoring, system formwork and scaffolding, should not be included in module A5.

- Module A5 should also take into account the transport from the construction site to the storage site of excavation spoil, possible harmful substances and debris remaining after demolition of the facilities. These emissions can be determined in a manner analogous to the methods described in module A4.

- In the absence of detailed data on the indirect emissions generated on site, general data can be used at the design stage - indicators determined for a typical construction site located in northern Europe, in a temperate climate.

**Table 6:** Proposed waste allowance values for different materials

TYPE OF MATERIAL	Waste allowance
Cast-in-place concrete, mortar, rebar, concrete pours, glass	5%
Precast concrete elements, steel and timber structures (beams, columns)	1%
Wood-based panels, wooden formwork (non-system) and temporary structures, stone cladding, paint coatings, corrosion and fire protection coatings	10%
Plasterboard cladding, masonry units	20%

**Table 7:** Typical indirect emissions values of the construction site in module A5

ADDITIONAL EMISSIONS ON SITE	Value per 1m <sup>2</sup> Pc of building
Average production of construction waste	5 kg/m <sup>2</sup>
Electricity consumption	37 kWh/m <sup>2</sup>
Diesel consumption	4,5 dm <sup>3</sup> /m <sup>2</sup>

## Use stage B1-B5

The carbon emissions associated with the use of a building, in terms of embodied carbon footprint, consist of the use, maintenance, repair, replacement and refurbishment of the components that make up the building. **Over the entire life cycle of a building, modules B1-B5 can collectively make a significant contribution, in the range of 30-50%.**

Of the modules B1-B5, the most important is usually module B4, which is related to the assumed service life of the individual building elements, after which they are completely replaced as a result of component usage, retrofit, or space redesign. Unless the project specifies products or equipment for which the manufacturer has provided a shorter useful lifetime, the values shown in Figure 12 should be adopted.

For the landscaping elements and external works, the useful life specified in Figure 11 can be assumed.



ELEMENT CATEGORY	EXTERNAL COMPONENT	EXPECTED SERVICE LIFE
 MEDIA	Connections, external networks, substations	30 years
 SITE DEVELOPMENT	Site drainage	30 years
	Pavements and paved areas (including off-road car parks)	25 years
	Fences, railings, walls	20 years

Figure 11: Expected service life for individual external elements







ELEMENT CATEGORY	BUILDING ELEMENT	OKRES UŻYTKOWANIA
 UNDERGROUND CONSTRUCTION OF THE BUILDING	Elements of the main load-bearing structure of the building in the underground part - foundations, columns, walls, bracing elements, floor and ceiling structure. Stairs, ramps, substructures for equipment and secondary structures, located in the basement.	min. 50 years (as for LCA)
 STRUCTURE OF THE OVERGROUND PART	Elements of the main load-bearing structure of the building in the above-ground part - columns, walls, bracing elements, ceiling and roof structure. Stairs, ramps, balconies, equipment and facade substructures and secondary structures located in the above-ground section and on the roof.	
 EXTERNAL PARTITIONS	Roof sheathing, thermal insulation and waterproofing	30 years
	Opaque facade elements, renderings, insulation, external doors	30 years
	Transparent facade elements, windows, skylights	35 years
	Paint coatings	10 years
 INTERNAL PARTITIONS	Non-load-bearing elements of the internal partition - insulation, screed, raised floors, suspended ceilings	30 years
	Partitions and curtain walls (non-structural)	30 years
 INTERIOR FINISHING AND FURNISHINGS	Internal plastering, carpets, ceramics, sanitary fittings, lifts	20 years
	Coatings, fittings	10 years
 INSTALLATIONS	Heat source, air preparation, ducting and distribution	20 years
	Cooling installation	15 years
	Hot and cold water distribution system, sewerage and drainage	25 years
	Fire extinguishing system and fuel system	30 years
	Electrical installation (equipment and distribution)	30 years
	Telecommunications installation, light fittings, sockets, switches, loudspeakers	15 years

Figure 12: Expected service life for individual building elements





## COMMENTS AND RECOMMENDATIONS

- The assumed **lifetime of the building elements has a significant impact on the results of the life cycle stages calculations.** The greater the number of replacement and refurbishment cycles required, the greater the impact on the embodied carbon. This is particularly true for the refurbishment of the building's internal systems, including cabling and piping, as well as finishing materials such as paint.
- Module B1 covers CO<sub>2</sub> emissions from building materials and equipment over the lifetime of the building. **Refrigerants can make a particularly large contribution to module B1 emissions.**
- Module B2 refers to the CO<sub>2</sub> associated with maintenance of: the roof, external walls, windows and external doors, finishes and installations.
- Module B3 includes CO<sub>2</sub> emissions from all activities related to the repair of building elements, including the products used. For many product groups, there is currently no data on the emissions covered by modules B1-B3, so the figures presented in the LCA for these modules may be underestimated. Therefore, unless more accurate data is available, it **is recommended to assume the emissions associated with B1-B3 modules on the basis of an indicator related to the total surface area of the building of about 5-10kg CO<sub>2</sub>e/m<sup>2</sup>.**
- Module B5 is related to the planned change of use of the site for future functions and involves a significant reconstruction of the building or part of it. **In the absence of a scenario of specific activities for module B5, it is recommended not to include this module.**

## Use stage B6-B7

Module B6 should consider the carbon emissions resulting from the energy consumption of the systems integrated into the building over its lifetime. These relate to the energy from heat or electricity consumed by the following systems: ventilation, heating, cooling, hot water preparation and lighting. When assessing buildings where renewable energy sources have been designed, it should be shown how the energy will be used. In the absence of information, it should be assumed that the energy generated on site first meets the needs of the building and is then exported to the grid. In the calculation of CO<sub>2</sub> emissions in module B6, it is recommended to rely on the results of building energy modelling, dynamic thermal simulations or energy calculations.

Module B7, on the other hand, refers to water consumption and can be omitted in the LCA carried out for the purpose of estimating the carbon footprint.



## COMMENTS AND RECOMMENDATIONS

- Emissions associated with module B6 are not included in the building carbon footprint and can be presented separately when determining the operational carbon of a building. They represent a significant or even dominant part of the total carbon footprint of a building, especially in existing buildings.
- As the energy efficiency of facilities improves and the grid decarbonises, the contribution of the operational carbon to the building lifecycle will decrease.
- The results for module B6, depending on the type of building and the scenarios adopted for the country's energy mix, are discussed in more detail in the case study presented further in the report.

## End of life stage C1-C4

The End-of-life stage of a building starts when it is no longer in use. **For the purpose of assessing the life cycle of a typical building, it is recommended to assume a 50-year lifespan.**

Modules C1-C4 take into account carbon emissions from demolition activities and the transport, processing and disposal of materials at the end of a facility's life. It is worth noting that the accuracy of the CO<sub>2</sub> data associated with the end-of-life stage

of a building is very low, as it refers to a rather distant future and requires many assumptions. However, the high uncertainty in the results for the end-of-life stage does not significantly affect the results of the building carbon footprint calculations, as the **contribution of C1-C4 modules to the embodied carbon is mostly small - at the level of a few percent.**



## COMMENTS AND RECOMMENDATIONS

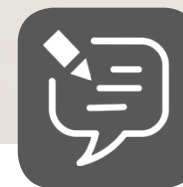
- Module C1 includes the CO<sub>2</sub> emissions associated with the de-construction and demolition of the building. In the absence of more precise data, it is possible to use an average emission factor of 3.4 kgCO<sub>2</sub> e/m<sup>2</sup> of the total building floor area.
- Module C2 should take into account the CO<sub>2</sub> emissions resulting from waste transport. Its value is mainly related to the distance of the landfill site from the building location. **For road transport over a distance of 50 km, an average emission value of 0.005 kgCO<sub>2</sub>e can be assumed for each kilogram of waste transported.**
- Carbon emissions associated with the reuse or recycling of materials at the end of the building life should be reported in module C3, while CO<sub>2</sub> emissions resulting from the disposal of materials that are not recovered for reuse or recycling should be reported in module C4. **Unless detailed EPD data are available, a proxy covering module C3 and C4 of 0.013 kgCO<sub>2</sub>e/kg can be adopted.**
- The share of emissions associated with C3-C4 modules will be higher if a lot of wood elements are used in the building (especially in the building structure). In this case, the biogenic carbon emissions stored in the wooden elements over the lifetime of the building should be included in the C3 and C4 modules.

**Carbon sequestration** is an important element of decarbonisation of construction, so **biogenic carbon emissions should be reported separately** to highlight this fact. Where justified, supported by design solutions that favour the circular economy, an end-of-life scenario for timber elements can be adopted that assumes no or partially reduced emissions, due to its reuse - the transfer of biogenic carbon to the new building. Demolition wood can also be recycled and used as raw material for wood-based products or as animal bedding. Such a scenario also allows at least a partial transfer of biogenic carbon dioxide to the new facility, although it also involves some additional energy expenditure due to the processing of the element. Another typical end-of-life scenario for wooden elements is to burn them to generate energy. In this case, biogenic carbon dioxide is released into the atmosphere, but on the other hand, energy is gained, the production of which in other ways would most often also involve greenhouse gas emissions. The potential energy recovery from the incineration of organic waste should be reported in module D. The least desirable end-of-life scenario for wooden elements is their disposal in landfills, where they will emit methane and carbon dioxide without any additional benefits.

For example, in the UK, it is estimated that about 55% of demolition wood is recycled, about 44% is incinerated, while only 1% goes to landfill. It is worth noting that modern landfills use techniques to capture gases from decomposing organic matter.

**For typical end-of-life scenarios for wood, the emission value in modules C3-C4 can be assumed to be 1.64 kgCO<sub>2</sub>e/kg wood,** thus the same as the biogenic carbon value assumed in modules A1-A3.





## Module D beyond the lifecycle

The D-module covers the potential environmental loads or benefits of reusing building components or recovering energy, beyond the lifecycle of the building. This module **can be a measure of how well a building meets the objectives of the circular economy**, which is one of the key routes to decarbonising construction. Estimating the value of the module D requires determining the amount of emissions that will be avoided in the future due to the reuse of a component. A precise determination of this value is therefore practically impossible, as we do not know the emission values associated with modu-

les A1-A3 for products that will be manufactured in 50 years' time, and there is no clear basis for determining the emissions associated with energy generation over such a distant time horizon. Therefore, the values for module D (e.g. determined from detailed EPDs) should be reported separately, and the main focus should be on describing the end-of-life scenario adopted in relation to design assumptions that promote circularity and maximise the recycling potential of the materials used.

## COMMENTS AND RECOMMENDATIONS

- In order to maximise the benefits covered by module D, the aim should be to ensure that the elements of the designed building can be reused to the greatest extent possible and recycled only when necessary.

## VERIFICATION OF THE OBTAINED RESULTS

It is recommended that the results of the LCA analyses of a building for the purpose of estimating the carbon footprint are subject to verification within the institution developing it or an external body. Therefore, both results and assumptions should be presented in an unambiguous and transparent manner. When verifying the assessment, attention should be paid to:

the scope of the analysis, in terms of building components and LCA stages,

sources of quantitative and qualitative (material) data used in the analysis,

compliance with EN 15804 standard for product data,

consistency of assumptions for whole building and component scenarios - lifetime of individual building elements and technical systems.

If a verification protocol is being developed, it should outline the qualifications of the verifier.

For a quick check of the results during the LCA development, the results obtained for the individual LCA modules and building elements can be continuously compared to the values obtained for other facilities for which a carbon footprint has been estimated. In case of significant deviations from the reference values, attention should be paid to the correctness of the qualitative and quantitative data adopted for the analysis.



# REPORTING FORM AND SCOPE

Environmental performance, based on the LCA analysis, is one of the elements of a contribution to sustainable development, so transparency and verifiability of the data used are fundamental to the assessment. The results of the assessment should be presented in detail and transparently so that the quality of the information can be assessed.

The recommendations presented in this chapter for the information contained in the building carbon footprint estimation report have been developed to meet the recommendations of EN 15804 and the European Level(s) system.

## GENERAL INFORMATION

The LCA analysis report should include the following general information:

\_\_\_\_\_ commissioning party data

\_\_\_\_\_ LCA analysis author data

\_\_\_\_\_ verifier data (if any)

\_\_\_\_\_ stage of analysis to be carried out: 1 or 2 or 3

\_\_\_\_\_ building type

\_\_\_\_\_ the assumptions made and data  
included in the calculations  
of modules A1-A5, B1-B5, C1-C4

\_\_\_\_\_ accepted deviations  
from the presented building LCA method



## BUILDING INFORMATION

An important part of the LCA analysis of a building is the preparation of a site description to ensure that the environmental performance of buildings with similar parameters can be compared.

The minimum scope of the building description refers to the location of the project and the climate in which it is located, the type and age of the building, the expected use and the special features of the building should also be reported. The required information needed for the description is summarised below.

### A

#### LOCATION AND CLIMATE

**Country and region** where the building is located.

**Climate zone in which the building is located** - heating and cooling degree days.

Heating and cooling degree days values for Poland based on climate data used for building energy performance. Values for the EU can be obtained using the [PVGIS](#) tool (photovoltaic geographical information system - generator of a typical meteorological year).

In the EU, it is required to define the climate zone in which the building is located. The climate zone is defined on the basis of heating and cooling degree days. Table 8 shows the climate zones and the corresponding ranges of heating and cooling degree days.

### B

#### BUILDING TYPE AND AGE

**Building type** - the description should include the type of building according to its purpose. The analysis can include office buildings, industrial buildings, commercial and retail buildings, residential buildings, educational health care buildings, etc.

**Year of construction** - the anticipated year in which construction will start and the year in which it will be put into use.

### C

#### BUILDING USE

**Anticipated use** - this refers to the number of people using the facility and the hours of operation of the building.

**Number of users of the building** - estimated number of residents, employees or spectators in the case of e.g. a theatre.

**Life expectancy** - LCA should be carried out for a period of 50 years, but the lifetime of the facility may differ from the reference study period.

### D

#### BODY OF THE BUILDING AND SPECIAL FEATURES

**Form and special features of the building** - when describing the analysed building, the form of the building and special features such as double facade, additional shading, etc. should be provided. In addition, information may be provided on the arrangement of usable areas in the building (for example, office spaces may be located on floors 1- 10, while the service area is located on the ground floor).

**Total surface area of a building** - the surface area of all the floors of a building, limited by the external outline of the building measured at floor level, including plastering, balustrades and cladding. The total area should be given to one decimal place, in the reference unit which is the square metre (m<sup>2</sup>).

**Range of building elements subject to LCA** - if any building elements have been deliberately omitted, these should also be indicated in the description.

**Table 8:** Climatic zones for individual degree day ranges

CLIMATE ZONE	PARAMETERS		Representative cities
	HEATING DEGREE DAYS	COOLING DEGREE DAYS	
ZONE 1	<1 500	>1 200	Athens - Larnaca - Luga - Catania - Seville - Palermo
ZONE 2	<1 500	>800-1 200	Lisbon - Madrid - Marseille - Rome
ZONE 3	>1 500-3 000	400-800	Bratislava - Budapest - Ljubljana - Milan - Vienna
ZONE 4	>1 500-3 000	<400	Amsterdam - Berlin - Brussels - Copenhagen - Dublin - London - Mâcon - Nancy - Paris - Prague - Warsaw
ZONE 5	>3 000	<400	Helsinki - Riga - Stockholm - Gdansk - Tovarene



## PRESENTATION AND DEMONSTRATION OF RESULTS

### Breakdown by building element

Depending on the complexity of the project and the detail of the data, it is advisable to present the results broken down into the main categories of building elements and works. A uniform breakdown and classification of the different building elements will help in comparing and interpreting the results and presenting conclusions. Various building element classification systems currently exist, but most distinguish the categories shown in the figure below.

For each category of elements, further subcategories are often also defined, e.g. foundations, walls, columns, ceilings, floors, external doors, internal doors, sanitary and electrical installations, etc. The Level(s) system additionally introduces a general classification of the elements of the building frame and shell (shell and core) and further distinguishes external works. A very detailed categorisation of the results into nar-

row groups can be helpful for comparative analyses of individual components, but when estimating the carbon footprint of an entire building, too many categories and subcategories negatively affect the clarity of the results, so it is recommended that the following classification is used by default, as shown in the figure below.



#### THE UNDERGROUND STRUCTURE OF THE BUILDING

The load-bearing structure of the building located below ground level - including foundation piles, external partitions in contact with the ground, and floors, columns and walls within the underground storeys, and stairs and ramps



#### CONSTRUCTION OF THE OVERGROUND PART

The load-bearing structure of the building located above ground level, the roof structure, balconies, mezzanines, stairs, ramps and secondary structures such as substructures for facades



#### EXTERNAL PARTITIONS

The building facade, external windows and doors, roof sheathing and curtain walls, unless classified as part of the structure of the above-ground part



#### INTERNAL PARTITIONS

Partition walls (unless classified as construction), screeding, raised floors, suspended ceilings, lightweight construction



#### INTERIOR FINISHING AND FURNISHINGS

Top layers of floors, ceilings and walls, e.g. carpets, ceramics, paintwork and equipment in common parts of the building, such as lifts, white goods



#### INSTALLATIONS

Building installations, including sanitary, electrical, teletechnical - their distribution and the equipment ensuring their operation

### ADDITIONAL ELEMENT CATEGORIES



#### EXTERNAL NETWORKS (OPTIONAL)

Hardened surfaces, off-road car parks, drainage



#### EXTERNAL NETWORKS (OPTIONAL)

Hardened surfaces, off-road car parks, drainage



#### TEMPORARY WORKS IN A5

Trench protection elements, crane foundations

Figure 13: Default classification of elements

## Standardisation and development of results

The results of the analysis should be presented in tabular form by building element and LCA phase. A model table is provided in Chapter 3.

For the purpose of comparing buildings with each other and in order to be able to assess them in terms of their life cycle GHG intensity, the results of the analysis obtained should be related to the total surface area of the building (Pc), expressed in m<sup>2</sup>.

### Total surface area of the building:

- It is the sum of the total areas of all storeys of the building. A storey is to be considered as all floors that are wholly or partly below ground level, storeys above ground level, attics, terraces, roof terraces, technical storeys and storage storeys.
- It is measured at floor level, following the outer contour of the building. Roof areas, unless permanently covered, are not included in the total area of the building, with the result that low-rise buildings will have a higher carbon footprint per their total area.

For buildings undergoing renovation, conversion and reconstruction, the carbon footprint of the works carried out should be related to the total surface area of that part of the building for which a change in function, an increase in energy efficiency or an improvement in other parameters occurs as a result of the works under consideration.

For some assessment schemes, it may be required to relate the results of the analysis to other parameters characterising the building, such as its volume, useful floor area, etc. In that case, the analysis should be carried out according to this methodology and the final results should be related to the indicated value. In that case, the analysis should be carried out in accordance with this methodology and the final results should be additionally related to the indicated volume.







# CHAPTER 3

## CASE STUDY



## AIM AND OBJECTIVES

To illustrate the methodology presented in the report for estimating the building carbon footprint, a case study was carried out for a model building, with three different functional or material options:

- **option 1: office building in reinforced concrete monolithic technology,**
- **option 2: office building (as option 1) in reinforced concrete technology with wood-concrete composite floors,**
- **option 3: multi-family residential building with reinforced concrete and brick technology.**

In the analysed scenarios, the LCA analysis was carried out in accordance with the methodology proposed in the previous chapter, taking into account the building life cycle modules A1-A5, B1-B5 and C1-C4. In addition, CO<sub>2</sub> emissions related to module B6 (energy consumption) were calculated, estimated for three different scenarios of decarbonisation of the power and heating network in Poland.

Estimates of the structural elements and building facade for the LCA analysis were derived from a 3D BIM model of the building. Information on the surface area of finishes, building envelope, equipment and installations and appliances in the building was taken from averaged data from analyses carried out for buildings with the same function and similar surface area.

The table below summarises the data sources used in the analysis.

**Table 9:** Sources of emissions data for different phases of the building life cycle

BUILDING LIFE CYCLE PHASES COVERED BY THE ASSESSMENT	DATA SOURCES
A1 - Extraction and production of raw materials	Databases with environmental statements and generic data available through the OneClick LCA
A2 - Transport to the production site	
A3 - Product manufacturing	
A4 - Transport to site	Calculated as part of the OneClick LCA, based on the building data entered and the scenarios adopted
A5 - Construction and installation process	
B1 - Use	Calculated on the basis of overall indicator values
B2 - Maintenance	
B3 - Repair	
B4 - Replacement	Calculated as part of the OneClick LCA, based on the building data entered and the scenarios adopted
B5 - Refurbishment	Included as part of module B4
C1 - De-construction/demolition	Calculated as part of the OneClick LCA, based on the building data entered and the scenarios adopted
C2 - Transport to disposal facility	
C3 - Processing waste for reuse/recycling	
C4 - Disposal	

### Assumptions:

- Quantitative data for building components, materials and equipment, were entered into OneClick LCA software, where EPDs or generic data were assigned for each item, from the options available. In the absence of an available EPD or generic data for a specific building component, data for materials or components with similar performance were selected. Where necessary, calibration factors were used to approximate the target GWP value using an EPD developed for a product

with different parameters. This approach was required especially for appliances where their kWh power was considered as the guiding parameter. Installation components, such as pipes or ductwork, consisting of multiple items with different dimensions (diameters or cross-sections), were converted to the total weight of the individual materials, including allowances, for e.g. slings, valves, dampers etc.

- To calculate the emission values associated with modules A4-A5 and B1-B5, assumptions along the lines outlined in the previous chapter of this study were used.
- Components with a negligible impact on the carbon footprint value were excluded from the LCA. It can be assumed that, similar to the emissions determined in EPDs, according to EN 15804, the total share of exclusions does not exceed 5% of the whole building.

## DESCRIPTION OF THE MODEL BUILDING

A simplified model of the building on a rectangular plan was developed for the analysis.

The building was subjected to LCA in three scenarios, differing in material solutions or function. In each case, the area of the building, the number of storeys and the structural scheme were unchanged.

To simplify the analysis, the support arrangement of the building

remained the same in each of the building scenarios analysed. As the floor spans of the modelled reinforced concrete building in the office and residential scenarios are identical, the embodied carbon value is also at a very similar level. It is worth noting that for the real-world examples of residential buildings, due to the typically smaller floor spans than in office buildings and the lower imposed loads, a lower carbon footprint value of the structure per area can be expected than that

presented in the analysis below. However, this simplification does not have a significant impact on the comparison between the operational and embodied carbon, which was the main objective of the case study. Figure 14 and Figure 15 show 3D images of the modelled building and a schematic cross-section through the building with its basic parameters.

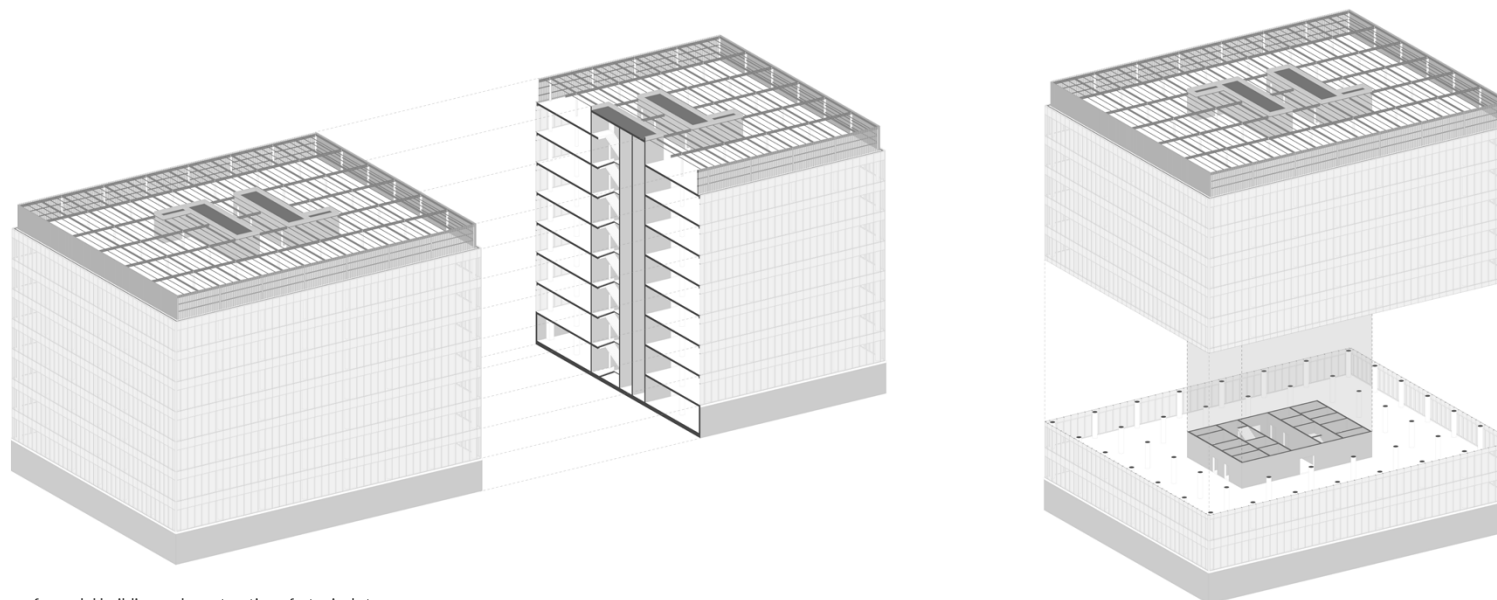


Figure 14: 3D images of a model building and construction of a typical storey

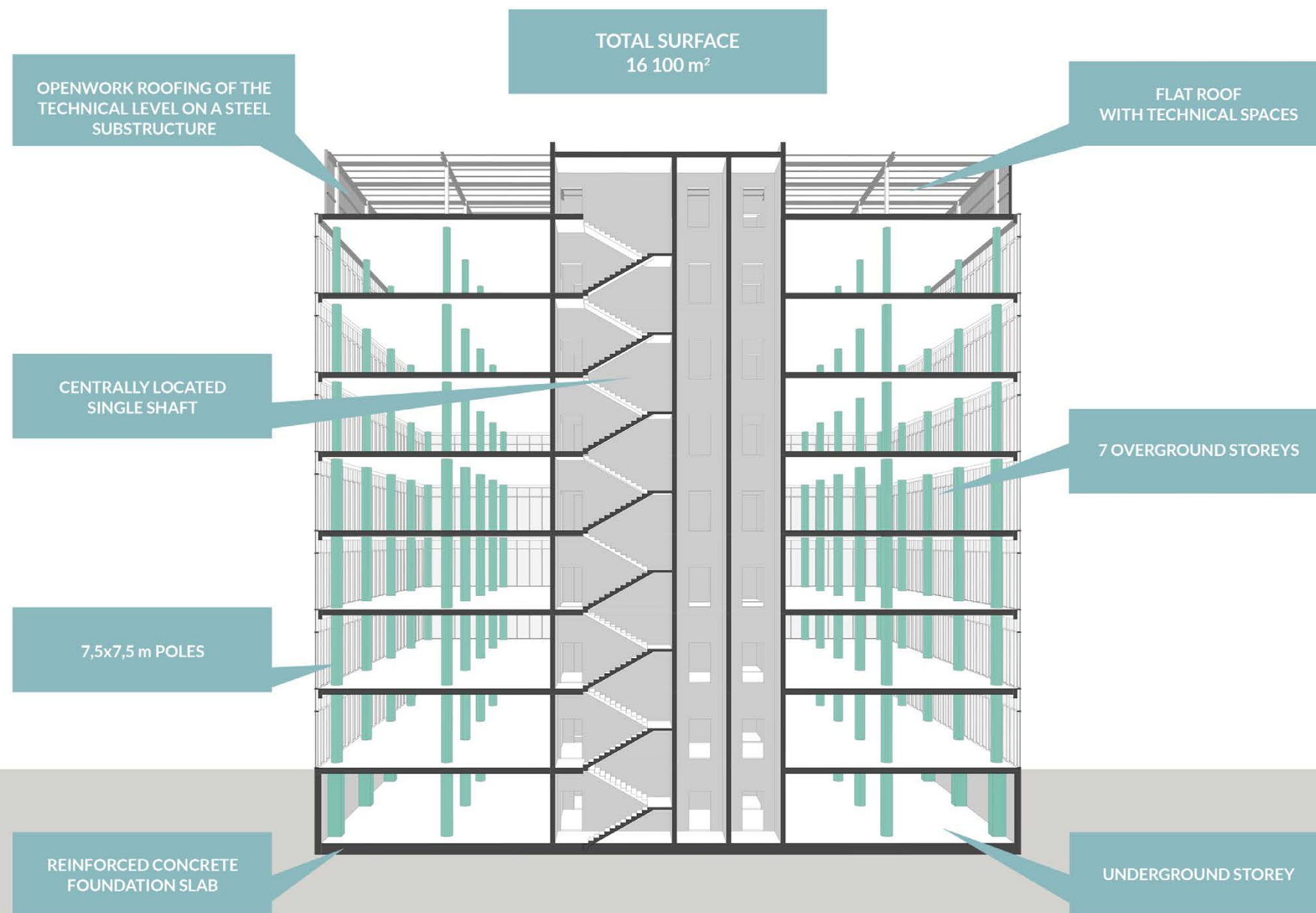


Figure 15: Diagram of a model building



The key differences between the model building options are outlined below.

## OPTION 1

- Office building with a technical storey in the basement and on the roof.
- Monolithic reinforced concrete structure. Slab-and-column structure with a core to ensure the stability of the building. The entire load-bearing structure of the building is constructed using reinforced concrete monolithic technology.
- The facade of the building is a glass curtain wall with aluminium profiles attached to the edges of the panels. The internal partitioning is mainly limited to lightweight construction in the common area of the building. A typical floor has suspended ceilings and raised floors, designed for loads as for office spaces.
- The building has the following installations and systems: central heating system, mechanical ventilation with heat recovery, cooling, plumbing, sprinkler, electrical and tele-technical systems.

## OPTION 2

- Office building, as in Option 1, with the exception of the overground storey ceiling construction structure, which in this scenario was constructed using **composite, timber-concrete technology, which reduced the use of concrete and reinforcing steel within the** overground storey structure by over 60% and introduced a significant amount of timber elements, in the form of cross-laminated timber (CLT) panels.
- For the purposes of the analysis, some of the partition walls were also replaced with CLT panel walls.
- Facade and installation solutions unchanged from Option 1.

## OPTION 3

- Multi-family residential building, with a technical storey in the basement and on the flat roof. Structural solutions as for Option 1.
- The facade of the building consists of masonry curtain walls, finished using the 'light-wet' method. Floating floors were used instead of raised floors.
- Installation solutions as for Option 1, with the following differences:
  - no refrigeration or sprinkler system,
  - revised mechanical ventilation system with heat recovery.

Each of the above building options has been developed for identical assumptions on the building elements to be assessed, consistent with the guidance provided in previous chapter.



The figure below provides information on the range of elements considered in the carbon footprint estimation.

For Options 1 and 3 of the model building, due to the material solutions adopted, the amount of biogenic carbon stored in the components is at a very low level and is mainly associated with finishes with a relatively short estimated lifetime. Therefore, the emission values associated with carbon sequestration in these options have been omitted for clarity of results. **GWP-biogenic** values are **only presented for Option 2**, in which part of the floor structure and vertical partitions are foreseen to be made of wooden elements. The GWP-biogenic value was reported separately from GWP-fossil and shown as negative in the charts within modules A1-A3, as the production cycle of the wood elements also includes the growth period of the tree, during which photosynthesis does not emit carbon dioxide, but captures it. This phenomenon is described and illustrated in the previous chapter of this report.

As part of the case study, the emission values associated with module D were not assessed. The model building did not include building components for reuse. For module D in this case study, the benefits primarily include the potential to recycle metal scrap used in industry. Rubble from the demolition of concrete and masonry structures also has the potential to be recycled - once sorted and crushed (down-cycling) it can be used as road sub-base or trench backfill.

	<b>THE UNDERGROUND STRUCTURE OF THE BUILDING</b>	Foundations, columns, walls, bracing elements, floor and ceiling construction, prefabricated stairs, ramps.
	<b>CONSTRUCTION OF THE OVERGROUND PART</b>	Columns, walls, bracing elements, floor and ceiling construction. Prefabricated stairs. <b>Exclusions:</b> foundations for equipment and secondary steel structures.
	<b>EXTERNAL PARTITIONS</b>	Roof sheathing, thermal and waterproofing insulation, opaque facade elements, render, thermal and acoustic insulation, external doors, translucent facade elements.
	<b>INTERNAL PARTITIONS</b>	System plaster walls, screed, suspended ceilings, raised floors. <b>Exclusions:</b> interior design elements not covered by the <i>shell and core</i> project.
	<b>INTERIOR FINISHING AND FURNISHINGS</b>	Paint coatings, ceramic tiles, internal doors. <b>Exclusions:</b> furniture, furnishings in the office and service area and other interior design elements beyond the scope of ' <i>shell and core</i> '.
	<b>INSTALLATIONS</b>	Light fittings, sockets, emergency lighting fittings, lighting controls and monitors, cable routes. Smoke and flow detectors, emergency boxes, control panels, intercoms, surveillance cameras, card readers, illuminated escape signs. Air handling units, exhaust fans, cooling towers, chillers, heat exchangers, chilled beams, heat pumps, steel heating and cooling system pipes, sprinkler system, drainage pipes, circulation pumps, separators. <b>Exclusions:</b> interior design elements not covered by the ' <i>shell and core</i> ' project.

Figure 16: Building elements to be assessed and exemptions

## RESULTS OF THE CARBON FOOTPRINT ESTIMATION

The following section presents the results of the carbon footprint estimation for each of the three model building options. The sections of the analysis considering: the embodied carbon

in modules A1-A5, B1-B5, C1-C4 and the operational carbon B6 are extracted.

### Upfront carbon footprint

The following tables (10, 11, 12) present the results of the carbon footprint estimation for the scenarios discussed, for each of the life cycle phases separately and collectively for the upfront embodied and embodied in use phase and end-of-life phase carbon footprint. Six basic categories of building elements were distinguished: underground building structure, structure of the above-ground part, external envelope, internal envelope, interior finishes with equipment, installations. In addition, allowances for construction-related emissions and emissions related to the use, maintenance and repair of the building were taken into account on the basis of indicator values.

Note the table of results for Option 2 of the building design, which shows a high proportion of biogenic carbon dioxide. According to the current PN-EN 15804+A2:2020-03 standard describing how to prepare environmental product declarations, the GWP value of **a product cannot be reduced by the amount of biogenic carbon dioxide stored in it**, but this value can be reported separately if it represents at least 5% of the GWP of the product.

**Table 10:** Results for Option 1 office building in monolithic reinforced concrete technology

LCA MODULES	A1-A3	A4	A5	B1-B3	B4	C1-C4	A1-A5 upfront carbon footprint	A-C built-in carbon footprint
BUILDING ELEMENT CATEGORIES:	kgCO <sub>2</sub> e							
Underground structure of the building	1 185 288	56 809	193 499	-	-	82 012	1 316 492	1 398 503
Construction of the overground part	2 422 280	88 368	323 459	-	-	36 222	2 635 009	2 671 231
External partitions	739 166	4 554	29 817	22 158	763 616	19 896	755 184	1 538 696
Internal partitions	592 781	5 773	113 784	15 928	548 921	10 658	642 300	1 201 880
Interior finishing and furnishings	573 511	11 880	141 875	29 422	1 013 967	25 220	639 939	1 679 126
Installations	1 424 918	5 149	84 906	93 492	3 221 955	5 428	1 462 711	4 690 094
Aggregate carbon footprint of elements in categories 1 to 6	6 937 944	172 533	887 340	161 000	5 548 459	179 436	<b>7 997 817</b>	<b>13 886 712</b>
Total area of the building: 16 100 m <sup>2</sup>	kgCO <sub>2</sub> e/m <sup>2</sup>							
Elements 1-6 per Pc	430.9	10.7	55.1	10.0	344.6	11.1	496.8	862.5



**Table 11:** Results for Option 2 - office building (as Scenario 1) in reinforced concrete technology with wood-concrete composite floors

LCA MODULES	A1-A3	A4	A5	B1-B3	B4	C1-C4	A1-A5 upfront carbon footprint	A-C built-in carbon footprint
BUILDING ELEMENT CATEGORIES:	kgCO <sub>2</sub> e							
Underground structure of the building	1 046 565	57 060	213 807	-	-	88 425	1 317 432	1 405 857
Construction of the overground part	1 822 614	41 179	180 840	-	-	176 745	2 044 633	2 221 378
External partitions	739 166	4 554	35 724	22 216	763 616	19 896	779 444	1 585 172
Internal partitions	461 023	4 507	102 586	12 262	421 497	11 779	568 116	1 013 654
Interior finishing and furnishings	649 548	13 839	169 594	32 787	1 126 976	26 493	832 981	2 019 236
Installations	1 424 918	5 149	101 726	93 735	3 221 955	5 428	1 531 793	4 852 911
Aggregate carbon footprint of elements in categories 1 to 6	6 143 834	126 288	804 276	161 000	5 534 044	328 766	7 074 398	13 098 208
Elements 1-6 per Pc	381.6	7.8	50.0		343.7	20.4	439.4	813.6
CO <sub>2</sub> sequestration (GWP-bio)	-2 427 641					**		

**Table 12:** Results for Option 3 multi-family residential building with reinforced concrete and masonry technology

LCA MODULES	A1-A3	A4	A5	B1-B3	B4	C1-C4	A1-A5 upfront carbon footprint	A-C built-in carbon footprint
BUILDING ELEMENT CATEGORIES:	kgCO <sub>2</sub> e							
Underground structure of the building	1 020 743	55 857	147 385	-	-	81 760	1 223 985	1 305 745
Construction of the overground part	2 422 280	88 368	277 262	-	-	36 222	2 787 910	2 824 132
External partitions	1 599 442	20 133	223 988	7 046	191 594	57 594	1 843 563	2 099 797
Internal partitions	910 901	10 641	138 933	34 300	932 726	11 184	1 060 475	2 038 685
Interior finishing and furnishings	569 879	11 857	120 796	43 011	1 169 597	25 213	702 532	1 940 353
Installations	935 275	10 883	82 050	76 643	2 084 175	24 469	1 028 208	3 213 495
Aggregate carbon footprint of elements in categories 1 to 6	7 458 520	197 739	990 415	161 000	4 378 092	236 422	8 646 674	13 422 208
Total area of the building: 16 100 m <sup>2</sup>	kgCO <sub>2</sub> e/m <sup>2</sup>							
Elements 1-6 per Pc	463.3	12.3	61.5		271.9	14.7	537.1	833.7



\* for the sake of simplicity, an end-of-life scenario assumed that 100% of the timber elements, binding biogenic carbon in their structure, will be reused or recycled without releasing carbon into the atmosphere.

These results are also presented in graphs for easier interpretation. Figures 17a, 17b and 17c show the contribution of each stage of the building lifecycle in the embodied carbon for all options.

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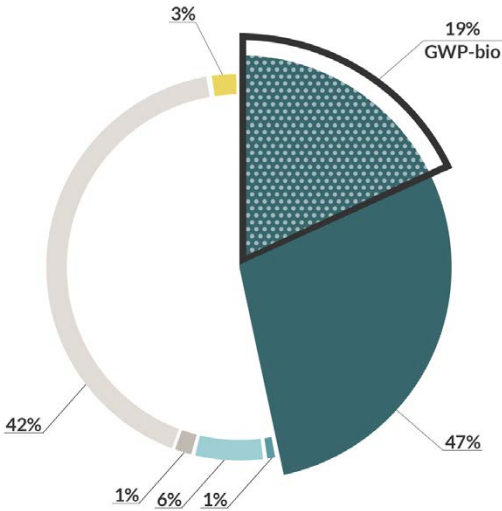
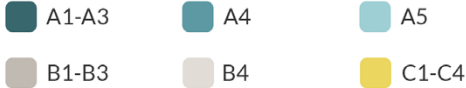


Figure 17b: Contribution of different phases of the building life cycle in the embodied carbon - Option 2

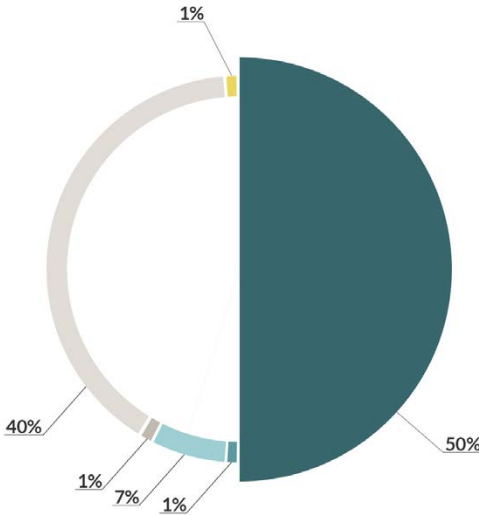


Figure 17a: Contribution of different phases of the building life cycle in the embodied carbon - Option 1

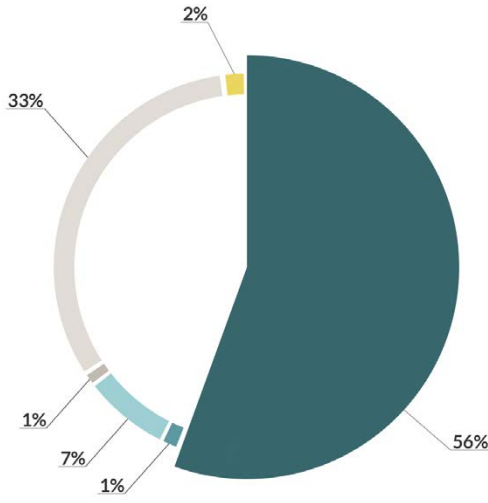


Figure 17c: Contribution of different phases of the building life cycle in the embodied carbon - Option 3

In Option 1 of the analysed building, modules A1-A5, which make up the upfront carbon, contribute to 57% of the embodied carbon. Modules B1-B5 also have a significant share, due to the large number of building installations subject to replacement over a 15-25 year period. A slightly lower contribution of stage A can be observed in Option 2, in which the reinforced concrete floor structure is replaced by monolithic construction with wood-concrete composite floors.

By temporarily storing biogenic carbon in building components (Option 2), the rate of greenhouse gas emissions can be slowed down, thus helping to combat climate change. Figure 18 shows how a large part of the emissions in modules A1-A3, associated with GWP-fossil, can be offset by biogenic carbon sequestration, shown by GWP-bio.

LEGEND:

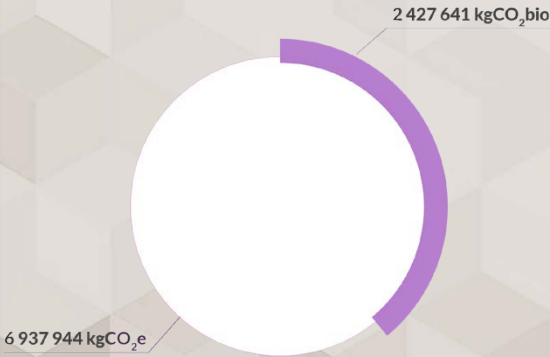
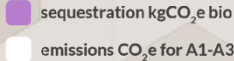


Figure 18: Contribution of CO<sub>2</sub> sequestration in modules A1-A3 (Scenario 2)

For the case considered (Option 2), up to 40% of the GWP-fossil value can be offset by GWP-bio, considering only the A1-A3 modules. At the scale of the embodied carbon over the entire lifecycle of the building, the percentage of GWP-bio, as shown in the graph below, is 19%.

In contrast, the results for Option 3 shown in Table 12 and Figure 17c (a residential building using the same technology as Scenario 1 with the same total area and geometry) highlight the impact of building function, facade type, number and ma-

terial of internal partitions and types of installation systems used. The embodied carbon in stage A increases to 64%.

The impact of individual building elements on the embodied carbon is shown in Figure 19.

The large impact of building installations on the embodied carbon is illustrated by presenting absolute values, expressed in kgCO<sub>2</sub>e by life cycle phase and building element category.

In the figure below, it is illustrated that in the building analysed, the embodied carbon of the building installations, taking into account their replacement cycle over their lifetime, matches that of the entire building structure (underground and above ground), while the other elements, such as the building envelope, interior and finishes with equipment, have a similar share. These results are decisively influenced by the assumptions made about the expected lifetime of the individual building elements, as with each replacement cycle of a given group of elements, their embodied carbon footprint is multiplied.

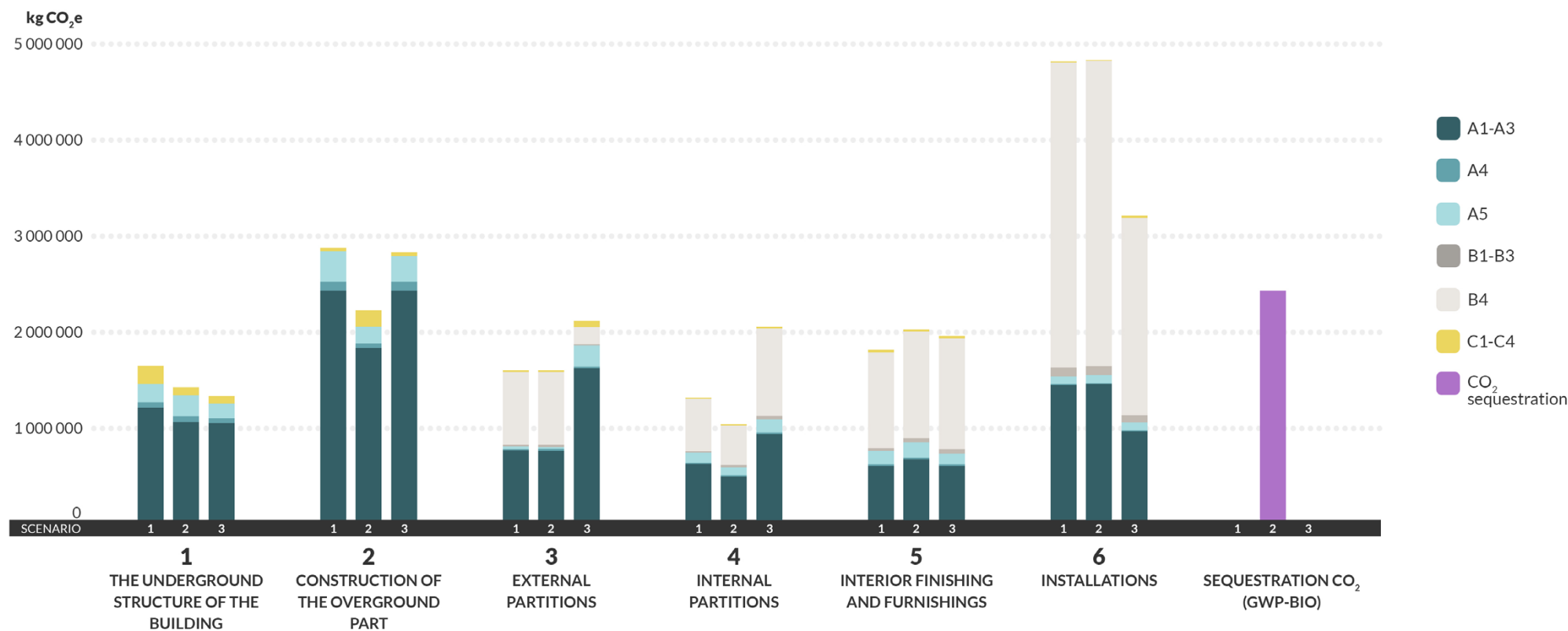


Figure 19: Contribution of building parts to the different phases of the LCA



In the next figure, for the purpose of discussing the results and illustrating the potential for using buildings as carbon stores, the absolute value of GWP-bio for the whole building is shown next to the positions corresponding to the GWP-fossil values defined for the individual element groups. Note, this figure does not represent additional greenhouse gas emissions, only

the sum of carbon dioxide absorbed from the atmosphere, stored in the building during its lifecycle and potentially beyond.

Option 3 for the residential building is significantly influenced by the embodied carbon in modules A1-A3 due to the concrete construction of the external walls, but offset by a smaller impact of modules B4/B5 for the internal installations in the residential building than in Option 3.

The effect of the number of element replacements on the proportions in their contribution to the carbon footprint can best be seen by compiling the pie charts with the results for the upfront embodied carbon (modules A1-A5) and the whole life embodied carbon (modules A-C).

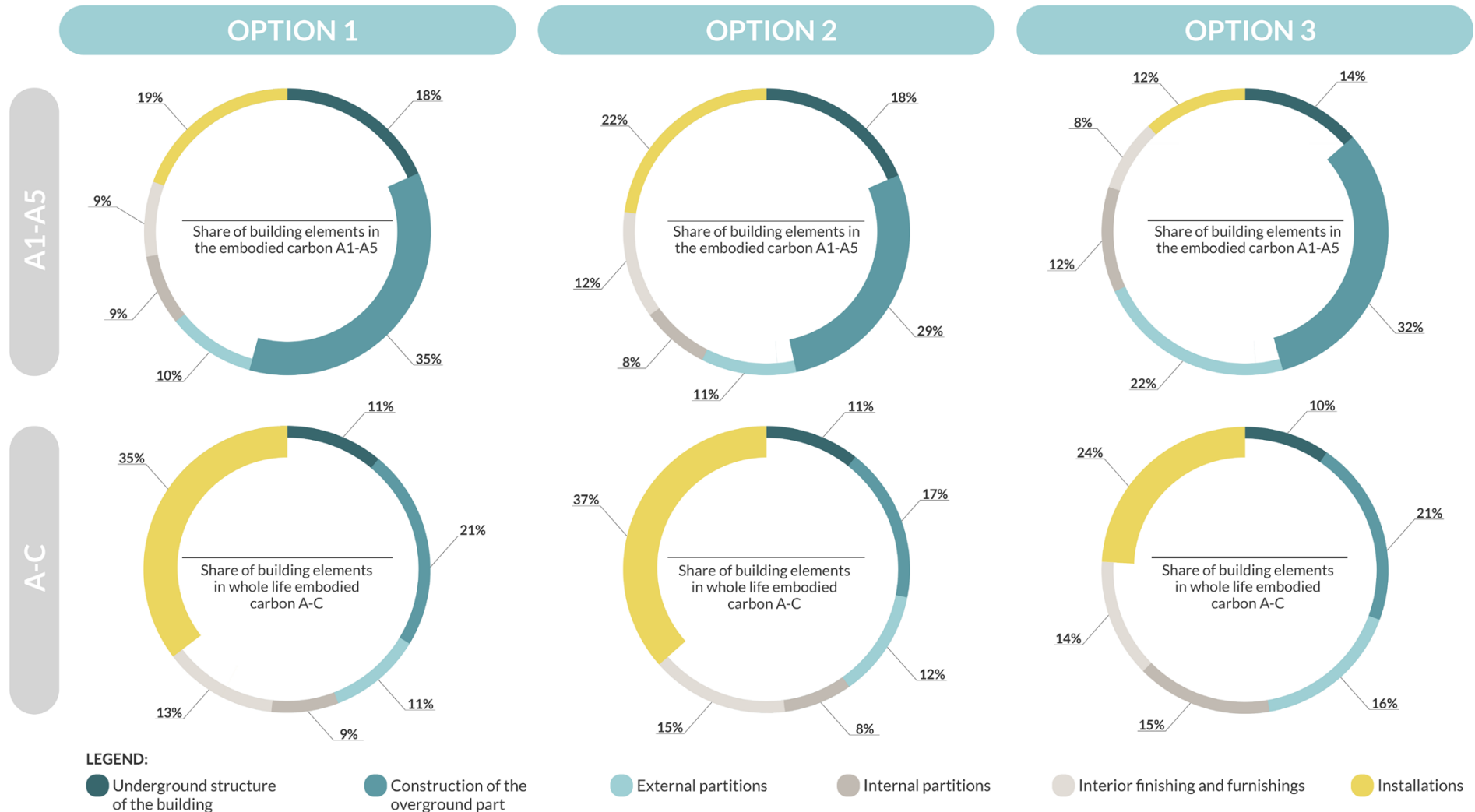


Figure 20: Contribution of building elements in upfront and whole life embodied carbon



## Operational carbon

### Assumptions

As part of this case study, the LCA analyses of a model office building (Option 1) and a residential building (Option 3) were extended to include an operational carbon, allowing the total carbon footprint for both building types to be estimated.

The first step in estimating the operational carbon of these buildings was to determine their energy needs, taking into account their use, the insulation of the envelope and the type of installations. The assumptions used to determine the electricity and heat demand are shown below.

### Option 1

- Office building with a total area of 16,100 m<sup>2</sup>.
- Insulation performance of partitions meeting technical conditions for newly constructed buildings.
- Density of people as for a standard office, heat gain from equipment and lighting typical.
- The building is supplied with thermal energy from the high-parameter district heating network for central heating and hot water.
- The building is equipped with a mechanical ventilation system that provides the required amount of hygienically suitable outside air at the right temperature and the removal of used air.
- Ventilation air is prepared in supply and extract air handling units with heat recovery. Thermal comfort in the office spaces is provided by chilled beams and radiators.
- The components of energy consumption that have been included in the calculation of the operational carbon:
  - district heating energy for heating, ventilation and hot water: **644,000 kWh/year**,
  - electricity for cooling, powering equipment (pumps, fans), lighting, office equipment (electricity not regulated by the methodology for determining the energy performance of the building): **1,127,000 kWh/year**.

### Option 3

- Multi-family residential building with a total area of 16,100 m<sup>2</sup>. Insulation of partitions meeting technical terms and conditions for newly constructed buildings.
- Use as for a typical contemporary multi-family building in Poland.
- The building is supplied with thermal energy from the high-parameter district heating network for central heating and hot water preparation.
- The building is equipped with a mechanical ventilation system that provides the required amount of hygienically suitable outside air at the right temperature and the removal of used air.
- The ventilation air is prepared in heat recovery supply and extract air handling units.
- Heat is distributed in the building via a pump central heating system, using water convection radiators.
- The components of energy consumption that have been included in the calculation of the operational carbon:
  - district heating energy for heating, ventilation, hot water: **611,800 kWh/year**,
  - electricity to power appliances (pumps, fans), lighting, domestic appliances (electricity not regulated by the methodology for determining the energy performance of the building): **354,200 kWh/year**.

Current CO<sub>2</sub> emissions for district heating and electricity from the electricity grid were used for the analyses:

- for district heating 0.31 kgCO<sub>2</sub>/kWh - carbon dioxide emission rate emitted to air from sources, when heat sold by Veolia Energia Warszawa S.A. in 2020,
- for electricity 0.75 kgCO<sub>2</sub>/kWh - emission factor for electricity for 2020, published in December 2021 based on KOBIZE data.

For the purposes of this study, four scenarios were adopted relating to CO<sub>2</sub> emissions from the district heating and electricity network in the subsequent years of use of the buildings:

- **scenario 0** - keep emissions constant as for year one over the lifetime of the building,
- **scenario 1** - slow rate of decrease in emissions 2% reduction from the previous year,
- **scenario 2** - moderate rate of decline in emissions - a 5% reduction from the previous year,
- **scenario 3** - high rate of decrease in emissions - a 10% reduction from the previous year.

It should be noted that only Scenario 3, which assumes a high rate of decrease in emissions, makes it possible to meet the European Union's goal of climate neutrality in the sense of eliminating CO<sub>2</sub> sources around 2050.

It is also worth mentioning that published reports on energy sources in Poland, and consequently on grid emissions, mostly present projections for the next 10-20 years, which is too short a period for determining the carbon footprint of buildings over their entire lifecycle. Therefore, the scenarios presented above should be treated as illustrative and bear in mind that they were created solely for the purpose of illustrating exemplary results of the operational carbon footprint of a building. The mere assumption of grid emission reductions in future years may not be valid, due to changing fuel market conditions.

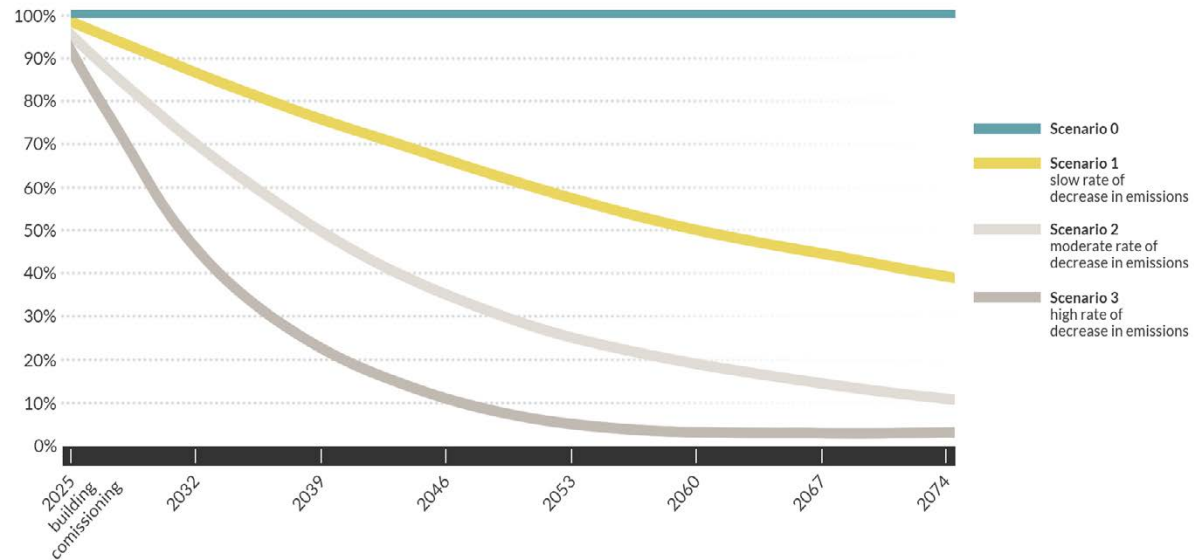


Figure 21: Decrease scenarios for CO<sub>2</sub> emissions from the power grid in Poland, for the estimation of the operational carbon

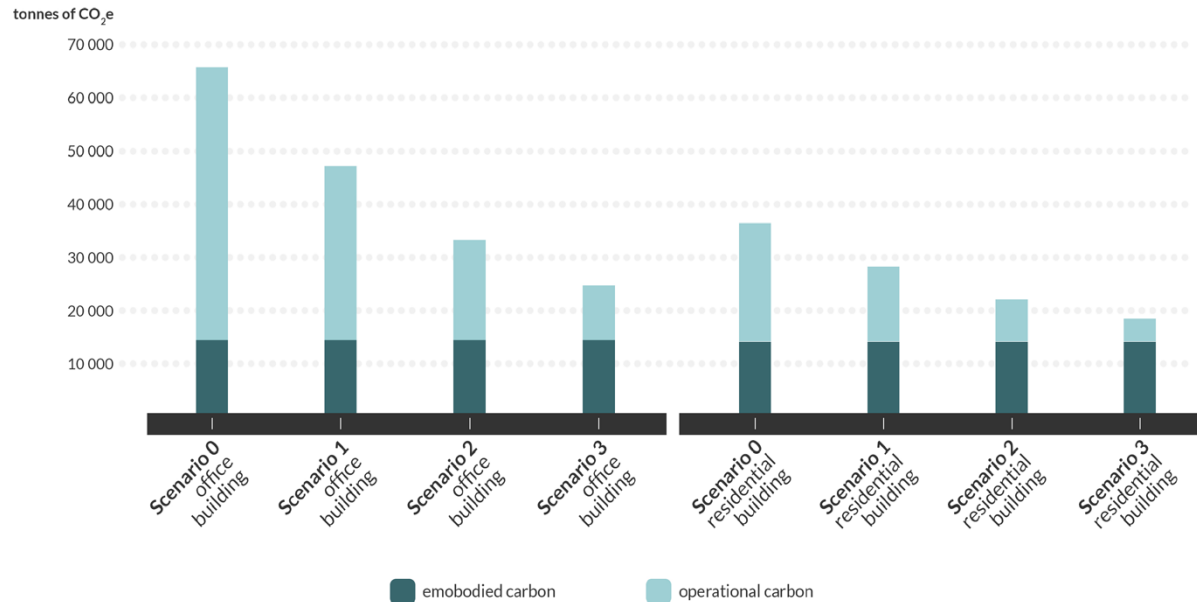


Figure 22: Comparison of embodied and operational carbon



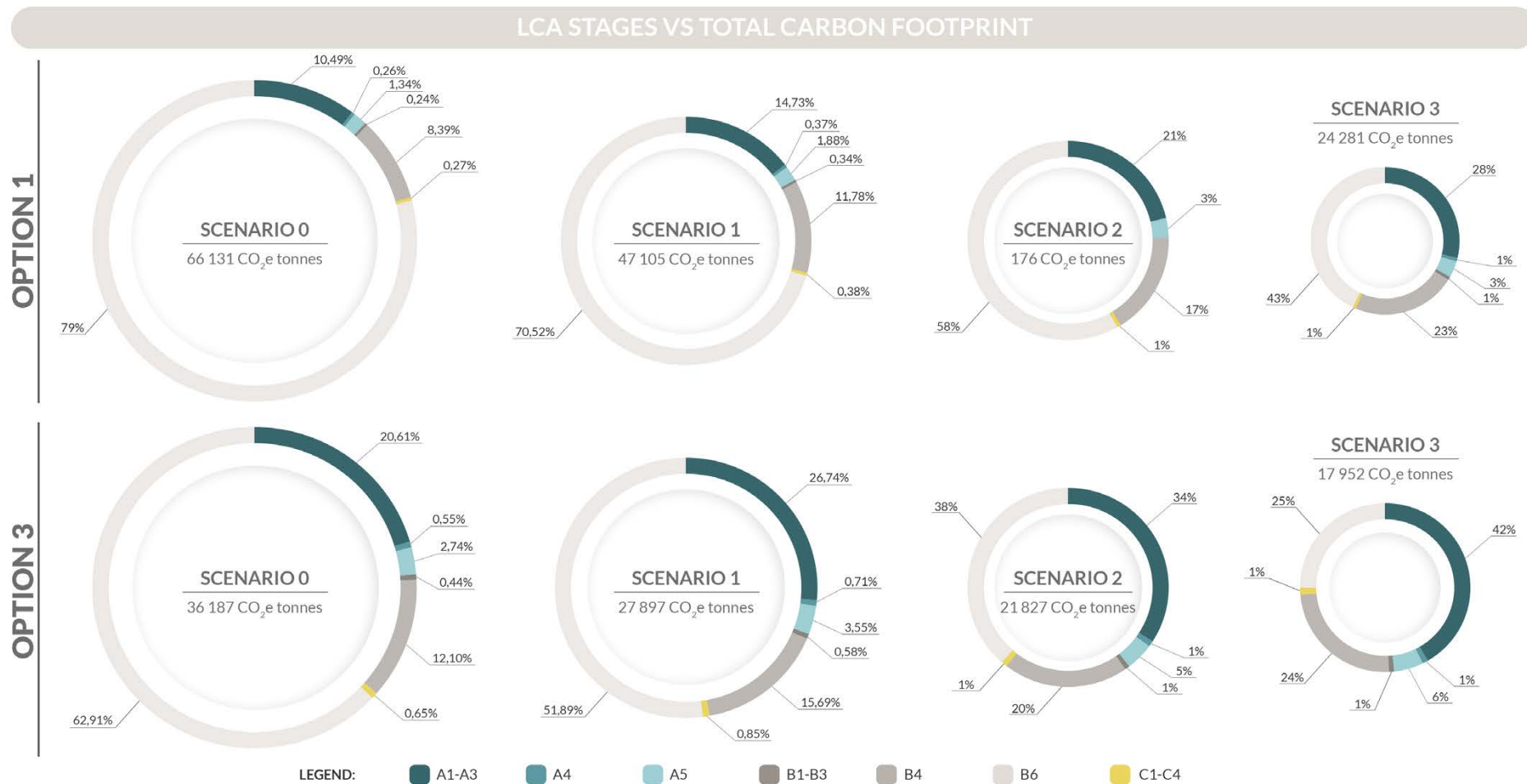
## ESTIMATING THE TOTAL CARBON FOOTPRINT OF BUILDINGS

The results of the total carbon footprint for a model office building (Option 1) and a residential building (Option 3) under different grid emission scenarios are presented in the next figure in quantitative terms. Within the total building carbon footprint, the total emissions associated with the embodied and the operational carbon are distinguished.

In order to further illustrate all the stages and their contribution to the estimation of the total carbon footprint of the building, pie charts have been developed as shown below.

Figure 23 illustrates the scale of the divergence of the operational carbon results between the different scenarios and in relation to the embodied carbon values for the two buildings analysed. This example shows that the assumptions made for grid emissions can have a decisive impact on the final result of the total carbon footprint estimate. **As it is practically impossible to predict grid emissions over a time horizon of more than 50 years, the estimation of the operational carbon of a building has to be subject to a very high**

**uncertainty in the result.** In order to minimise the uncertainty of the building whole life carbon result, it is suggested that module B6 should be excluded from the scope of the analysis and only report results for the embodied carbon should be conducted. On the other hand, information on the value of the operational carbon of a building can be indirectly determined as part of the energy performance based on the final energy indicator.



**Figure 23:** Comparison of the contribution of LCA stages to the total carbon footprint





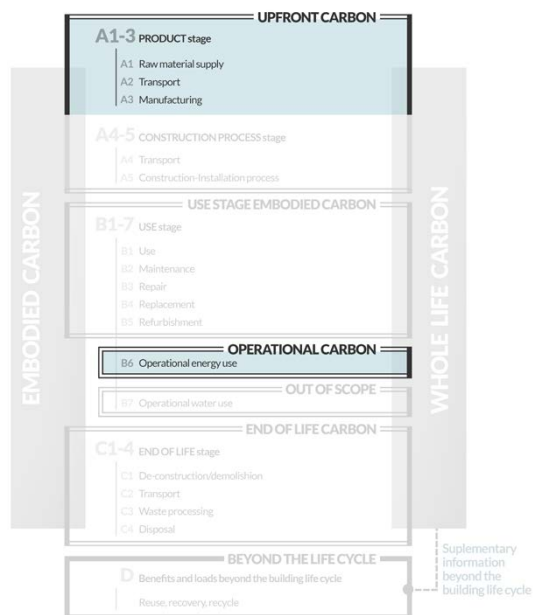
# CHAPTER 4 SUMMARY

The challenges of sustainability in the built environment go beyond the mere reduction of CO<sub>2</sub> emissions during the use phase, expressed through the operational carbon. The construction process and the use of materials also result in significant CO<sub>2</sub> emissions.

In June 2021, PLGBC published *How to decarbonise the built environment by 2050. Whole life carbon roadmap for Poland*, in which one of the key actions was to identify the need to integrate LCA of buildings into building regulations.

The present report and the following summary are the proposal to introduce a standardised method for estimating the carbon footprint of buildings. Based on the assumptions presented and the results obtained, two method types are proposed: a simplified and a full method.

**Simplified method - takes into account modules A1-A3 responsible for embodied emissions in the product stage and operational emissions per CO<sub>2</sub>e.**



## SIMPLIFIED METHOD - RECOMMENDED

### A PRODUCT STAGE

#### A1 RAW MATERIAL SUPPLY

- The product stage, comprising modules A1-A3, is the most significant component of the building LCA and typically exceeds 50% of the embodied carbon over the entire building lifecycle.
- The correct estimation of the values for this stage is crucial for the correctness of the total embodied carbon results. The results for the subsequent stages of the building lifecycle are dependent on the values defined within modules A1-A3.
- The idea of assessing the carbon footprint for these stages is very simple and consists of adding up the emissions for each of the building elements included in the analysis and does not require additional assumptions that are impossible to verify at the design stage.
- For the calculations, a quantity statement for building materials and equipment and averaged data for products (generic) or detailed data for products (from EPDs) should be used.
- When calculating the carbon footprint, the CO<sub>2</sub> sequestration phenomenon should be taken into account within modules A1-A3, and the value of stored carbon should be presented separately, without including the GWP fossil in the balance.
- When developing the results for modules A1-A3, consideration should be given to whether the products used in the project contain biogenic carbon. New EPDs, developed in accordance with EN 15804:2012+A2:2020, should distinguish the CO<sub>2</sub>e value associated with the biogenic carbon stored in the product, but older studies or some aggregated data may not contain this information. In the absence of detailed data, it can be assumed that 1 kg of wood stores approximately 1.64 kgCO<sub>2</sub>e. This value is based on EN 16449, assuming that 50% of the biomass is used for wood production and the rest is waste (roots, crown of the tree).

### B USE STAGE

#### B6 OPERATIONAL EMISSIONS

- The contribution of the operational carbon to the total carbon footprint of a building, depending on the type of building and the assumptions made regarding the decarbonisation of the energy grid, can range from 20% to 80%. Including such a large component of emissions in the assessment, which is at the same time subject to very high uncertainty, would make LCA relating to the total carbon footprint of a building lose their value as a tool for comparing buildings with each other.
- Operational emissions are to be assumed on the basis of the calculation of the final energy demand according to the applicable methodology for drawing up energy performance certificates for the building, depending on the type of energy carrier. The emission value given as GWP must include all greenhouse gases (Table 1).
- The volume of greenhouse gas emissions making up the operational carbon (module B6), should be determined for one year, based on the most recent data on the energy carriers used.



## SIMPLIFICATIONS ADOPTED - MODULES NOT INCLUDED

The modules that make up the construction process stage, A4 and A5, on average make up no more than 5% of the embodied carbon, of which road transport of materials within the country accounts for about 1%. Predicting this at the concept or construction design stage is difficult to estimate - it requires data on all transport of construction products. Reliable collection of this information would allow emissions from the A4 module to be included in the as-built analysis and, in the longer term, national recommendations for typical means of transport and distances over which products are transported.

Module A5 including earthworks, excavation, temporary works, on-site material handling, energy and water consumption during building construction requires estimates or measured data during construction. The lack of literature data for construction sites in Poland and the insignificant share of the module A5 in the total embodied carbon allows this module to be omitted. Reliable collection of information on energy consumption during construction and the amount of waste generated would allow emissions from A5 to be included in the as-built analysis and for future national recommendations.

For modules B1-B3, there are not many data and studies available and their contribution to the whole building is mostly estimated at 0.5-1%. Their impact is therefore considered negligibly small.

Modules B4 and B5, i.e. replacement and refurbishment, account for a large share of the building's embodied carbon, as much as 35-40%. Depending on the assumptions made

regarding the multiplicity of replacements of certain building elements, their share may be even higher, while the emissions associated strictly with module B5 going beyond the replacement of elements related to the ordinary maintenance of the building are almost impossible to determine. The B4 module is related to the need to define a standard lifetime for a building element, installation or appliance as proposed in this methodology. Making other assumptions about the standard lifetime can generate large discrepancies in the calculation of the B4 module, up to several tens of percent. In practice, B4 is a partial duplication of modules A1-A3 of the selected building elements. Taking the same data in the perspective of replacement multiples over 50 years is subject to large uncertainties in the result, due also to the time-varying emissions associated with the production of building products.

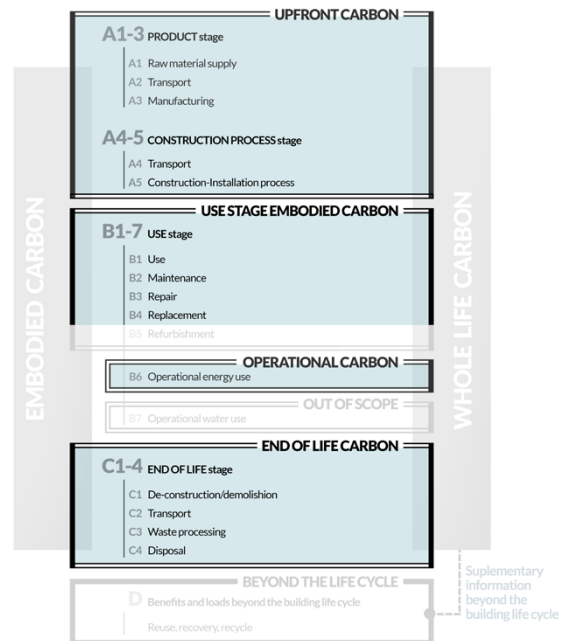
Module B5 covering emissions related to the anticipated refurbishment of the building including changes to the external wall construction, adaptation of rooms or changes to the use of the building is not foreseeable. In practice, part of the emissions related to module B5 may be included in the emissions foreseen for module B4.

The end-of-life phase of the building, i.e. modules C1-C4, mostly contribute to the embodied carbon as half of the values defined for the modules associated with the construction process stage (A4-A5). This means that in typical buildings, their total contribution can be as low as 2% and can be ignored in the simplified method.

The short-term but immediate application of the simplified method will allow a standardised approach to estimating a building's carbon footprint, which in turn will enable comparisons between facilities within different building types. Additionally, the collection of data on a building's embodied carbon during the product stage will allow the development of GWP indicators for materials and equipment and the creation of a national database.

# FULL METHOD

Full method - takes into account modules A1-A5, B1-B4, C1-C4 responsible for embodied emissions in the product, use and end-of-life as well as operational emissions per CO<sub>2</sub>e.



## A PRODUCT STAGE

### A1 RAW MATERIAL SUPPLY

### A2 TRANSPORT

### A3 MANUFACTURING

- These modules should be calculated according to the guidelines of the simplified method.

### A4 TRANSPORT

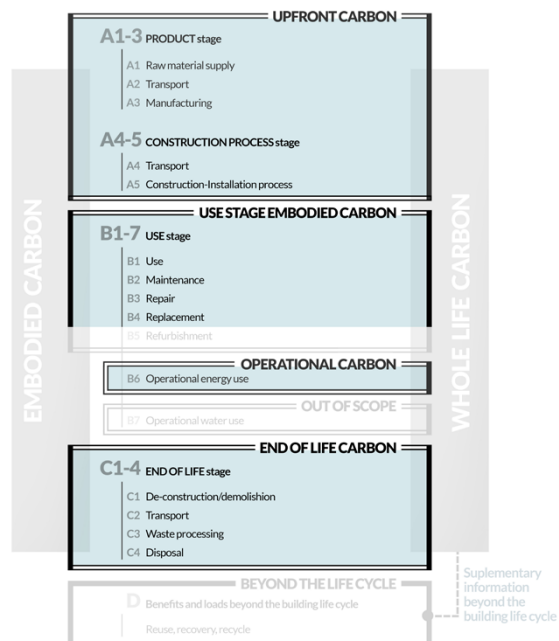
- Module A4 - mostly this module does not contribute much to the embodied carbon - it can be estimated at 1%. Carbon emissions associated with transport should be calculated on the basis of monitoring:
  - the distances between the factory and the construction site (including handling and temporary storage areas),
  - mode of transport with emission factor (kgCO<sub>2</sub>/kg/km),
  - the weight of the material to be transported and the degree of filling of the means of transport.

In the absence of the aforementioned data at the project stage, the transport scenarios presented in Table 5 can be adopted. Ultimately, a set of emission values for different national average transport distances needs to be developed.

## A5 CONSTRUCTION-INSTALLATION PROCESS

- Module A5 - emissions resulting from the construction process contribute moderately to the overall embodied carbon and typically do not exceed 5%. For sites requiring very extensive earthworks and temporary works, the values determined for A5 will be higher. Indicatively, Tables 6 and 7 can be used to estimate the A5 module.

**Full method - takes into account modules A1-A5, B1-B4, C1-C4 responsible for embodied emissions in the product, use and end-of-life as well as operational emissions per CO<sub>2</sub>e.**



## FULL METHOD

### B

#### USE STAGE

##### B1

##### USE

##### B2

##### MAINTENANCE

##### B3

##### REPAIR

- Module B1 covers carbon emissions from building materials and equipment over the lifetime of the building. Emissions associated with servicing and refrigerant leaks from installations and repairs to equipment should be included in the calculations.
- Module B2 relates to the CO<sub>2</sub> emissions associated with maintenance of: the roof, external walls, windows external doors finishes and installations.
- Module B3 takes into account emissions from all activities related to the repair of the building element including used products.
- In the absence of specific data for modules B1-B3, it is recommended to assume emissions based on an index of 5-10 kg CO<sub>2</sub>e/m<sup>2</sup>.

### B4

#### REPLACEMENT

- Module B4 relating to the replacement of building components is linked with the necessity of assuming their standard service life of the building component, installation or appliance according to Figure 11.

### B6

#### OPERATIONAL EMISSIONS

- Operational emissions related to building energy consumption and media type should be calculated according to the guidelines of the simplified method. The results for module B6 should be presented separately from the embodied carbon.

### C

#### END-OF-LIFE STAGE

##### C1

##### DE-CONSTRUCTION /DEMOLITION

##### C2

##### TRANSPORT

##### C3

##### WASTE PROCESSING

##### C4

##### STORAGE/DISPOSAL

- Module C1 includes emissions from de-construction and building demolition. In the absence of data, an average emission factor of 3.4 kg CO<sub>2</sub>e/m<sup>2</sup> is proposed.
- Module C2 takes into account emissions from waste transport. In the absence of data, an average emission over a distance of 50 km of 0.005 kg CO<sub>2</sub>e/kg of waste can be assumed.
- Module C3 is responsible for reporting the carbon emissions associated with the reuse or recycling of materials at the end of a building's life and module C4 for emissions resulting from the disposal of materials that are not recovered for reuse or recycling. In the absence of data, it is recommended to adopt a proxy of 0.013 kg CO<sub>2</sub>e/kg of waste.



## SIMPLIFICATIONS ADOPTED - MODULES NOT INCLUDED


Module B5 covering emissions related to future refurbishment of the building including changes to the external wall construction, adaptation of rooms or changes to the use of the building is not foreseeable. Future renovation work on such a large scale should be the subject of a separate LCA analysis.

Module D - estimating the value of this module requires the determination of the amount of emissions that will be avoided in the future due to the reuse of the component. It is virtually impossible to determine this value precisely, as we do not know the emission values associated with modules A1-A3 for products that will be manufactured in 50 years' time, and there is no clear basis for determining the emissions associated with energy generation over such a distant time horizon. For this reason, values for module D are not determined. In the opinion of the authors of this report, a better measure for determining the potential for avoiding future emissions would be an indicator for the degree of adaptation of a building to a circular economy, which is the subject of other studies.

**The feasibility of the full method requires the development of a national database containing unit emission indicators for:**

- **construction products, appliances and technical systems, including the end-of-life stage,**
- **type of transport of construction products and fuel, and average transport distances specific to Poland,**
- **stages of the construction of different types of buildings, taking into account the different energy carriers needed during the construction process to power machinery and construction facilities, as well as the proportion of construction waste for each group of materials,**
- **energy carriers.**

**Furthermore, consideration of the operational carbon over the full lifecycle (50 years) can be correctly estimated if a national GWP reduction strategy is adopted, reflecting the adopted scenario of using renewable energy sources and moving away from fossil sources.**



**The need to calculate the carbon footprint of buildings raises the challenges and requires concrete actions from the construction sector.**

**These are the following:**

**Making it compulsory to calculate the carbon footprint of a building on the basis of an accepted uniform methodology**

- Given that the LCA analysis of a building is one of the elements describing the building and indeed its environmental impact, it will be appropriate to introduce a new chapter into the 'Regulation on technical conditions to be met by buildings and their location'.
- The data collected should be recorded as part of the drawing up of energy performance certificates for the building. This data will allow an assessment of the emissivity of buildings and, in the future, will determine the setting of appropriate limits for the different building types required by the relevant regulations.
- For new buildings, the obligation to carry out an LCA analysis should be harmonised to the guidelines of existing legislative documents and approved in the near future as part of the revision of the EPBD.
- In the case of retrofitting or conversion/extension of a building, the analyses should include the carbon footprint within the scope of the retrofit and not include data about the building in its existing state.

Experts performing LCA should have an engineering degree, preferably in construction, architecture or related fields. A register of persons authorised to perform analyses should be introduced - entry in and access to the register, similar to the energy performance certificates register.

The tool for performing LCA analysis should be commercial, but validated and based on a developed methodology. Reports generated by different commercial tools should have a consistent design and form.

A central generic database should be developed for building products, appliances and technical systems. This data can be successfully used when calculating the carbon footprint at the conceptual stage of a project. It may be helpful to use the range of building elements listed in Level(s) to create the database, thus ranking materials within given categories/subcategories.

At the same time, a national database of EPD-declared construction products, designated according to a uniform methodology, should be developed. The specific database will allow a real assessment of the lifecycle impact of a building on the basis of the adopted methodology in construction or detailed design and as-built design.

Manufacturers of construction products should be motivated to produce EPDs for their products. In addition, the creation of a national emissions database for construction products, broken down into emission classes, will allow differentiation of construction products in terms of their environmental impact. In the longer term, EPDs for construction products should be made mandatory.

The management and supervision of the data base should be the responsibility of the government administration.

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43. [Ministry of Ecological Transition, France \(2022\)](#), *Règlementation environnementale RE2020*
44. [Ministry of Foreign Affairs of Denmark \(2020\)](#), *Global Climate Action Strategy*
45. [PART 2 An industry-proposed amendment to UK Building Regulations 2010](#)
46. [Piońska, M. \(2022\)](#), *What the EU Taxonomy is all about*. Future Industry Platform
47. [Council of the European Union \(2022\)](#), *European Green Deal*
48. [Ramboll \(2022\)](#), *Towards embodied carbon benchmarks for buildings in Europe*

## STANDARDS

49. [EN 15804](#) Sustainability of buildings. Environmental product declarations. Basic principles for the categorisation of construction products
50. [EN 15804+A2:2020-03](#) Sustainability of construction works - Environmental product declarations - Basic principles for the categorisation of construction products
51. [EN 15978:2012](#) Sustainable buildings - Assessment of environmental performance of buildings - Calculation method

## LEGISLATION

52. [Directive \(EU\) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency \(Text with EEA relevance\) \(L 156/75\)](#)
53. [Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions A wave of renovation for Europe - greening our buildings, creating jobs, improving quality of life \(COM\(2020\) 662 final\)](#)
54. [Ministry of Local Government and Regional Development, Norway \(2022\)](#), *Several measures to increase reuse and reduce climate emissions from the building industry (in norw. Fleire tiltak for å auke ombruk og redusere klimautslipp fra byggenæringa)*
55. [Announcement by the Minister of Climate and Environment of 2 March 2021 on the national energy policy until 2040](#)
56. [Proposal for a Directive of the European Parliament and of the Council on the energy performance of buildings \(recast\) \(COM/2021/802 final\)](#)
57. [Regulation \(EU\) No 305/2011 of the European Parliament and of the Council of 9 March 2011 laying down harmonised conditions for the marketing of construction products and repealing Council Directive 89/106/EEC Text with EEA relevance](#)
58. [Annexes to Commission Delegated Regulation \(EU\) .../... supplementing Regulation \(EU\) 2020/852 of the European Parliament and of the Council](#)
59. [Regulation \(EU\) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing a framework for achieving climate neutrality and amending Regulations \(EC\) No 401/2009 and \(EU\) 2018/1999 \(European Climate Law\)](#)





# PLGBC

Polish Green Building Council

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