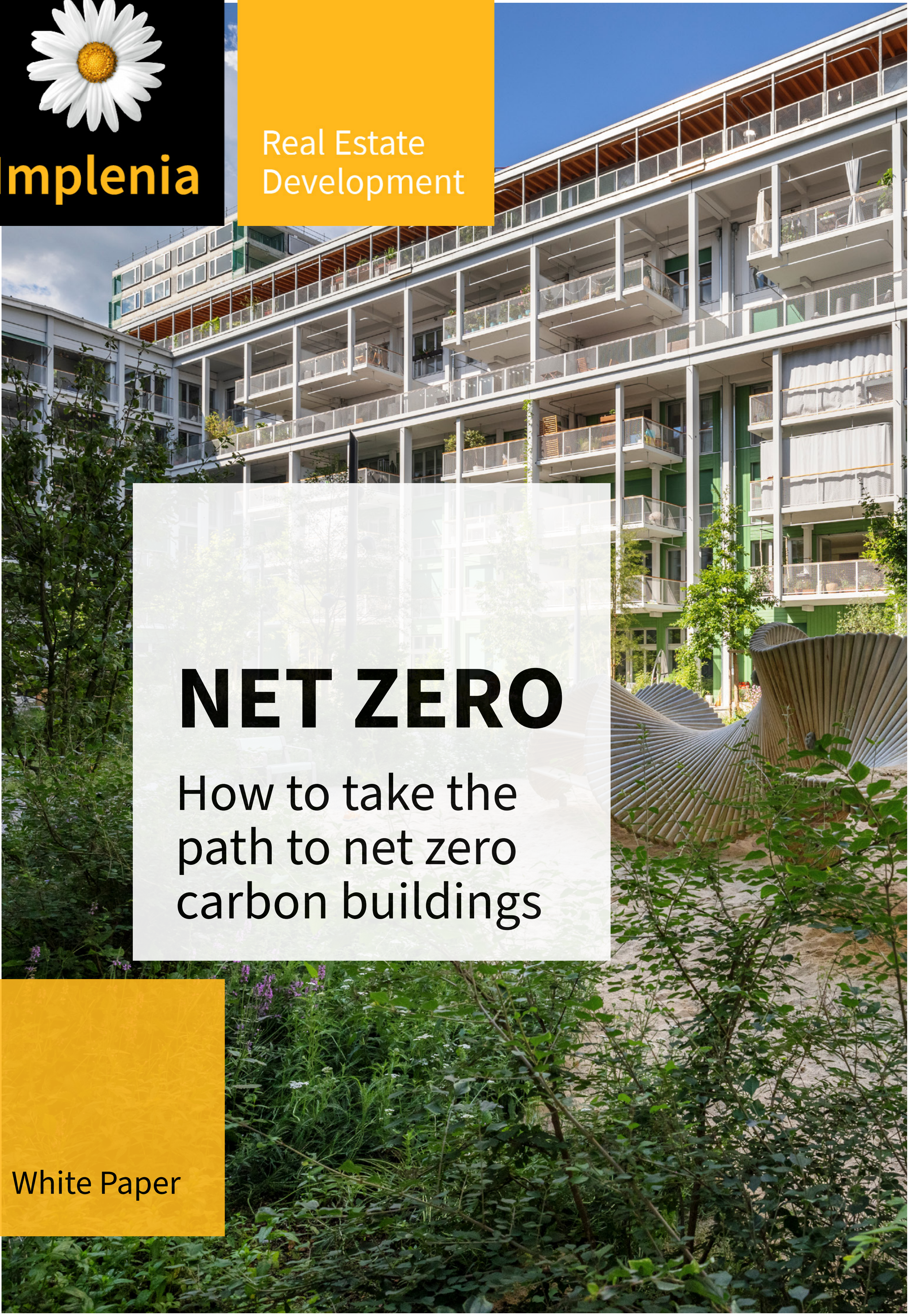
Implenia

Real Estate
Development



NET ZERO

How to take the path to net zero carbon buildings

White Paper

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Foreword

«With the right combination of design, the use of renewable energies, smart systems and ecological materials, we are developing the buildings that future generations deserve.»

Marc Lyon, Head Real Estate Development Switzerland

As a leading international construction and real estate service provider, Implenia takes its environmental and social responsibilities seriously. As part of its ESG engagement Implenia wants to contribute to a sustainable real estate industry – one that creates social cohesion instead of division and that operates safely within, not beyond, the limits of our planet. Through regenerative design approaches, real estate should not only emit less, but create good for the environment and society. In view of the looming climate crisis, decarbonising the building stock and developing climate-friendly new buildings is of crucial importance.

Buildings no longer necessarily have to be heavy climate polluters. Every renovation and new development project should address the question of how the future property can serve people and the environment equally over the long term. By developing, building and operating large real estate projects, Implenia has a significant opportunity to help meet climate targets. We are entering an era of net zero and carbon positive buildings that can serve as decentralised power plants, CO_2 sinks and habitats for (bio)diversity. Implenia Real Estate Development intends this white paper to be one of many contributions to this new era.

Introduction

> «The fact that CO_2, is transparent and odourless is the greatest tragedy for humankind.»

Sobek 2020

The exponential increase in anthropogenic greenhouse gas concentration since industrialisation is leading to an enhanced greenhouse effect. This is causing irreversible damage to natural ecosystems and to our society. Rising sea levels, extreme weather events such as droughts and floods, and species extinctions are familiar examples. To preserve livelihoods and intergenerational equity, actions towards climate-mitigation and adaptation are essential.

The real estate sector is responsible for around 36% of primary energy consumption and 37% of greenhouse gas emissions. It is rightly becoming the focus of civil society and policy makers in their efforts to reduce global carbon emissions and meet the Paris Agreement's 1.5-degree target by 2050. Decarbonisation must move to the heart of real estate development, construction and management.

Development of Global Greenhouse Gas Emissions

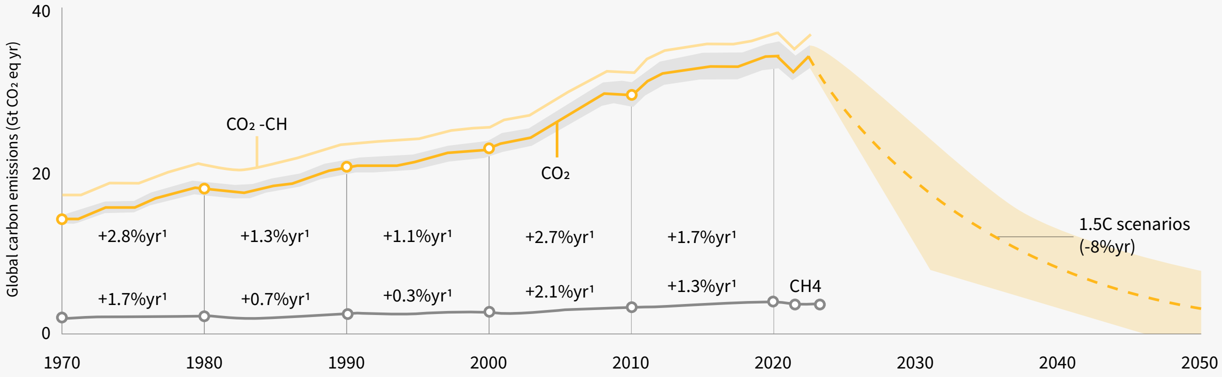
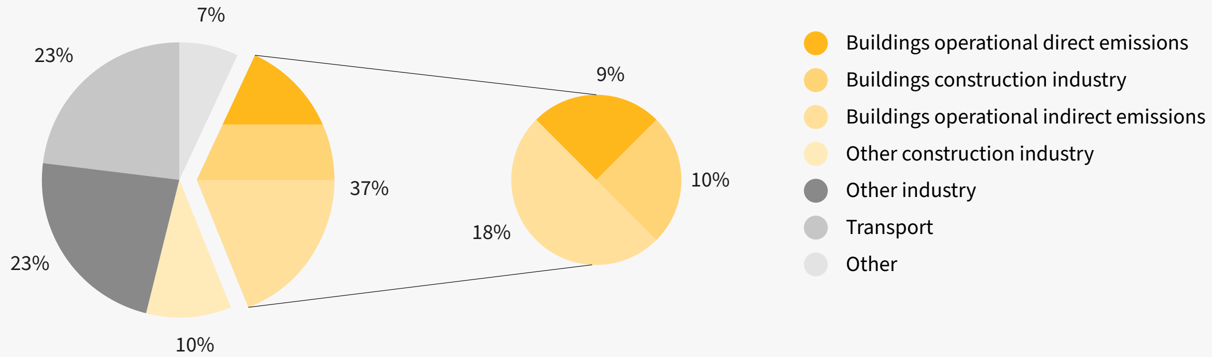


Figure 1: Figure redesigned based on "nature reviews earth & development"[1]

Global Share of Buildings and Construction Final Emissions (in CO_2eq.), 2020

Figure 2: Global share of emissions, 2020[2]



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[1] cf. Liu et al. 2022, p.2

[2] based on United Nations Environment Programme 2020, p.4

Definition of Net Zero

Within academic and political circles there are different interpretations of “net zero”. Some studies use the term “net zero carbon” to refer solely to the operating emissions of a building. Others also include the carbon embodied in the building materials, but regard renewable materials such as wood as carbon sinks. And still other definitions have a specific interpretation when it comes to the topic of offsetting.

To create a common ground of understanding, this report suggests the following definition of net zero carbon.

Our Definition
Total carbon emissions related to the construction and annual operational energy consumption of the building, as well as its end-of-life demolition, reach at least a balance of net zero; or surplus emissions are fully compensated by an overproduction of renewable energies on-site or by carbon offsets.

Typically, a net zero carbon building contains a high share of renewable, biogenic materials, is highly energy efficient and is powered largely or even completely by on-site and/or off-site renewable energy sources like photovoltaic (PV) or solar heat. Carbon offsetting is regarded as only an interim solution where technical issues or other circumstances do not allow a building to achieve net zero standards (see chapter on Carbon Offsetting).

Net Zero Equation

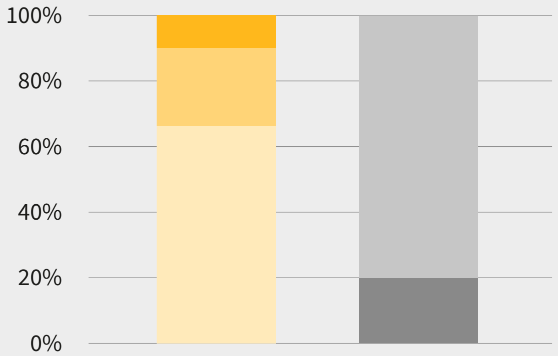


Figure 3: Definition of NZCB

- ● End-of-life
- ● Operational Carbon
- ● Embodied Carbon
- ● Overproduction of renewable energies
- ● Offsetting

Main strategies to reach net zero:

1. Reduce material and energy consumption
2. Use carbon neutral or carbon-negative materials
3. Use only renewable energies for heating, cooling and electricity

Life Cycle Phases

Decarbonising a building requires a perspective that considers the entire life cycle of that building. Starting with site selection, through the development and construction phase, to the operation and end-of-life of a building, all decisions and actions should be assessed for their overall impact. The European EN 15978 standard, to which this study refers, presents a framework for a building's life cycle phases that can be used when analysing its environmental performance in a Life Cycle Assessment (LCA) (Figure 4).

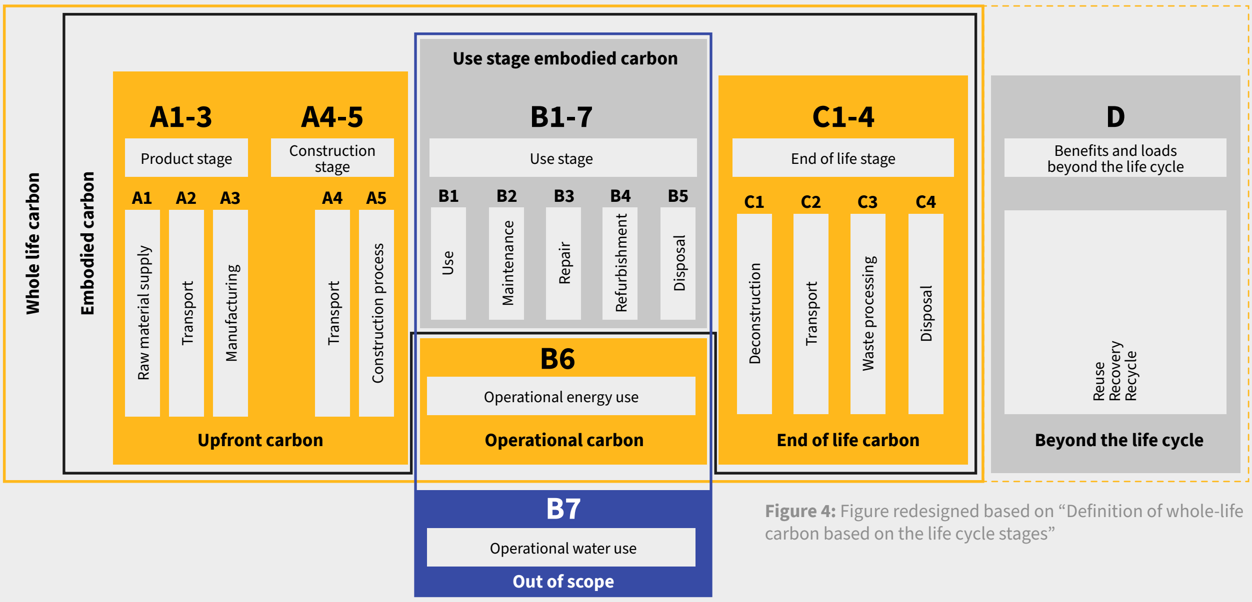


Figure 4: Figure redesigned based on "Definition of whole-life carbon based on the life cycle stages"

Important Terminology

Whole-life carbon
Emissions from all lifecycle phases, encompassing both embodied and operational carbon together. Their global warming potential (GWP) is quantified in units of carbon dioxide equivalence. A kilogram of carbon dioxide therefore has a GWP of 1 $kgCO_2e$.

Use stage embodied carbon
Emissions associated with materials and processes needed to maintain the building or infrastructure during use, such as for refurbishments.

Operational carbon
The emissions associated with energy used (B6) to operate the building or in the operation of infrastructure.

Beyond the lifecycle
Carbon emissions or emission reductions resulting from the reuse or recycling of materials, or emissions avoided by using waste as a fuel source for the same or another product or process (module D). Consideration of module D is key for maximising resource-efficient uses of materials at the end of life.

Embodied carbon
Carbon emissions associated with materials and construction processes throughout the whole lifecycle of a building or infrastructure.

Upfront carbon
The emissions caused in the materials production and construction phases (A1-5) of the lifecycle before the building or infrastructure is actually used.

End of life carbon
The carbon emissions associated with deconstruction/ demolition (C1), transport from site (C2), waste processing (C3) and disposal (C4), i.e. the phases of a building or infrastructure's lifecycle which occur after its use.

Carbon Distribution

Two central questions arise with regard to decarbonisation: at which point in the life cycle of a building are most carbon emissions generated, and when should measures be introduced to have the highest possible impact.

An analysis (based on the Swiss SIA 2040 norm) of 30 residential and six office buildings currently being developed by Implenia shows that around 74% of overall life cycle carbon occurs as embodied carbon (A-C) while operational carbon (B6) makes up only 26% (see Figure 5).

Another evaluation based on a European data set consisting of 214 new multi-family buildings and 108 office buildings shows the distribution of emissions purely at the level of embodied carbon. This analysis shows that around 72% of the carbon impact occurs in the process of raw material extraction, transportation, manufacturing, and construction (A1-A5, upfront carbon). 24% is attributable to the operational phase, and 4% to the end of life phase (see Figure 6). Both evaluations show that there is significant decarbonisation potential at the level of embodied carbon. The type and origin of building materials, classified as upfront carbon is therefore very important. Unfortunately, the focus of regulations and subsidies is still very much concentrated on operational emissions.

Shares of Embodied Carbon and Operational Carbon

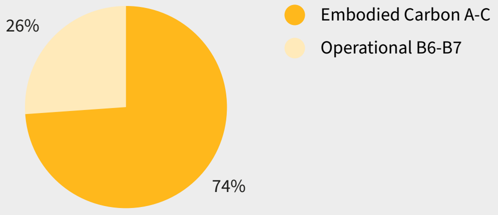


Figure 5: Estimated shares of embodied carbon and operational carbon based on internal assessment of 30 residential and 6 office development projects.

Estimated Distribution of Embodied Carbon Emissions per Life Cycle

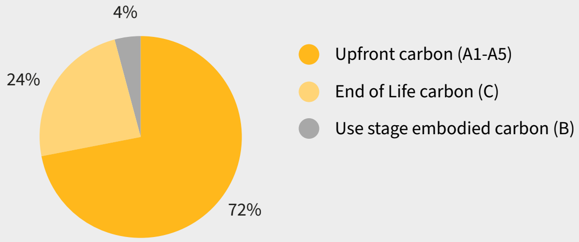


Figure 6: Estimated distribution of embodied carbon emissions per life cycle based on European dataset of 214 multi-family houses and 108 office buildings.

Carbon Benchmarks

Various national benchmarks help to identify where a project stands in terms of operational and embodied carbon. The Swiss SIA 2040 Energy Efficiency Path, for instance, currently suggests a target value for offices and residential buildings of 9 $kgCO_2/m^2/a$ for embodied carbon, as well as 2 $kgCO_2/m^2/a$ (residential) and 4 $kgCO_2/m^2/a$ (offices) for operational carbon. Any reading below these values is currently considered a good result, though it is clear that this benchmark will not be sufficient in the long term. Every project has different prerequisites, so results must always be considered in the context of prevailing local conditions. A broad study of 36 Implenia development projects based on SIA 2040 conducted in 2022 showed an average portfolio value of 3.6 $kgCO_2/m^2/a$ for operational carbon and 10.4 $kgCO_2/m^2/a$ for embodied carbon. To provide an international reference, other institutional and national benchmarks in Europe were compiled and set against each other, though they are not entirely comparable, due to different underlying calculation methods (see Figure 7 and Figure 8).

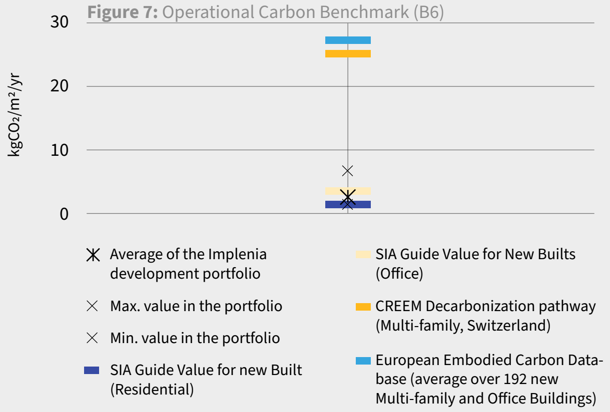
For operational carbon, the Climate Risk Real Estate Monitor (CRREM) provides country- and use-specific benchmarks for all countries in the European Union (EU) as well as for the largest international real estate markets, including Switzerland. It defines decarbonisation pathways for buildings based on the Paris Agreement's commitment to limit global warming to 1.5 °C. The different pathways are tailored to the country of origin of the building and its sectoral market.[3] As *Figure 9* shows, Switzerland's current operational carbon intensity for multifamily buildings, for instance, lies at 18.1 $kgCO_2/m^2/a$, which is below the German and EU average. To meet the carbon budget derived from the Paris Climate Agreement, the building industry in each signatory country is expected to shift the carbon emissions of its entire building stock below the specified decarbonisation pathway.[4] A building that lies above the curve, is referred to as a stranded asset.

To address growing regulation and take a leading role in decarbonization, Implenia Real Estate has set the following decarbonisieurngs targets for development projects in Switzerland:

- For new builts: Net zero by 2030 for operational emissions and 2040 for embodied carbon.
- For refurbishments: Net zero operational carbon by 2050.

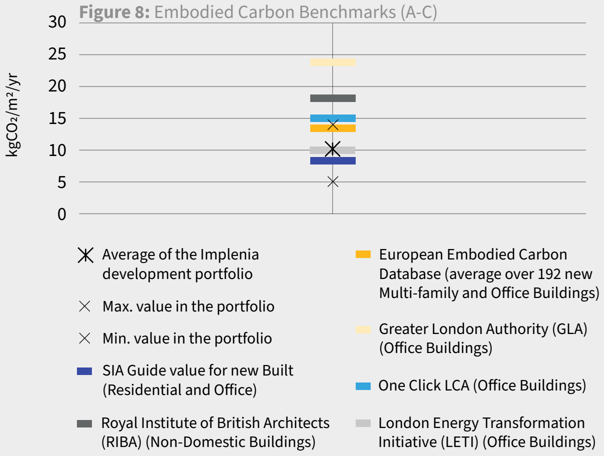
Operational Carbon Benchmark (B6)

Figure 7: Operational Carbon Benchmark (B6)



Embodied Carbon Benchmarks (A-C)

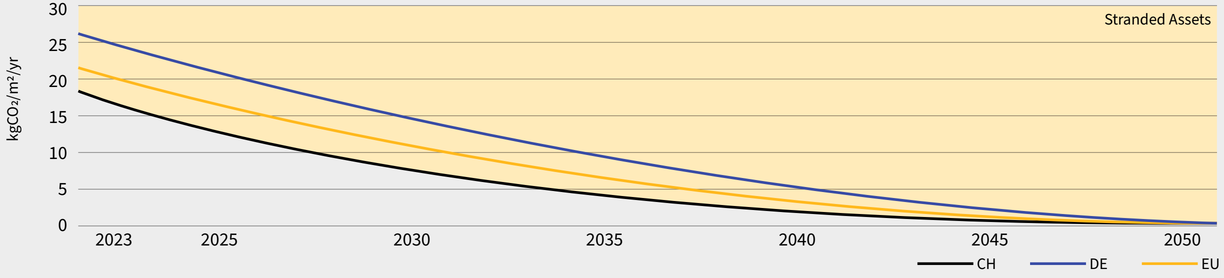
Figure 8: Embodied Carbon Benchmarks (A-C)



Decarbonisation Pathways for Operational Carbon (B6)

Residential Buildings for Multi-Family Houses

Figure 9: Decarbonisation Pathways for Operational Carbon (B6)



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[3] cf. Hill et al. 2021, p. 18
[4] cf. CRREM Project 2021

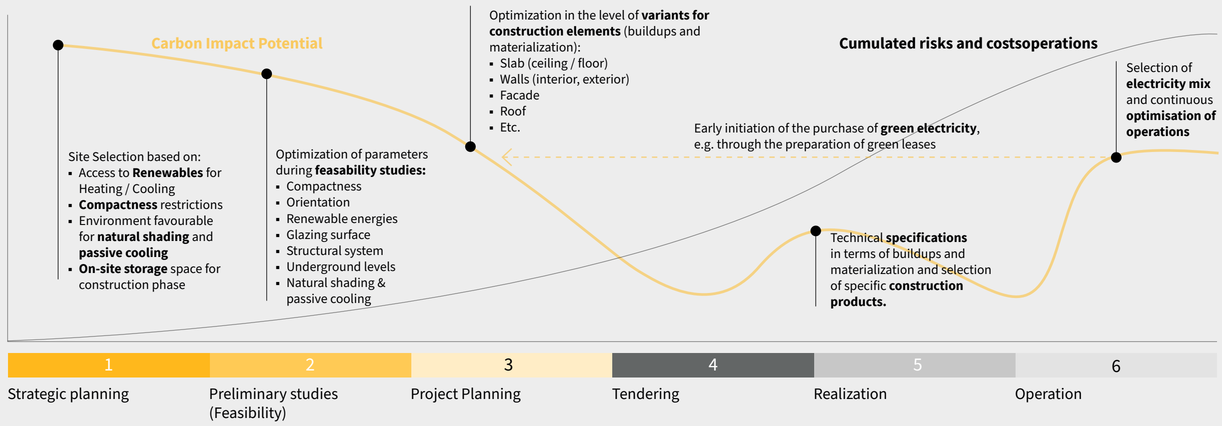
Main Levers of Decarbonisation

There is no single solution for reducing a building's whole-life carbon content.

There has to be a combination of different strategies that address topics including: efficiently designed materials, building compactness, carbon-efficient energy systems and low-carbon building materials. The analysis of 36 Implenia development projects showed that the most effective levers for decarbonisation are to be found in the early planning phase, starting with site selection. If site conditions are unfavourable from the point of view of renewable energy, it is significantly more difficult to achieve net zero. Building parameters that are defined at an early stage – such as the shape, compactness, orientation, underground levels and supporting structure – also have a significant influence on emission targets. Later in the process, materials and products are selected to ensure construction elements meet specific performance targets for structural engineering, building physics and fire safety. As shown in Figure 10, further effective levers emerge in the operating phase when determining the electricity mix and making choices to continuously optimise operations.

Impact Chronology of Decarbonisation

Figure 10: Impact Chronology of Strategies and Levers



The following chapters look at the individual levers for reducing operational and embodied carbon emissions. Figure 11 provides an initial overview of these levers.

Main Levers for Decarbonisation on the Level of Operational and Embodied Carbon

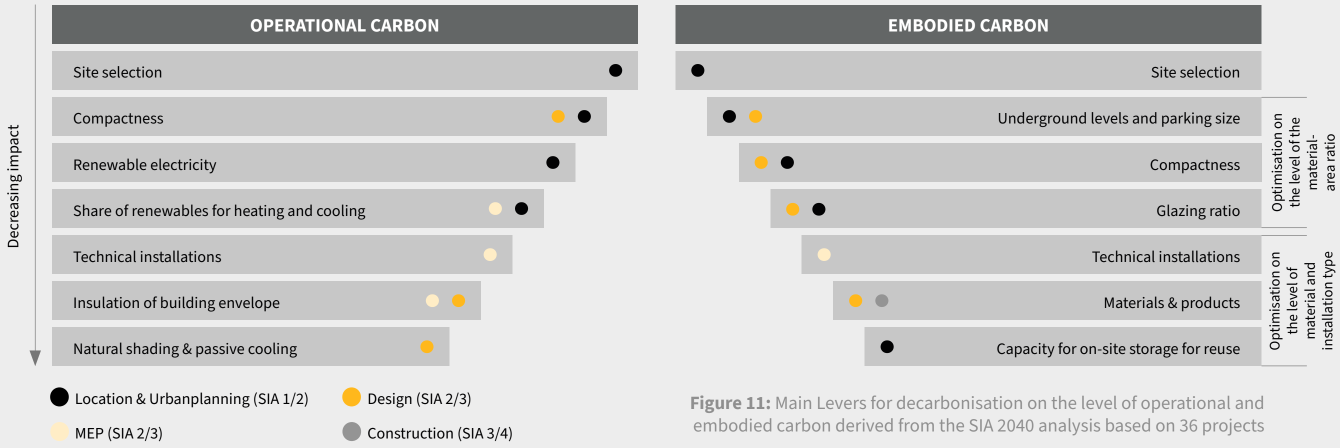


Figure 11: Main Levers for decarbonisation on the level of operational and embodied carbon derived from the SIA 2040 analysis based on 36 projects

Site Selection

The decarbonisation potential of a project depends strongly on exogenous, site-specific factors.

The site-specific variables which influence a building's carbon balance include its access to renewable energies for heating and cooling (e.g. district heating or geothermal heat), site topography and geology, potential for solar power production, the shape of the site – which indirectly influences a building's form and compactness – and the environmental conditions relating to natural shading and passive cooling. The development of a net zero carbon building should therefore start with a thorough site analysis based on the aspects mentioned above. It is important to involve and sensitise teams that deal with site acquisition and to implement processes that ensure site selection is properly validated.

Compactness

There is a strong correlation between a building's compactness factor and its operational and embodied carbon footprint.

According to SIA 380:2015 the compactness factor is derived from the ratio of the thermal building envelope area (*Ath*) to the energy reference area (*AE*). This equation gives the building envelope number: *Ath /AE*. Large, compact buildings tend to have a lower heating demand per square metre than smaller, less compact buildings with the same thermal insulation standard. The compactness factor also has an impact on the level of embodied carbon, since compact buildings tend to achieve a better material quantity to surface ratio (e.g. less material input per square metre of net floor area).

If, for example, every other storey of a building with a floor area of 6,720 m² is staggered by three metres as shown in Figure 12, it creates 2,520 m² more building envelope surface, while the floor area and energy reference area remain the same. The compactness factor deteriorates significantly from a good 0.8 to a rather moderate 1.2.[5] Usually the size of building correlates to its compactness value, as shown in the following example. Two buildings, a large one and a small one, both with solid construction, have been evaluated on the basis of the SIA 2040 calculation tool for embodied carbon.

Both buildings have a glazing ratio of 30 percent of the facade area. They differ in size, but not in shape or construction method. A comparison of the values of both buildings shows that the large building with the lower compactness factor has much lower carbon emissions, at 7.7 $kgCO_2/m^2/a$, than the small one, at 12.3 $kgCO_2/m^2$. The compactness factor for a given geometric shape decreases as the volume increases.

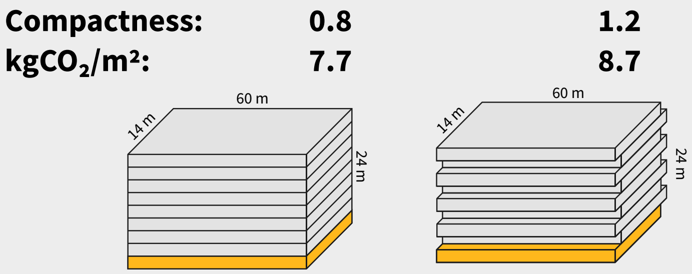


Figure 12: Comparison of compact and non-compact structures[6]

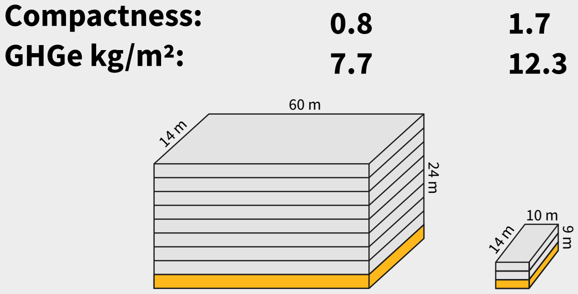


Figure 13: Comparison of big and small structures[7]

[5] cf. SIA-Effizienzpfad Energie 2018, p. 32
[6] based on SIA-Effizienzpfad Energie 2018, p. 29
[7] based on SIA-Effizienzpfad Energie 2018, p. 29

Renewable Electricity

On-site renewable electricity includes any renewable energy that is collected or generated within the site boundary, and that is either consumed on site or sold as surplus electricity to the grid.

To reduce a building's operational footprint, it is important both to produce the maximum amount of renewable electricity on-site, and to reduce purchases of electricity from the grid by using battery storage or newer technologies such as ice storage or air pressure storage.

The absolute global radiation that falls on a module depends on the orientation and tilt angle. In Switzerland, south-facing surfaces are considered best for maximising electricity yield. The relative annual radiation on surfaces related to global irradiation is shown in Figure 14. The horizontal surface equals 100% which, in the case of Switzerland and Germany, is 1100 kWh/m²a. On south facing facades, solar radiation reaches a value of 77% of annual global solar irradiation, and 57% on east and west facing facades.[8]

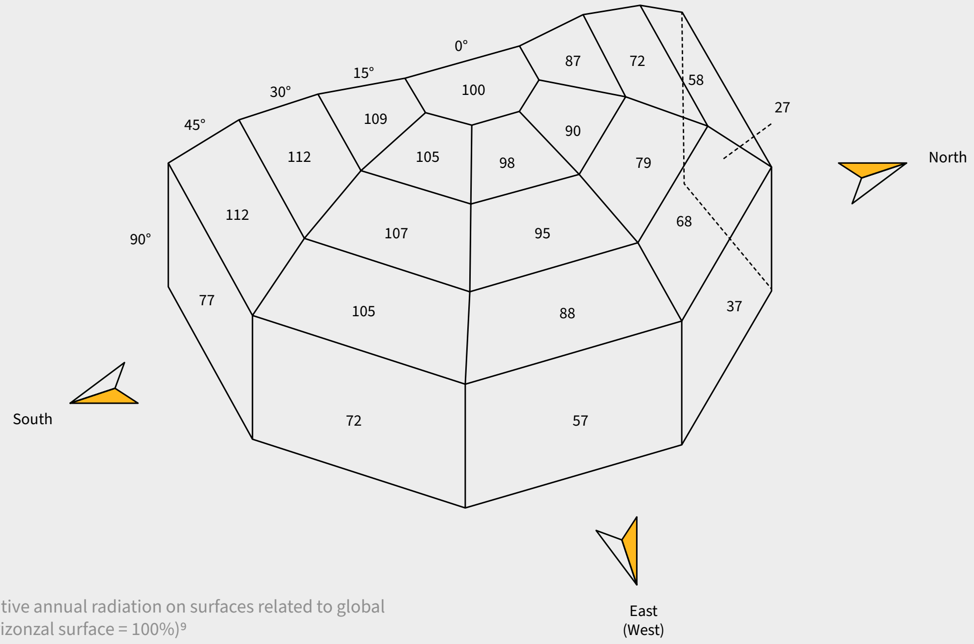


Figure 14: Relative annual radiation on surfaces related to global irradiation (horizonzal surface = 100%)[9]

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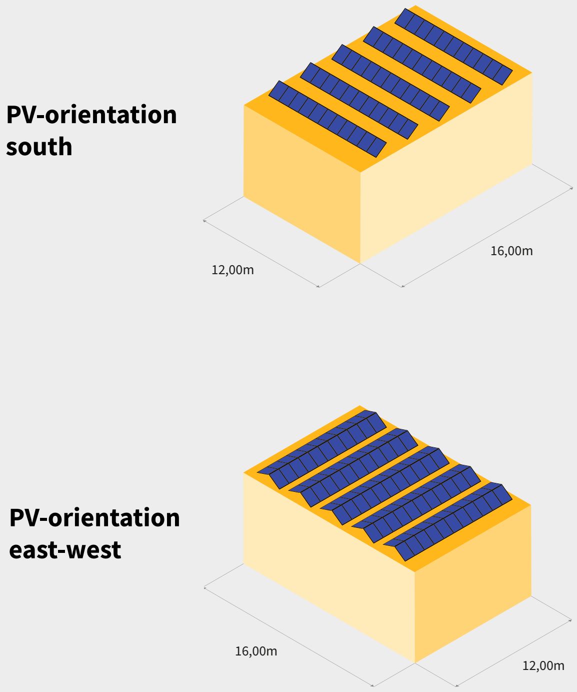
[8] cf. Bagda 2016, p. 51

[9] based on Bagda 2016, p. 52

However, to maximise self-consumption, it is important to consider the building's electricity consumption over the course of the day based on user behaviour. Under certain conditions, it might make sense to direct the horizontal and vertical PV system to the east and west in order to harvest the morning and evening sun.

Another aspect to consider is efficient use of space. East-west oriented PV roof panels with an inclination of 15 to 20 degrees generate only 85% of the power generated by the same quantity of south facing panels.[10] However, east-west installation of a PV system is more space efficient (Figure 15). This means that east-west oriented PV systems can deliver twice the installed kilowatt peak of a south oriented PV system on the same surface.

Green Electricity
Green electricity refers to electricity generated from renewable sources such as wind, water, and sun. In Switzerland, a relatively effective way of reducing a building's carbon footprint is to sign a supply contract for electricity that is labelled "naturemade star". This will help reduce carbon emissions in the operational phase thanks to an electricity mix based 100% on renewable and ecological energy sources. In general, a high percentage of renewable electricity sourced from the grid is very critical to achieving net zero.



PV-orientation south

PV-orientation east-west

Figure 15: Space efficiency of different PV orientation [11] [12]

[10] cf. Burkhardt 2022a
[11] BuGG Bundesverband GebäudeGrün e. V. 2022
[12] Institut für angewandtes Stoffstrommanagement 2021

Natural Shading & Passive Cooling

Natural shading can play a significant part in reducing the energy required for cooling and heating and thus in cutting operational carbon emissions.

Whenever an appropriate outdoor area is available, trees and plants can serve as shading elements in summer and thus reduce solar heat loads and the so-called “heat island” effect.

Heat Island Effect
Heat islands are urban areas that experience higher temperatures than less populated areas. Built features such as buildings, roads, and other infrastructure absorb and radiate solar heat more than natural landscapes such as forests and water areas.

Green facades and roofs are other efficient ways of positively influencing the indoor climate in both summer and winter. Trees can protect a facade from cold winds in winter. Deciduous trees also function as natural dynamic sunshades: they provide shade in summer but do little to restrict solar heat gain in winter after they have lost their leaves. Biodiversity considerations must also be taken into account when designing a greening concept.

Efforts to reduce the energy used for cooling must include strategies for efficient passive cooling. These could include efficient cross-ventilation in apartments, or natural ventilation via inner courtyards or staircases. When it comes to windows, it should be noted that high window sashes are more effective than wide ones in terms of natural cooling.

Strategies for Passive Cooling

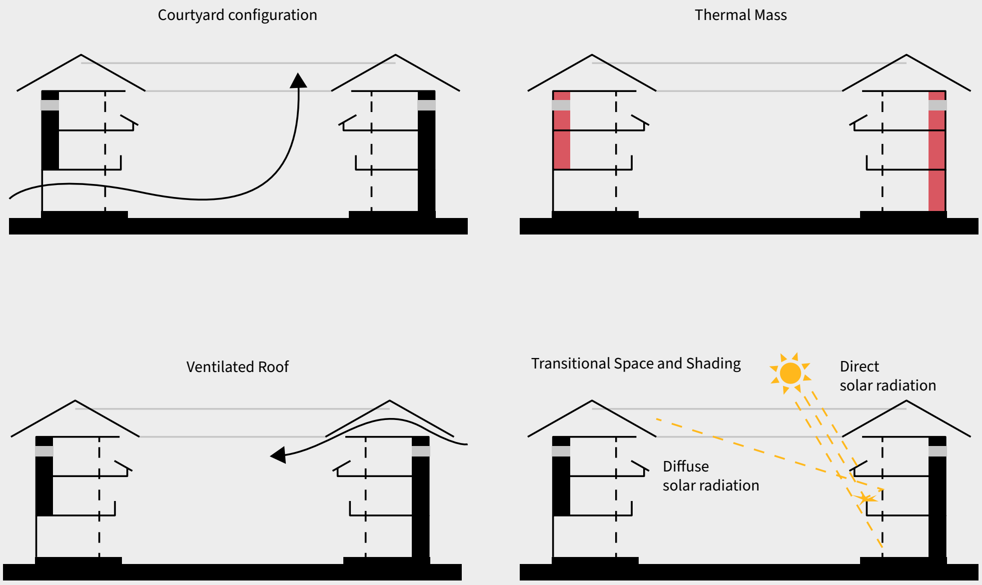


Figure 16: Examples of passive cooling strategies extracted from Passive cooling strategies of Tulou in Fujian, China, 2018 [13]

[13] Yang, Jiaji; Cadima, Paula 2018, p. 2

Underground Levels

Excavation and foundations account for about 10% of embodied carbon emissions. Depending on the number of underground levels this value can also be significantly higher.

Load-bearing components such as foundations, floor slabs and external walls below ground level can usually only be made of CO_2-intensive reinforced concrete components. Excavations also lead to an enormous displacement of ground material which requires a high energy input during construction.

There are two ways to reduce embodied carbon emissions from underground levels. The first and more effective one is to reduce the number of underground levels to a strict minimum, prioritising necessary storage and service areas. This approach usually means reducing or omitting car parking spaces and compensating for this with parking spaces for bicycles. These days, there are also viable concepts for placing car parking spaces above ground in elevator towers if space permits. The second approach, which can be combined with the first, should prioritise reuse of excavation materials for backfilling and outdoor facilities and, if the material quality allows it, for on-site production of concrete or clay-based building materials. This procedure ensures a closed material cycle.

Glazing Ratio

Determining a building's optimal glazing ratio is not a simple task, as it affects a variety of issues that can have opposing effects. One of the most common trade-offs is as follows: the bigger the glazing surface on the facade, the greater the risk of overheating the rooms in the summer months and the higher the embodied carbon, since glass is in general more carbon intensive than typical external wall and facade materials. At the same time, the bigger the glazing surface, the greater the solar gain in winter and the better the daylight factor.[14]

Factoring in these aspects, and based on the analysis of 36 internal development projects, the ideal balance seems to be a glazing ratio in the range of 50-70% for offices and 20-50% for residential buildings. The glazing surface should always be defined project specifically within these two ranges, taking into account factors such as embodied carbon, daylight, solar gain, surrounding buildings and local climatic conditions.

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[14] cf.Büttner et al. 2021, p. 163

Technical Installations

When planning technical installations for building services, one focus is on reducing energy consumption by applying smart, low-tech and efficient options.

As can be seen in the two following diagrams, the distribution of final energy consumption for offices and residential buildings differs significantly. For residential and office buildings the greatest energy consumption is attributable to heating, followed by hot water generation for residential, and air conditioning for offices. Heating, hot water and air conditioning are responsible for up to 81% of energy consumption in residential buildings and 68% in office buildings, meaning that these are the most important levers for reducing a building's operational carbon footprint.[15] The carbon emissions of a technical installation obviously depend on the energy source as well as the level of energy consumption, but these two charts make clear which levers should be pulled to make the most effective reductions in operating emissions.

Technical installations should be evaluated not only from the point of view of their operational emissions, but also in terms of their embodied emissions. The internal analysis of development projects shows that 15 to 20% of embodied carbon emissions are generated by technical installations. The available data on embodied carbon in installations is still very sparse, so it will be necessary in the future to analyse this area in greater detail and to measure the emissions of each installation over its entire life cycle. This area still holds a lot of potential for improvement.

An important question that often arises at project level is whether a centralised or a decentralised ventilation system is more efficient in terms of energy consumption and carbon emissions over the entire life cycle. While decentralised ventilation systems require fewer ducts for distribution, they do involve numerous smaller installations rather than one large one, which could possibly offset the gains in terms of embodied carbon emissions. Meanwhile, the efficiency of a centralised ventilation system is higher than that of multiple smaller decentralised solutions. However, the energy consumption for distribution is higher for centralised solutions due to pressure losses. Ultimately, these factors have to be analysed in more detail to make an informed decision about which system to favour.

Distribution of the energy consumption of private households (2020)

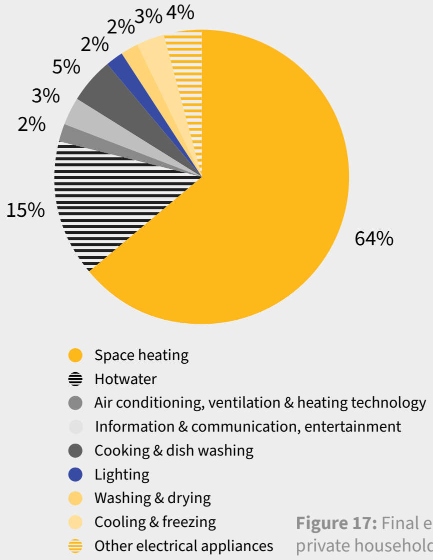

Figure 17: Final energy consumption of private households total 60 TWh/a (2020)[17]

Distribution of energy consumption of offices for the service sector (2020)

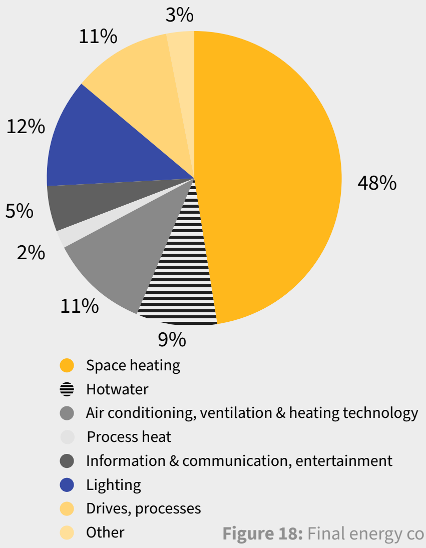

Figure 18: Final energy consumption of offices total 38 TWh/a (2020)[16]

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[15] based on Kemmler and Spillmann 2021, pp. 45–58
[16] based on Kemmler and Spillmann 2021, p. 58
[17] based on Kemmler and Spillmann 2021, p. 45

Thermal Consumption

Operational emissions emitted by a building's heating and cooling system depend on three factors: first, the building's insulation performance; second, its operational efficiency including consumption behaviour; and third, the energy sources used for heating and cooling and the associated carbon impact factor.

For new buildings, the real leverage from a decarbonisation point of view is at the level of the energy source, since the legally prescribed insulation values are already relatively high. Additionally, an increase in insulation values always has a negative impact on the level of embodied emissions. Not surprisingly, a heating or cooling system purely based on renewable energies such as heat pumps fuelled by an on-site PV system or by geothermal energy, leads to a significantly better carbon footprint than fossil-based systems. The task, then, is to maximise the share of renewable energies used for heating and cooling (incl. water).

It is important to note that regardless of the heating system used, carbon emissions also depend on the correct installation, maintenance, and operational management of a building. Many systems around the world operate in an inefficient range which results in a performance gap between the predicted carbon values and the actual values. It is vital, therefore, to ensure a high level of operational efficiency.

In a study conducted by Global Emissions Model of Integrated Systems (GEMIS), different heating systems were compared on the basis of their greenhouse gas emissions. Figure 19 shows the main results of the GEMIS study. Swiss data provided by the KBOB, shown on the same graph, shows a similar picture – except for all the systems based on heat pumps. This discrepancy, measured in kgCO$_2$/kWh, is attributable to the electricity consumer mix in Switzerland which has a significantly lower impact factor due to a higher share of renewables.

Greenhouse Gas Emissions of Different Heating Systems

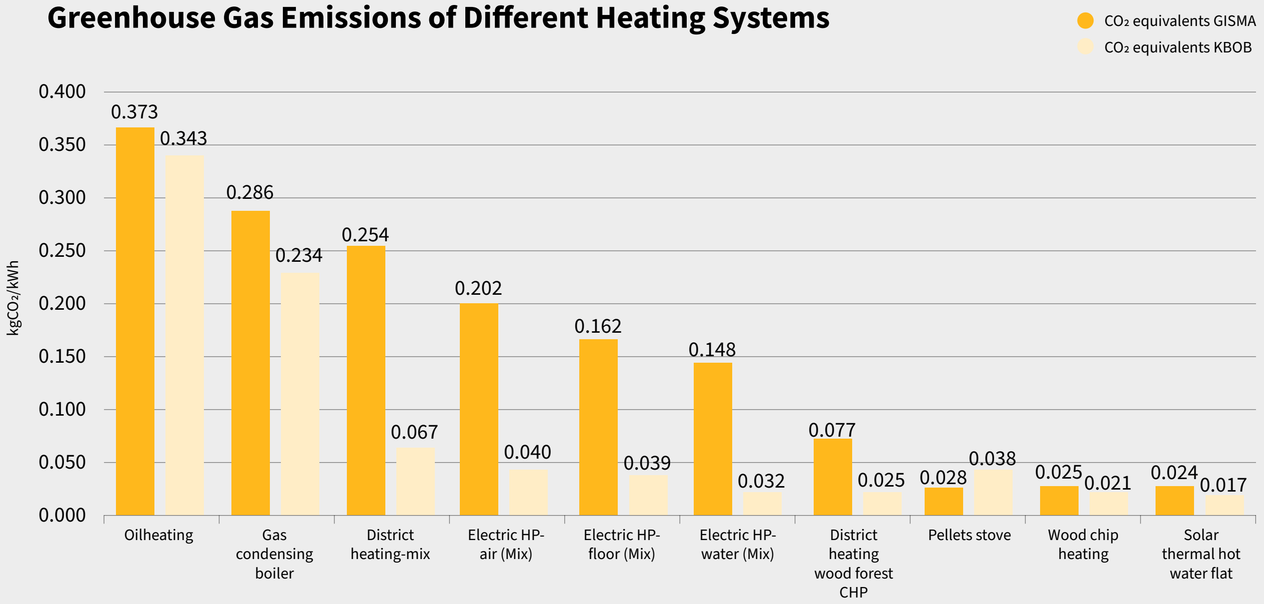

Figure 19: Greenhouse gas emissions of different heating systems [18] [19]

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[18] based on IINAS GMBH 2021

[19] based on Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren KBOB 2022

Materials & Products

A dataset of the embodied and total life-cycle carbon in buildings across Europe was evaluated to determine the distribution of embodied carbon at the building level and to identify the most important levers for change.

The assessment of 168 multi-family buildings and 53 office buildings allows us to determine the average carbon emissions of different building components and building services. Even though these are average values, the major levers can be identified at a relatively high level (see Figure 20 and Figure 21). Of course, as suggested in the previous chapters, the figures depend very much on specific building parameters such as the building's size, compactness, number of underground levels, the applied load-bearing structure, facade type, and type of building services. A comparison of eight Implenia development projects based on the SIA 2040 standard shows a relatively large variation from project to project (Figure 22). The specific distribution of embodied carbon must therefore always be determined at project level.

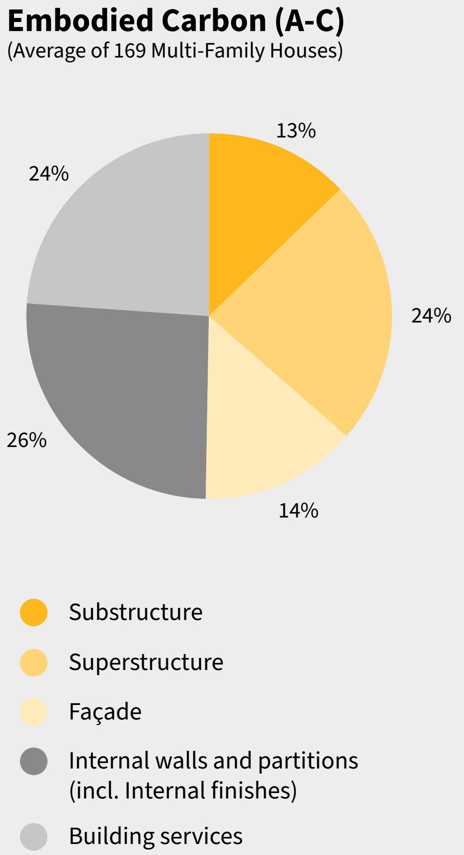


Figure 20: Embodied Carbon (A-C) of 169 Multi-Family Houses

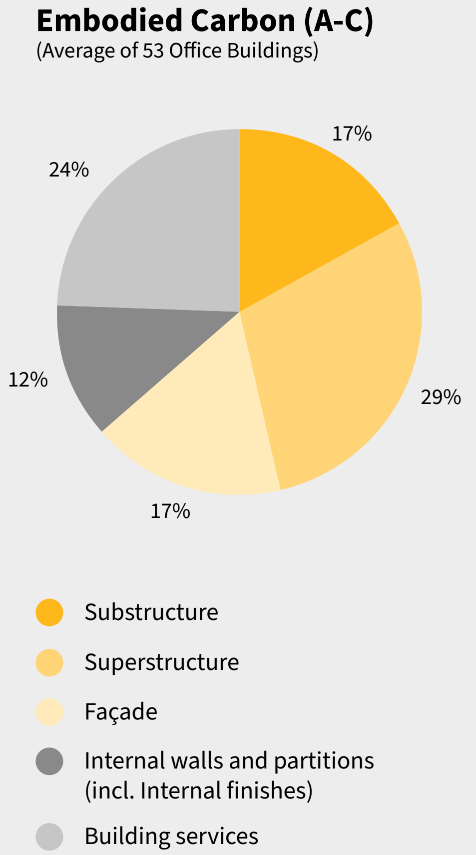
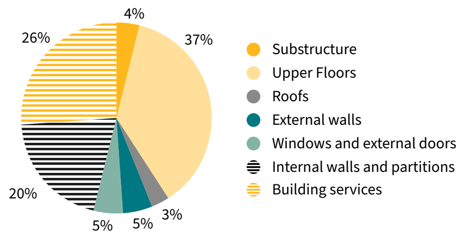


Figure 21: Embodied Carbon (A-C) of 53 Office Buildings

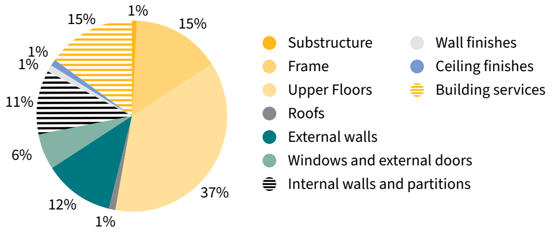
Comparison of eight Implenia Development projects on the level of Embodied Carbon

Embodied carbon (A-C), Project Krokodil



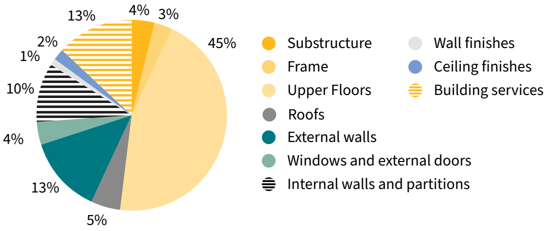
- Use: Residential, Supermarket, Administration
- Surface m² (GIA): 31,035
- Above-ground levels: 6 (on one side 7)
- Underground levels: 1.5 (2.UG only partial)
- Structure: 1-7 floor timber construction, ground floor reinforced concrete

Embodied carbon (A-C), Project Rocket



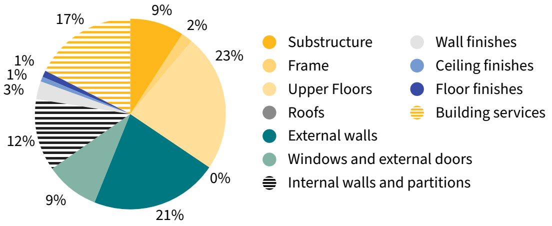
- Use: Residential, Commercial, Hotel
- Surface m² (GIA): 44,800
- Above-ground levels: 32
- Underground levels: 3-4
- Structure: Horizontal construction PI (timber reinforced concrete combination), vertical timber construction

Embodied carbon (A-C), Project Tigerli



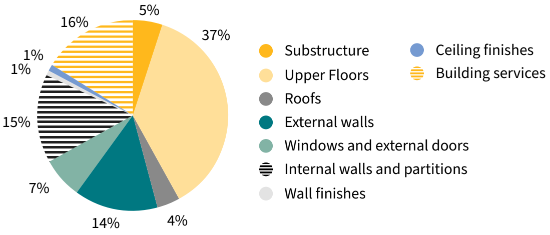
- Use: Social housing
- Commercial Surface m² (GIA): 7,481
- Above-ground levels: 6-7
- Underground levels: 3-4
- Structure: Horizontal construction PI (timber reinforced concrete combination), vertical timber construction

Embodied carbon (A-C), Project Roy



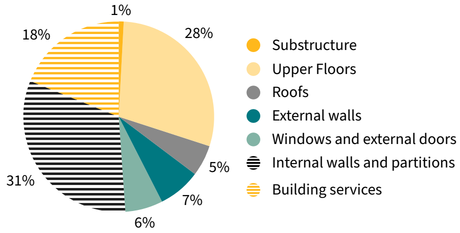
- Use: Residential, Supermarket
- Surface m² (GIA): 31,739
- Above-ground levels: 6-7
- Underground levels: 1
- Structure: Reinforced concrete columns and floors

Embodied carbon (A-C), Project Bigboy



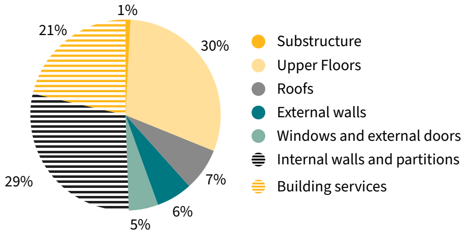
- Use: Residential, Supermarket, Retail
- Surface m² (GIA): 15,994
- Above-ground levels: 15
- Underground levels: 2
- Structure: Reinforced concrete

Embodied carbon (A-C), Project Tender Highrise



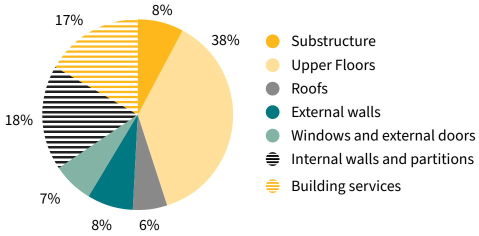
- Use: Residential, Supermarket, Retail
- Surface m² (GIA): 5,884
- Above-ground levels: 10
- Underground levels: 2
- Structure: Reinforced concrete columns and floors

Embodied carbon (A-C), Project Tender Riegel



- Use: Residential, Retail, Supermarket
- Surface m² (GIA): 6,428
- Above-ground levels: 6
- Underground levels: 2
- Structure: Reinforced concrete columns and floors

Embodied carbon (A-C), Project sue&til



- Use: Residential
- Surface m² (GIA): 40,139
- Above-ground levels: 5-6
- Underground levels: 1
- Structure: Timber Construction

Figure 22: Comparison of eight development projects on the level of their embodied carbon

In order to reduce embodied carbon emissions at the component level, different options for the various components must be compared at the CO_2 level throughout the planning and development process. Such a comparison makes it possible to identify the option with the lowest carbon footprint and, if necessary, to make further optimisations. Thanks to the SIA 2040 analysis, Implenia was able to develop benchmarks at the level of individual components and thus provide the development team with more certainty. As suggested by Figure 23, which compares different slab variants, it is also interesting to compare the cost impact of different options. The team can then identify variants that perform better not only on the CO_2 level, but also financially. CO_2-pricing is becoming increasingly important, so it is also worth integrating this aspect into the calculation.

Most important building components in terms of embodied carbon:

- Structural Systems
- Exterior Wall Constructions (load-bearing)
- Interior Wall Constructions (load-bearing)
- Interior Wall Constructions (non-load-bearing)
- Facade Cladding Systems
- Floor Slab Constructions
- Roof Slab Constructions
- Foundation Constructions
- Window Frames and Glazing
- Floor Finish Constructions

CO_2-pricing

CO_2-pricing incentivises companies to reduce their emissions by introducing a price on greenhouse gas emissions. Although CO_2-pricing is not yet mandatory in most countries, some companies already include an estimated internal carbon price as a so-called "shadow price" in their business case.

Floor Slab Constructions

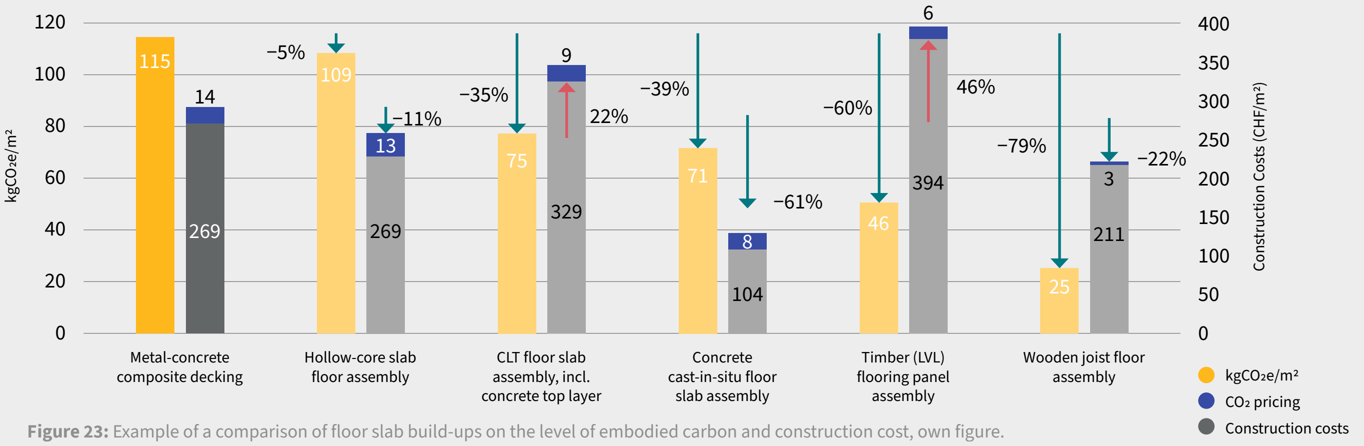
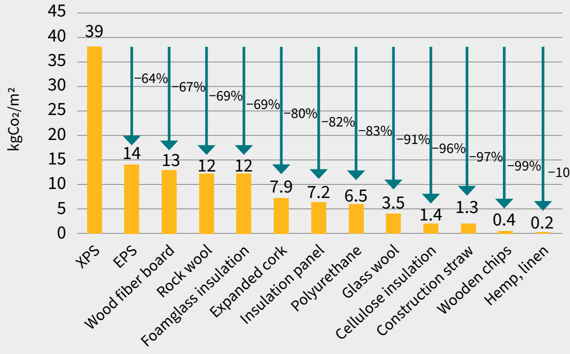


Figure 23: Example of a comparison of floor slab build-ups on the level of embodied carbon and construction cost, own figure.

Once a component's build-up has been defined, further optimisation can be run at the level of the individual material layers by using less of the same or by selecting more eco-friendly alternative materials or products (e.g. higher recycling content, energy efficient production process, short transportation distance). In doing so it is important to compare materials and products with similar performance levels. The selected materials and products should not, of course, compromise the functional performance of the component (e.g. acoustics or fire protection). In a proper comparison of different thermal insulation materials, for instance, a targeted u-value (thermal transmittance) would have to be defined and compared with the respective lambda values (heat conductivity) of the products investigated.

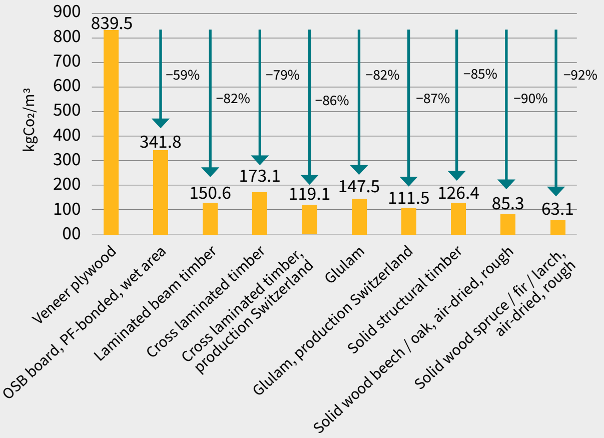
Thermal Insulation

Figure 24: Carbon comparison of different thermal insulation materials



Timber Products

Figure 25: Carbon comparison of different timber products



Excursus on Building Materials

High carbon materials:
Materials which generate a considerable amount of operational and embodied carbon emissions over their life cycle.

Examples:
- *Most steel products*
- *PUR, PIR, XPS insulation*

Low carbon materials:
Materials that have lower embodied and operational carbon emissions compared to conventional materials without compromising the end product's functional requirements and performance properties.

Examples:
- *Recycled metals*
- *Linoleum*
- *Clay*

Carbon-neutral materials:
Materials that, over the course of their entire life cycle, remove as much carbon from the atmosphere as they release.

Examples:
- *Most timber products because they release CO_2 at the end of life*
- *Products with carbon capturing capabilities (i.e. specific concrete products)*

Carbon-negative materials:
Materials that remove more carbon from the atmosphere than they release over the course of their entire life cycle.

Examples:
- *Fast growing natural fibres (i.e. hemp, straw, wool)*
- *Mycelium (mushroom-based materials)*

Capacity for on-site storage

Excavation works lead to an enormous displacement of soil material, which requires a high energy input during construction. This in turn impacts the CO_2 balance of the entire execution phase. As suggested in a previous chapter, the reuse of excavated material is an important lever for reducing a building's carbon footprint. However, if excavated material is used for backfilling, or for landscaping, or for on-site concrete production, there has to be sufficient space to store the material during the execution phase. The same applies to the reuse of existing building components in replacement projects, since these components have to be stored properly throughout the construction period. If reuse is going to be at all possible, planners must already be thinking about the available storage space when choosing the project's location. If there is sufficient space for storage, this space must be integrated into the site logistics concept at an early stage. The need for adequate space means that large-scale projects built in different phases usually offer the best conditions for reuse.

Carbon Offsetting

The term “net zero” does not imply that there are absolutely no emissions, because it allows the possibility of offsetting remaining carbon emissions through sequestration or “negative emission” strategies.

The remaining carbon emissions at building level are compensated at another level than the building itself by investing in offsetting programmes. However, the concept of carbon offsetting is quite contested in the context of net zero. Critics legitimately point out that the mere possibility of buying carbon credits from third parties reduces companies’ incentive to work on their own carbon footprint through planning, innovation, etc. – so the true source of the problem is not addressed. This paper shares this opinion and sees carbon offsetting purely as an interim solution when technical solutions or circumstantial reasons mean that a building cannot achieve net zero standards. Carbon offsetting should only be used to reach net zero, therefore, if all technical measures have failed or if uncontrollable exogenous factors (e.g. a legal requirement to connect to a district heating system based on fossil fuels) make it impossible to achieve the target.

There are different ways to offset carbon emissions. Not every offsetting method has a long-term compensatory effect. Some types of offset may just prevent carbon emissions, some may only sequester carbon emissions in the short and medium term, while others may serve as a long-term carbon sink.

To reach net zero by means of offsetting, the offsetting itself must lead to the extraction of carbon from the atmosphere and the sequestration of that carbon in biomass or in minerals. The mere avoidance of carbon emissions by increasing the efficiency of industrial processes, for instance, does not in fact create a carbon offset. The overall equation remains carbon positive. In addition, caution is required when it comes to biological sequestration. Biobased materials can remove carbon dioxide through photosynthesis as a plant or tree grows – or regrows once the biomass is harvested. However, the captured carbon only remains bound in the biomass until it burns or rots, at which point the wood, for example, releases the same amount of carbon that it previously stored. Geological carbon sequestration provides a long-term solution: this retrieves carbon from the atmosphere and captures it in underground geological formations – rocks – for an indefinite amount of time.

Carbon Balance of Different Types of Offsetting

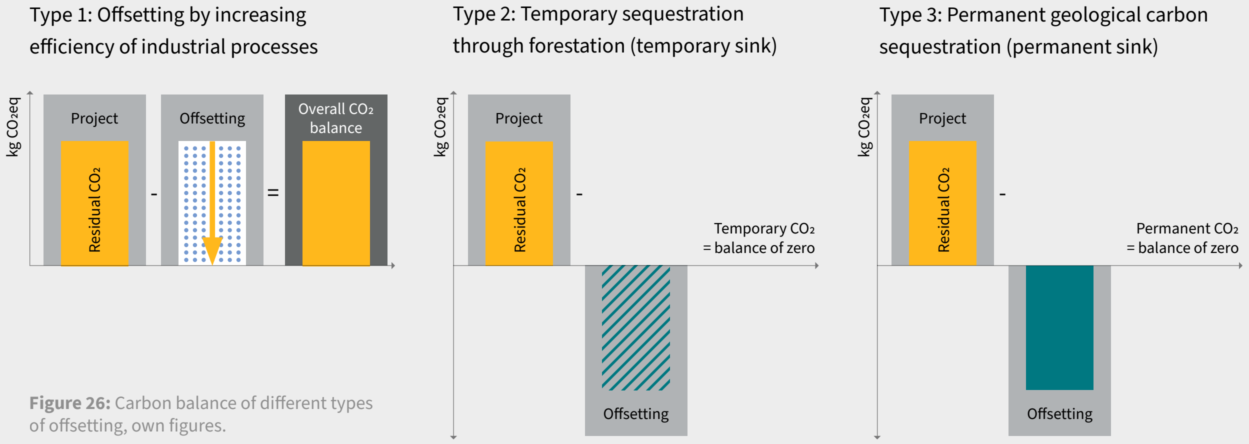


Figure 26: Carbon balance of different types of offsetting, own figures.

Conclusion

Because it accounts for 37% of greenhouse gas emissions, the construction sector has great potential to help in the effort to achieve global climate targets.

In order to meet these targets, governmental regulation is expected to increase in the upcoming years as a framework is established for net zero buildings. There is already a noticeable increase in market demand for climate resilient, net zero buildings, especially by institutional investors. To meet this demand, real estate developers, contractors and operators need to adapt their approaches, processes and decision-making, and must consider the issue of carbon emissions at all levels of the decision-making process. While there are already calls for climate-positive buildings, the path towards net zero buildings has only just begun. To conclude, based on the research and analysis underlying this paper, the following action guidelines for decarbonisation towards net zero should be considered:

Introduce carbon **indicators** in all project phases and apply tools to measure emissions.

Define an **achievable carbon target** for a project at an early stage of development based on the project's location and use typology.

Work hard to identify a project's **optimal design parameters** in terms of compactness, size, orientation, renewable energy potential, glazing ratio, structural system and levels by means of feasibility studies and comparative analysis.

Focus on **embodied carbon**: optimise each components' build-ups, and opt where possible for carbon neutral or negative materials. Put **LCA indicators** at the centre of decision making throughout the design process.

Produce and buy **renewable energies** for heating, cooling and electricity consumption.

Choose efficient **technical installation** only, and only when necessary. Make sure they are operated efficiently during the operational phase.

Introduce new project management processes based on cross-phase **collaboration** and **shared incentives** towards the targeted carbon footprint.

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Sustainability Report

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