PCAF Guidance on financing the European building transition to net zero

Financing towards net-zero buildings

a PCAF project

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About PCAF: The Partnership for Carbon Accounting Financials (PCAF) is a global, industry-led initiative of financial institutions that work together to develop and implement a harmonized approach to measure and disclose the greenhouse gas (GHG) emissions associated with loans and investments, known as financed emissions. Currently, over 300 financial institutions have committed to the initiative. In November 2020, PCAF published the first-ever Global GHG Accounting and Reporting Standard for Financial Industry, which covers the financed emissions of loans and investments in commercial real estate, mortgages, and various other asset classes. PCAF collaborates with several organizations, institutions, and coalitions, including CDP, the Science-Based Targets initiative (SBTi), and the UN-convened Net-Zero Asset Owner Alliance (NZAOA). PCAF is supported by Guidehouse, a global consulting firm specializing in energy, sustainability, risk, and compliance for the financial industry. Guidehouse serves as the Secretariat of PCAF, providing technical support to PCAF signatories in the development and implementation of the Global GHG Accounting and Reporting Standard for the Financial Industry.

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Disclaimer: The sole responsibility for the content of this publication lies with the authors.

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Executive Summary

Need for a net-zero building transition

The transition to a net-zero economy by 2050 and achievement of the Paris Agreement requires the transformation of all sectors. At the same time, the urgency for net-zero emissions and fossil fuel independence is greater than ever. In Europe, the building sector needs particular attention as it contributes to approximately 36% of greenhouse gas (GHG) emissions. Additionally, nearly the entire building stock is considered energy inefficient, with an average building renovation rate of less than 1% each year across countries in the European Union (EU).[1]

Key role of the financial industry

Significant investments are required to transform the European building sector towards net zero. Building renovation is one of the sectors with the most significant investment gap in the EU. It has been estimated that 275 billion euros of additional investment in building renovation is needed each year to achieve the 55% GHG reduction target of the EU Renovation Wave by 2030 compared to 1990 levels.[2] In order to finance this transformation, the financial industry requires clear guidance on how to set priorities to decarbonize their mortgage and commercial real estate (CRE) portfolios rapidly. While more and more financial institutions commit to net zero and join relevant initiatives, few have defined specific actions to achieve the targets. Upcoming binding regulations such as by the European Banking Authority (EBA)[3] on disclosing financed emissions by 2024 demonstrate the need for action.

Required guidance on how to decarbonize building portfolios

The purpose of this report is to provide guidance to financial institutions on how to approach the net-zero journey and decarbonize their building portfolios using a stepwise approach, from any starting position. This guidance is intended for any financial institution, particularly for banks and investors with known use of proceeds in mortgage and CRE portfolios.

Joint vision on net-zero buildings

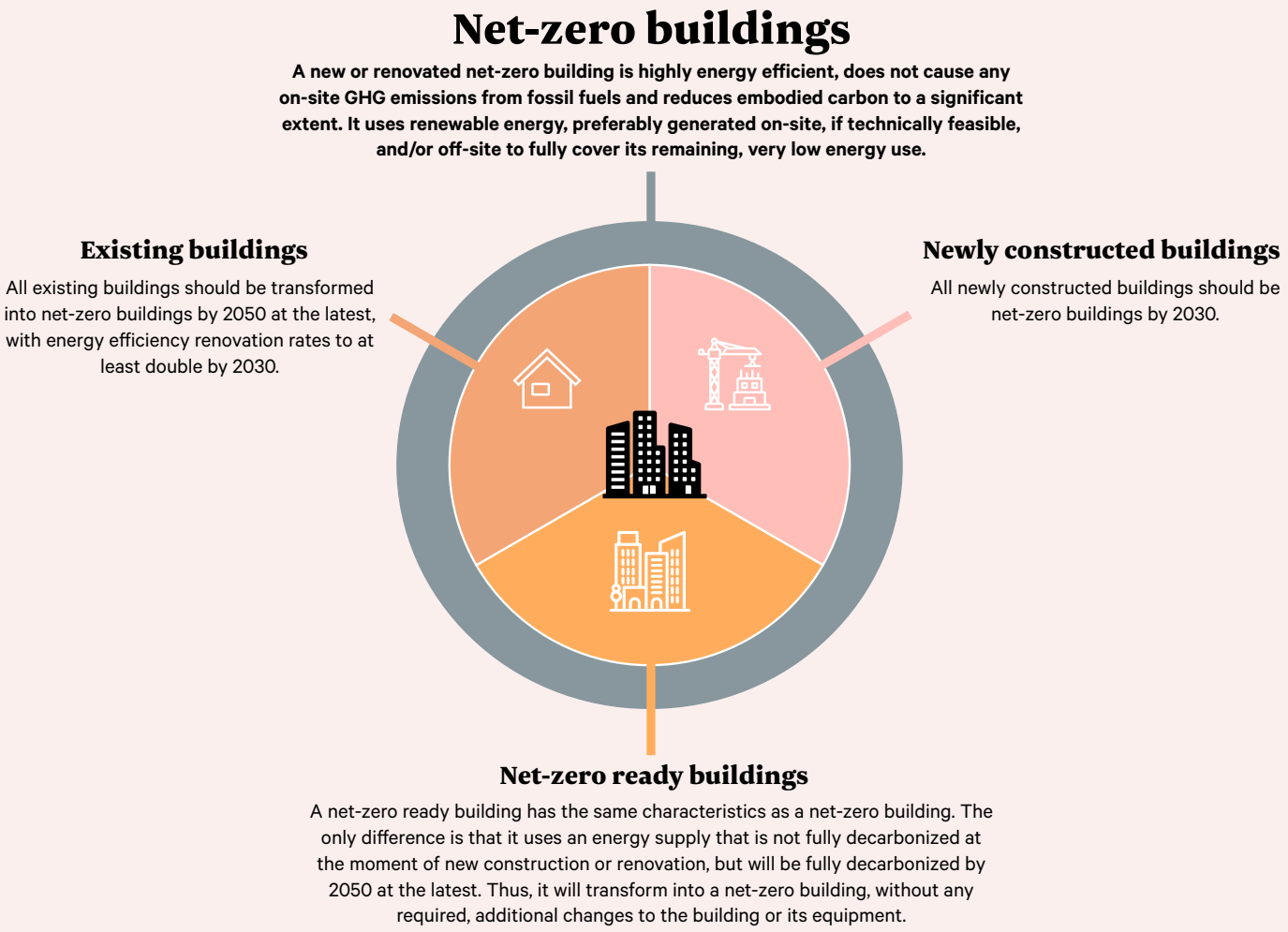
Financial institutions expressed the need for a joint vision of how a net-zero building is defined, specifically, what the corresponding requirements are and how to get there. This is considered a crucial prerequisite to starting the net-zero journey and financing the European building transition. This guidance provides an aligned net-zero building definition which seeks to reduce the energy use through energy efficiency measures and supply the reduced energy use through 100% renewable energy, preferably on-site. At the same time, a net-zero building does not generate any on-site GHG emissions from fossil fuels and reduces embodied carbon to a significant extent. Corresponding requirements support financial institutions in identifying and financing corresponding buildings. Based on the definition, an overarching pathway towards net-zero buildings guides financial institutions to steer their strategies and actions.

1 Buildings Performance Institute Europe (BPIE) (2017); European Commission (EC) (2020a)

2 European Commission (EC) (2020c)

3 In the EBA's binding standards on Pillar 3 disclosures on Environmental, Social and Governance (ESG) risks, PCAF is referenced for providing the methodologies to measure and disclose financed emissions.

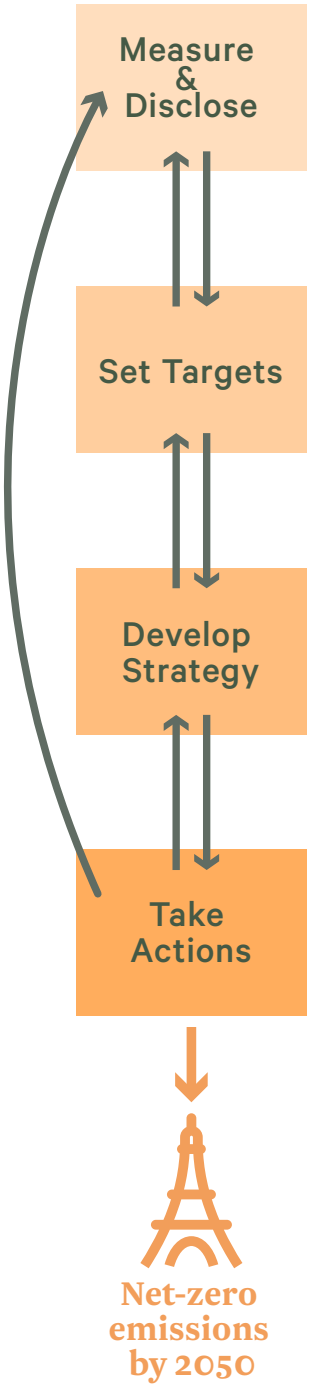
Figure 1: Aligned net-zero building definition and its components



The net-zero journey

The net-zero journey includes four key steps, i) measuring and disclosing of GHG emissions, ii) establishing climate targets, iii) developing a strategy for implementation and iv) taking action. This guidance presents a stepwise approach along these four steps for financial institutions to decarbonize their mortgage and CRE portfolios. This approach finds its foundation in the experiences of financial institutions that already started their net-zero journey. It is important to note that it is intended as an iterative process with feedback, lessons learned and good practices continuously feeding into this loop.

Figure 2: Stepwise approach to net zero



Key steps of the net-zero journey

Measure and disclose: Measurement of GHG emissions is the first step in starting the net-zero journey. This data forms the basis on which financial institutions can meet disclosure rules, identify the highest emitters in the portfolio, set climate targets, and prepare further actions. The PCAF European building emission factor database serves as a key tool for financial institutions to overcome data gaps and thus, to measure and track the financed emissions of their building portfolios. This publicly available database offers a specified set of emission and energy factors for mortgages and CRE for all countries in the EU, as well as Norway, Switzerland and the United Kingdom.

Set targets: After portfolio emissions have been measured and disclosed, the next step in the net-zero journey – target setting – involves the development of climate targets and establishment of a corresponding portfolio decarbonization pathway. This exercise can be done with the help of the Sectoral Decarbonization Approach (SDA) by the Science Based Targets initiative (SBTi). The decarbonization pathway of an illustrative CRE portfolio in this guidance highlights the immediate need for considerable efforts before 2030 to reach the ultimate net-zero emissions objective by 2050.

Develop strategy: Following target setting and pathway development, financial institutions need to create an implementation strategy how to decarbonize their mortgage and CRE portfolio in line with the identified pathway. Based on the characteristics of the building portfolio, corresponding decarbonization plans with appropriate emission reduction measures can be determined. A menu of emission reduction measures based on proven technologies is provided in this report, which financial institutions can apply according to their financed building types and conditions. Illustrative cases depict possible modular combinations of the emission reduction measures depending on the building characteristics.

Take action: The last step of the net-zero journey is about making the building transition actionable, particularly through the development and deployment of net-zero transition products and services. A set of suitable financial products and services is presented, possessing considerable climate impact, compatibility with a net-zero pathway and upscaling potential. Depending on financed building types, financial institutions are able to select and implement the applicable financial products and services to decarbonize their building portfolio.

Urgent need for immediate action

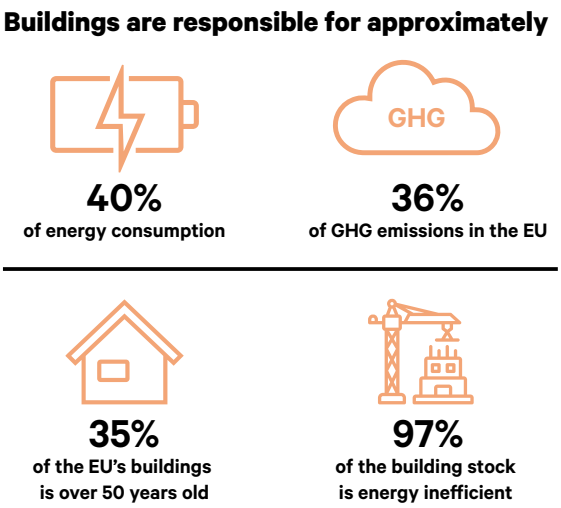
2030 marks a critical intermediate target to achieve a net-zero building stock by 2050. Strong decarbonization efforts need to happen before 2030 to stay in line with the Paris climate goals, especially due to the static nature of the building sector. The later decarbonization measures are initiated, the more drastic they need to be, resulting in higher costs and stranded assets.[4] Moreover, as the regulatory environment changes, it may become harder to sell poorly performing assets. Consequently, effort levels and speed of activities to decarbonize building portfolios need to increase immediately.

4 World Bank (2015)

1 Key role of the financial industry to enable the European building transition

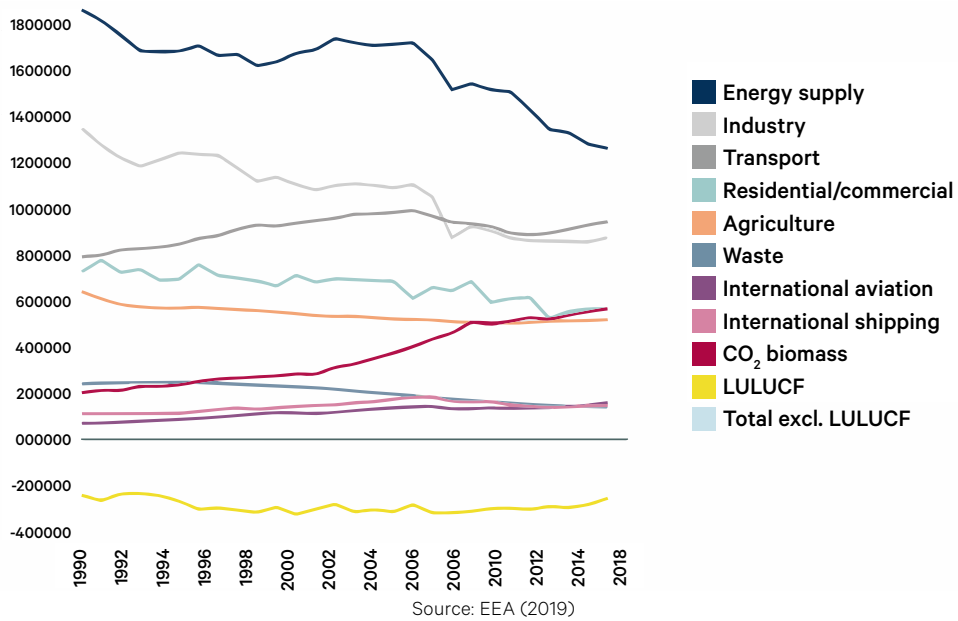
The transition to a net-zero economy by 2050 and achievement of the Paris Agreement requires the transformation of all sectors. At the same time, the urgency for net-zero emissions and fossil fuel independence is greater than ever. The building sector needs particular attention as it accounts for 40% of energy consumption and 36% of GHG emissions in the EU. Figure 4 depicts the steady and significant share of GHG emissions in European residential and commercial buildings. Over 97% of the building stock is considered energy inefficient (i.e. below an energy performance certificate (EPC) rating A), resulting in immense energy losses and expenditure.[5] On average, less than 1% of buildings are renovated each year across EU countries.[6] Therefore, decarbonization measures in existing buildings need to increase drastically and be target-oriented while new buildings need to lead the way towards net-zero emissions.

Figure 3: Key figures on the EU building sector



Sources: EC (2020a), BPIE (2017)

Figure 4: GHG emission development by sector in the EU, in kt CO_2e



Source: EEA (2019)

5 Buildings Performance Institute Europe (BPIE) (2017)
6 European Commission (EC) (2020a)

Given the urgency of the matter, renovations and energy efficient buildings are at the heart of the European Green Deal, with the objective to transform Europe into the first climate-neutral continent by 2050.[7] The current revision of the Energy Performance of Buildings Directive (EPBD)[8] aims to specify the corresponding transition needed to decarbonize the building stock and to deliver required intermediate targets, e.g. to at least double building renovation rates until 2030 as part of the Renovation Wave.[9]

Significant investments are required to realize these initiatives and transform the European building sector towards net zero. Building renovation is one of the sectors with the most significant investment gap in the EU. It has been estimated that to achieve the proposed 55% GHG reduction target of the Renovation Wave by 2030 compared to 1990 levels, 275 billion euros of additional investment in building renovation is needed each year.[10] [11]

To accelerate the transition of the building stock towards net zero, financial institutions need clear guidance on how to set priorities to decarbonize their building portfolios. This includes providing finance to support specific renovation approaches, appropriate new construction and the implementation of highly energy efficient technologies and their development. This will enable the necessary long-term structural change of the European building stock. As the financial industry takes steps towards net zero, it will incentivize building owners, real estate developers and the broader building sector. Currently, more and more financial institutions commit to net zero and join relevant initiatives, but few have defined specific actions to achieve the targets. Upcoming binding regulations such as by the EBA[12] on disclosing financed emissions by 2024, stress the need for action.

The PCAF project Financing towards net-zero buildings, funded by the Laudes Foundation, addresses the need to mobilize the financial industry to accelerate the transition of European buildings towards net zero by 2050. It guides financial institutions to stay on the required course and report on the positive impact in a transparent, robust, and standardized way. PCAF supports financial institutions throughout the entire net-zero journey, from measuring and disclosing GHG emissions, over setting climate targets and developing a decarbonization strategy to taking appropriate actions to achieve a net-zero emission building stock at least cost and without detours. This constitutes an iterative process with feedback, lessons learned and good practices continuously feeding into this loop.

7 European Commission (EC) (2019)
8 European Commission (EC) (2021c)
9 European Commission (EC) (2020b)
10 European Commission (EC) (2020c)
11 Based on the Impact Assessment for the revision of the EPBD, additional annual investment costs in the two HIGH scenarios are estimated at about 152-157 billion euro in 2030 (European Commission (EC) (2021a)).
12 EBA has published binding standards on Pillar 3 disclosures on Environmental, Social and Governance (ESG) risks, in which they require all banks under its jurisdiction (EU banks & non-EU banks with EU subsidiaries) to disclose financed emissions from June 2024 onwards (European Banking Authority (EBA) (2022)). PCAF is referenced for providing the methodologies to measure and disclose financed emissions.

The purpose of this report is to provide clear guidance to financial institutions on how to join the net-zero journey and decarbonize their building portfolios using a stepwise approach, from any starting position. It is intended for any financial institution, particularly for banks and investors with known use of proceeds in mortgage and CRE portfolios.

The following section, section 2, explores the challenges impeding the financing of a net-zero building stock and requirements to overcome them.

Section 3 develops a harmonized net-zero building definition as a prerequisite to financing the building transition.

Building on these specifications, section 4 presents a stepwise approach to reaching a net-zero building stock by 2050. The approach is based on experiences of financial institutions that already initiated their net-zero journey. This section provides guidance on the required effort level and speed to decarbonize building portfolios as well as tools and indicators to measure and track the progress. To make the building transition actionable, a set of technical measures and financial products complement the pathway.

2 Addressing challenges to finance a net-zero building stock

A range of challenges have prevented the European financial industry from being able to engage in the transition of the building stock towards net zero on a large scale. The key challenges presented in this section have been identified together with the Core Project Team and Expert Advisory Group of the PCAF project Financing towards net-zero buildings, consisting of European and global financial and building sector stakeholders.

The corresponding needs of financial institutions can be broken down into three categories:

A&U aggregation & upscaling,
D&M data & methodology and
A&V alignment & vision.

A&U **Fragmented building projects** - The European building sector mostly consists of micro and small-sized enterprises. This fragmentation is reflected in the size of building projects, and consequently, in limited financial attractiveness of individual projects to financial institutions. New business models and financial products for financial institutions are required to aggregate project size, resulting in larger project pipelines, energy and cost savings as well as the enhanced speed of deep energy retrofits and sustainable construction.

A&U **Limited awareness of benefits** - Key actors in the building sector (such as landlords) are often unaware of the multiple benefits of investing in sustainable building improvements (e.g. raised property value, energy and cost savings) and lack technical expertise. Besides the need for awareness raising and marketing campaigns as well as technical trainings, adequate financial products can incentivize sustainable construction and renovation. The more products are on the market, the more actors will become aware.

D&M A&V **Lack of shared vision and understanding of data needs** - Key actors from policy, business, and finance lack a common vision of how to decarbonize the building stock, i.e. through which measures and at what speed. A shared understanding of data needs and quality, as well as robust and standardized information management across the information value chain is a precondition, e.g. regarding the GHG assessment along the whole life cycle of buildings, including both operational and embodied carbon.

A&U D&M **Scattered data availability to assess climate impact** - The overall fragmentation of the European building sector, especially the different implementation and scope of EPCs as well as the variety of building type classifications across European countries, results in scattered and incomplete data. This scattered data landscape impedes the measurement of financed emissions from mortgage and CRE portfolios. The status quo assessment is key to taking further steps towards net zero.

D&M A&V **Lack of aligned approaches to track progress** - Methodologies for net-zero target setting are in place and are applied by frontrunner financial institutions but are only partially aligned. The lack of aligned approaches and clear indicators hinders tracking the progress of the net-zero transition of the European building stock.

A&U **Limited collaboration between financial industry and policymakers** - Financial institutions have limited collective action in engaging with European policymakers and regulators to increase the ambition level on the decarbonization of buildings. Aligning actions between the policy and financial industry can raise broad awareness and accelerate the building transition, e.g. by combining financial products with existing subsidies.

A&V **Lack of harmonized guidance** - The financial industry lacks clear guidance on how to decarbonize their portfolios and thus, accelerate the European building stock transition. More and more financial institutions commit to net zero and join relevant initiatives, but few have defined specific actions to achieve the targets and to set up financial products and services that support building sector clients to foster long-term structural change.

Understanding the challenges and addressing the identified needs (see figure 5) are key to overcoming the factors that impede the European financial industry in financing a net-zero building stock.

Figure 5: Categories of needs to address challenges

A&U	D&M	A&V
Aggregation & Upscaling	**Data & Methodology**	**Alignment & Vision**
The financial attractiveness of sustainable building projects needs to be raised through bundling and up-scaling. This can be fostered through appropriate financial products, creating financial incentives to make buildings more sustainable as well as marketing materials, highlighting the economic benefits of emission reduction measures.	To initiate the net-zero journey, data sets are required enabling financial institutions to estimate the financed emissions of their building portfolios and set net-zero targets. This needs to be accompanied by clear indicators and standardized approaches to monitor the climate impact and progress towards net zero.	Collaboration between organizations and other relevant stakeholders working on net-zero target setting methods and decarbonization of the built environment is crucial to foster alignment and joint vision, thus, enabling financial institutions to take on their key role in the building transition.
Read more in sections 4.3 and 4.4	**Read more in sections 4.1 and 4.2**	**Read more in sections 3 and 4**

Considering the identified needs, the following sections provide guidance to accelerate the transition towards net-zero buildings, starting with a consolidated definition of a net-zero building, followed by recommendations along a stepwise approach towards net zero.

3 Alignment of net-zero building definitions

It is crucial for financial institutions to understand the concept of net-zero buildings and the corresponding requirements. Due to the variety of different terminology and scopes of existing definitions, financial institutions approached PCAF and raised the need for a harmonized net-zero building definition. This is a prerequisite to start the net-zero journey and finance the European building transition.

To provide financial institutions with an aligned net-zero building definition, PCAF attempted to harmonize existing terminology and definitions on (net-) zero energy and emission buildings (see Annex I for a non-exhaustive list). This alignment has been done in close consultation with the Core Project Team and Expert Advisory Group of the PCAF project Financing towards net-zero buildings.

The evolved building definition (see figure 6) seeks to reduce the energy use through energy efficiency measures and supply the reduced use through 100% renewable energy, preferably on-site where reasonable and feasible. At the same time, a net-zero building does not generate any on-site GHG emissions from fossil fuels and reduces embodied carbon to a significant extent (with an intermediate target of at least 40% less embodied carbon by 2030). Corresponding requirements support financial institutions in identifying and financing corresponding buildings.

It is important to note that this is considered a working definition which may be updated and further specified over time, potentially due to perceived ambiguity, widening of scope, clearly evolving paradigms on new regulations, thresholds, etc.

Figure 6: Aligned net-zero building definition

Aligned net-zero building definition

All newly constructed buildings should be net-zero buildings by 2030 and all existing buildings should be transformed into net-zero buildings by 2050 at the latest, with energy efficiency renovation rates to at least double by 2030.

A **new or renovated** net-zero building is **highly energy efficient, does not cause any on-site GHG emissions from fossil fuels** and **reduces embodied carbon to a significant extent**. It uses **renewable energy, preferably generated on-site**, if technically feasible, and/or **off-site** to fully cover its remaining, very low energy use.

REQUIREMENTS:

Energy efficiency:

- A net-zero building is highly energy efficient, i.e. there should be very ambitious thresholds for energy needs and/or use, that, e.g., can be defined as total primary energy use[13] (as potentially included in the updated EPBD).

Energy supply:

- A net-zero building uses locally available renewable energy sources, e.g. solar thermal, solar PV, PV thermal and geothermal, if technically feasible.
- In case of green electricity use, energy attribute certificates (Renewable Energy Certificates – RECs, Guarantees of Origin – GOs, Power Purchase Agreements – PPAs conveying RECs or GOs) are required and need to comply with the GHG Protocol Scope 2 Quality Criteria[14] and with an additionality component (ensuring additional renewable energy capacity). They need to be issued by an accredited external provider. Green gas needs to be directly sourced (e.g. substantiated through direct contracts with corresponding suppliers).

Emission scope:

- All buildings should be net-zero operational carbon. Fluorinated refrigerants (specifically hydrofluorocarbons – HFCs and hydrofluoroolefins – HFOs) need to be replaced by alternative sustainable solutions (e.g. natural refrigerants or sorption cooling technologies).
- Newly constructed buildings and renovations will have at least 40% less embodied carbon by 2030, with a focus on significant upfront carbon reduction, resulting in net-zero embodied carbon by 2050.[15]
- Carbon removals can be used to neutralize any residual carbon emissions (max. 10%[16]) that cannot yet be eliminated. The emissions can be offset within the project or organizational boundary or through verified offsetting schemes.

Methodological scope:

- Any very low residual energy use still required is fully covered within a monthly or shorter time interval of a year.
- In case of surplus on-site generation in any time interval, this should neither be transferred to another time interval nor credited as exported energy to avoid double-counting.

13 The metrics 'energy needs' and 'total primary energy use' are defined in EN ISO Standard 52000.
14 Greenhouse Gas Protocol (GHG Protocol) (2015)
15 United Nations Framework Convention on Climate Change (UNFCCC) (2021), World Green Building Council (WorldGBC) (2022)
16 Science Based Targets initiative (SBTi) (2021a)

Acknowledging that not all buildings can be net-zero buildings from the start, an aligned net-zero ready building definition is also provided (see figure 7). A net-zero ready building has the same characteristics as a net-zero building. The only difference is that it uses an energy supply such as electricity or district heat that is not fully decarbonized at the moment of new construction or renovation, but will be fully decarbonized by 2050 at the latest. Thus, a net-zero ready building will transform into a net-zero building by 2050 at the latest, without any further required modifications to the building.

Figure 7: Aligned net-zero ready building definition

Aligned net-zero ready building definition

A net zero-ready building will transform into a net-zero building by 2050 at the latest, without any required, additional changes to the building or its equipment.

A **new or renovated** net-zero ready building is **highly energy efficient, does not cause any on-site GHG emissions from fossil fuels and reduces embodied carbon to a significant extent**. It uses **renewable energy, preferably generated on-site**, if technically feasible, and/or **an energy supply that will be fully decarbonized by 2050 at the latest** to fully cover its remaining, very low energy use.

REQUIREMENTS:

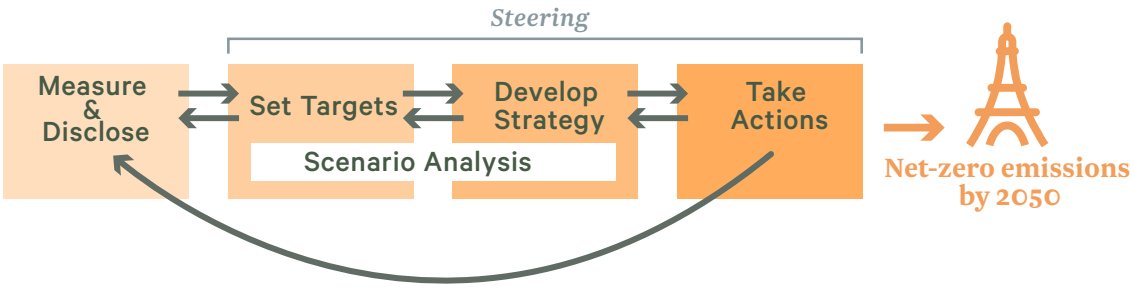
The same requirements apply as for the net-zero building definition.

4 Stepwise approach for financial institutions towards a net-zero building stock by 2050

This section presents a stepwise approach that guides financial institutions through the decarbonization process of their mortgage and CRE portfolios, i.e. from measuring and disclosing GHG emissions, over setting climate targets and developing a decarbonization strategy to taking actions (see figure 8). It is an iterative process with feedback, lessons learned and good practices continuously feeding into this loop. This approach finds its foundation in the experiences of financial institutions that already started their net-zero journey.

In the following sub-sections, guidance is provided along the four key steps for the decarbonization of building portfolios. To initiate this net-zero journey, tools and indicators to measure and disclose GHG emissions in the building portfolios and to track the improvements are presented. Subsequently, guidance on the required effort level and speed to decarbonize building portfolios is provided. Based on a menu of emission reduction measures as well as a set of new financial products and services, financial institutions can select and apply appropriate instruments to develop and implement their decarbonization strategy, thus, making the building transition actionable to their choice.

Figure 8: Stepwise approach for financial institutions to decarbonize their building portfolios



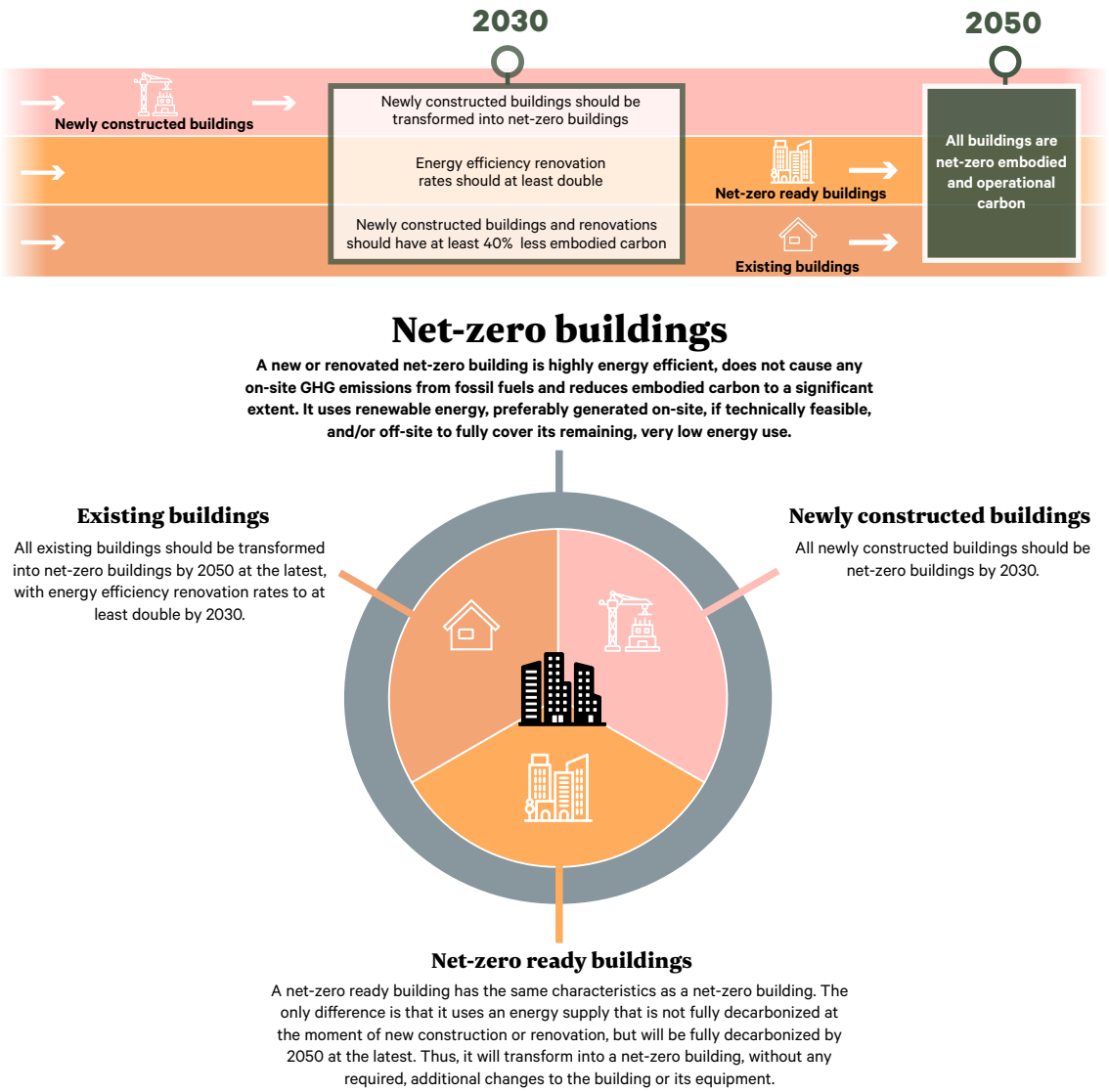
The stepwise approach is underpinned by an overarching pathway towards net-zero buildings for financial institutions to steer their strategies and actions. Based on the aligned net-zero building definition and its requirements, the corresponding pathway to reach a net-zero building stock by 2050 provides overall guidance for financial institutions (see figure 9). The ultimate objective for all buildings is to reach net-zero whole life carbon emissions[17], i.e. operational and embodied carbon, by 2050, at the latest. The transition speed varies depending on the building state: New construction should be built directly as net-zero buildings by 2030, thus, in a highly energy efficient manner, not causing any on-site GHG emissions from fossil fuels and reducing additional embodied carbon to a significant extent. At the same time, renovations in existing buildings need to reduce energy consumption through energy efficiency measures and cover the reduced energy

17 World Business Council for Sustainable Development (WBCSD) (2021)

use by (on-site) renewable energy. Acknowledging that some buildings might still need an energy supply that will decarbonize by 2050 at the latest, a net-zero ready building will transform into a net-zero building without any required modifications.

The timeline marks a critical milestone in 2030, by when global building sector emissions should be halved to reach the ultimate objective[18], highlighting the drastic need to increase effort levels and speed of activities immediately. All newly constructed buildings should be transformed into net-zero buildings and energy efficiency renovation rates of existing buildings should at least double by 2030. Moreover, embodied carbon should be reduced by at least 40%, with a focus on significant upfront carbon reduction. The subsequent sub-sections walk through the required steps for the decarbonization of building portfolios under close consideration of this overarching pathway towards a net-zero building stock.

Figure 9: Overarching pathway to reach a net-zero building stock



18 United Nations Framework Convention on Climate Change (UNFCCC) (2021)

4.1 Measure and disclose: Assessing and tracking of GHG emissions

To start the net-zero journey and track the improvements needed, the measurement of GHG emissions of mortgage and CRE portfolios is a prerequisite. This forms the basis on which financial institutions can meet disclosure rules, identify highest emitters in the portfolio, set climate targets and prepare further actions. Tracking the financed emissions to see if the progress is aligned with the set target and pathway is crucial to move towards a net-zero building stock.

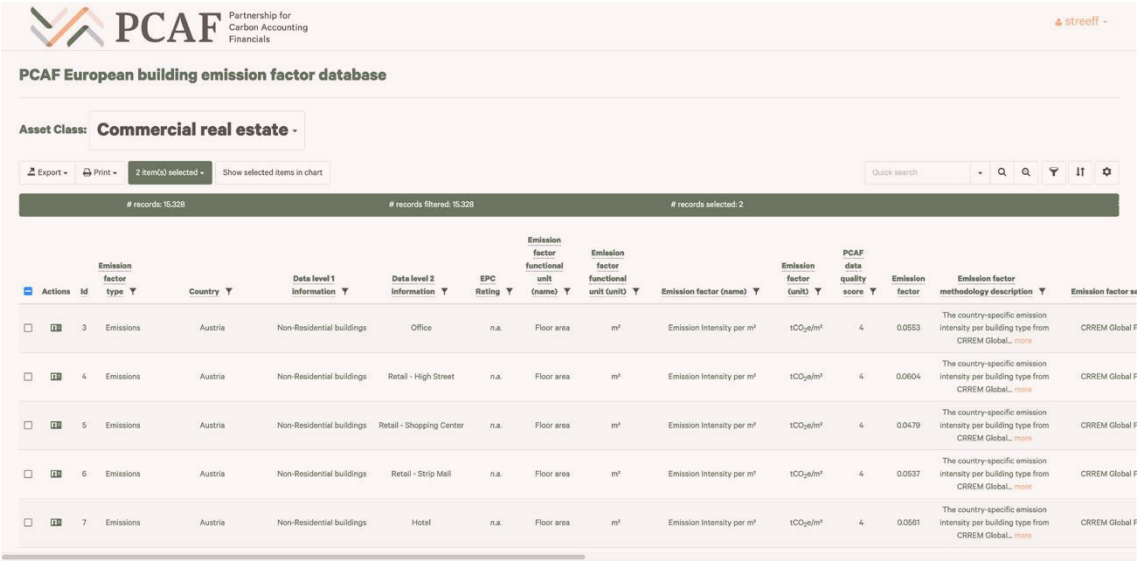
Emission intensity is the key indicator to assess GHG emissions as well as to set and track climate targets on a mortgage or CRE portfolio. Energy intensity is another crucial factor to also account for the energy reduction required in the building sector. These indicators are commonly expressed in:

- **Emission intensity: kgCO_2e or tCO_2e per square meter per year**
- **Energy intensity: kWh or MWh per square meter per year**

Emission and energy intensity factors are correlated but cannot be applied interchangeably. Energy efficiency measures can result in considerable emission reductions but not necessarily in net-zero emissions. Thus, using both indicators in combination allows considering the "energy efficiency first" principle of the EU Renovation Wave whilst at the same time striving for greening the energy supply.

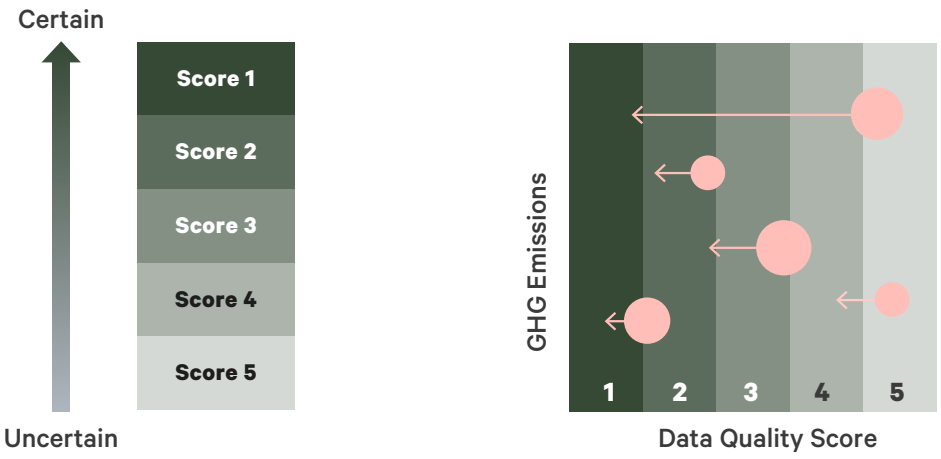
Scattered and incomplete asset level data, different implementation and scope of EPCs across European countries, as well as variety of building type classifications impede the availability of adequate data to measure and track emissions from mortgage and CRE portfolios. The PCAF European building emission factor database serves as a key tool for financial institutions to overcome data gaps and thus, to initiate the journey towards net zero by measuring and tracking the financed emissions of their portfolios. It offers a specified set of emission and energy factors for mortgages and CRE for all countries in the European Union, as well as Norway, Switzerland, and the United Kingdom. The database is publicly available to all financial institutions and further interested stakeholders. Depending on data availability, financial institutions can distinguish between asset classes, European countries, residential and non-residential building types, and EPC ratings, to extract the specified emission (tCO_2e) or energy intensity (MWh) per floor area (m²) or unit (#) from the database.

Figure 10: Structure of PCAF European building emission factor database



The PCAF European building emission factor database provides the data quality score related to the emission and energy intensity factors, ranging from a score of 3 to 5 (score 1 and 2 concerns actual building emissions). This data quality score reflects the accurateness and certainty of the data used. PCAF emphasizes that using floor area data (together with the EPC rating, if available) enables a higher quality of the carbon accounting exercise, leading to more accurate and representative emission estimation with such data. However, as many financial institutions do not yet collect information on floor area, this higher quality approach is often not possible.

Figure 11: Data quality score



Based on the data available, the data hierarchy should be followed in order of preference (see figure 11, see the Global GHG Accounting and Reporting Standard for the Financial Industry for details). To ensure reliability and validity, the underlying input data should be audited and verified. Certified data is more reliable compared to self-declared statements.

Overall, high-quality data provides more accurate emission results and is therefore essential to accurately track progress. Data quality should improve over time and financial institutions should use the highest possible quality data. As more data sources become available, financial

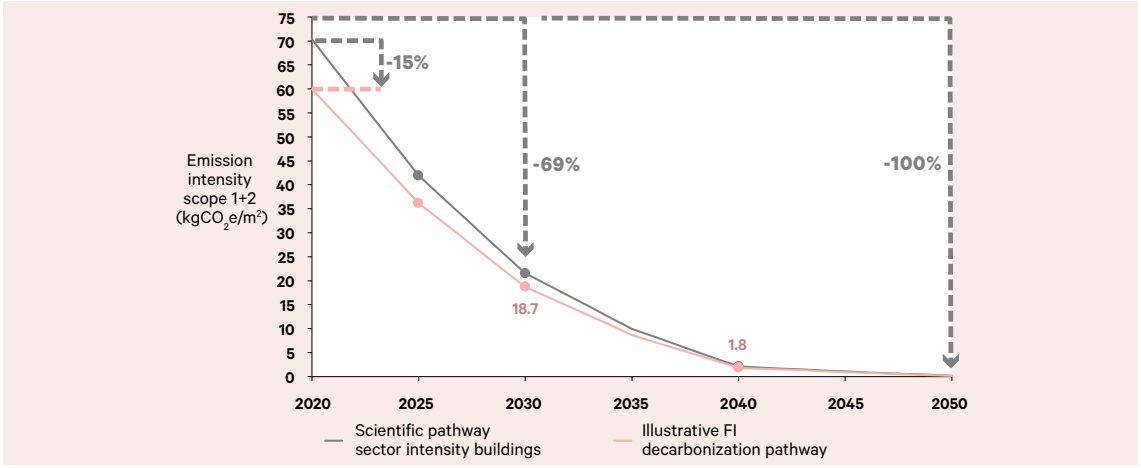
institutions are expected to move up the data hierarchy. Eventually, actual measured data (e.g. actual energy consumption of properties) should be used to calculate emissions and monitor progress. However, data limitations should not deter financial institutions from taking the first steps of the net-zero journey. Estimated or proxy data help to identify carbon-intensive hotspots in portfolios and develop corresponding climate strategies.

4.2 Set targets: Decarbonization pathway of building portfolios

The measurement of financed emissions helps financial institutions to understand the GHG impacts of their mortgage and CRE portfolio, e.g. the characteristics of the financed building types, and to set priorities for the reduction of that footprint, e.g. on the highest emitting building types. Based on this assessment, financial institutions are able to take the next step in the net-zero journey by determining the overall climate targets and the corresponding required portfolio decarbonization pathway, i.e. the transition of the GHG emissions from their building portfolio to align with scientific climate scenarios (e.g. scenarios by the Carbon Risk Real Estate Monitor (CRREM), International Energy Agency (IEA)) to net zero by 2050 or sooner. In addition to long-term net-zero climate targets, it is crucial to set intermediate targets on the portfolio level that reflect the speed and effort level needed for decarbonization and enable financial institutions to track progress and steer on any divergences. Overall, green governance between climate targets, general corporate goals and implementation needs to be well considered by the top management to prevent a 'green action gap' due to misaligned commitments and implementation.

By applying the SBTi Sectoral Decarbonization Approach (SDA)[19], figure 12 depicts the required decarbonization pathway for an illustrative CRE portfolio, converging towards the building sector pathway of a scientific climate scenario to achieve net-zero emissions by 2050. Assumptions for the calculations can be found in Annex II. The emission intensity baseline amounts to 60 $kgCO_2e/m^2$, which is 15% below the global sectoral average. This lower baseline might be due to higher energy demand for renewables and electricity, lower emission intensity of electricity and heat generation, or other factors. The year 2030 marks a critical intermediate target by when the emission intensity of the illustrative portfolio needs to be reduced by 69% relative to 2020 to achieve a net-zero CRE portfolio by 2050.

Figure 12: Target year emission intensity of illustrative CRE portfolio

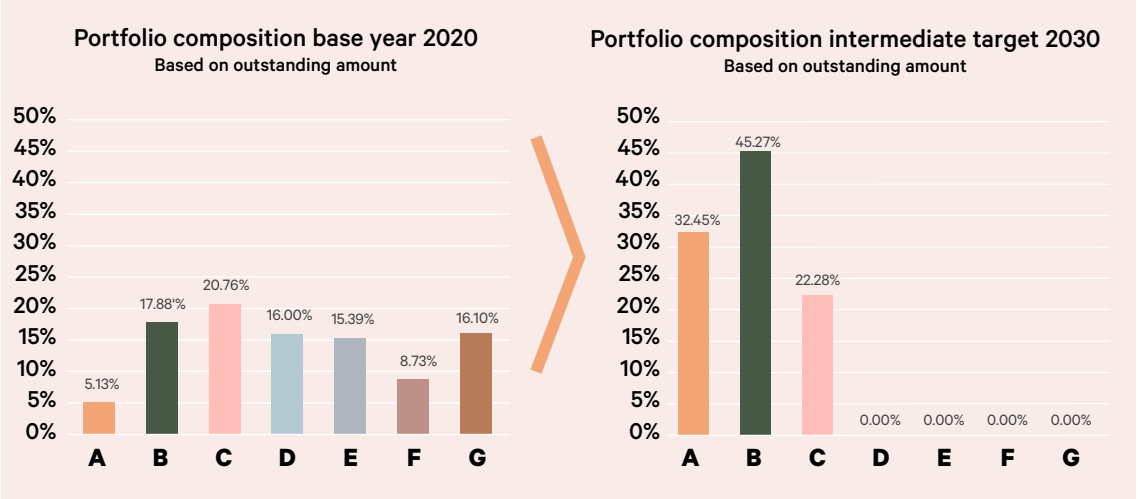


19 SBTi supported by Guidehouse (formerly Ecofys) has developed the SDA as a key science-based target-setting method. This approach is based on a sectoral pathway for a given climate scenario and can be applied to any homogeneous sector (e.g. buildings, electricity, steel, cement, etc.). SBTi currently develops further methodologies, tools and guidance relating to the building sector based on the SDA methodology (find more details here).

The exact emission intensity reduction depends on the respective portfolio composition, but this illustrative decarbonization pathway highlights the urgent need to start acting now, especially due to the static nature of the building sector. The later decarbonization measures are initiated, the more drastic they need to be, resulting in higher costs and stranded assets.[20] Moreover, as the regulatory environment changes, it may become harder to sell poorly performing assets. Thus, strong efforts need to happen before 2030 to stay in line with the overall 2050 Paris climate goals. This involves rapid energy efficiency improvements of the building stock, including large-scale retrofits and widespread electrification of heating through heat pumps (and their efficiency increase), as well as switches to renewable energy.

To make the required effort level before 2030 more tangible, figure 13 highlights the required shift in the composition of EPC ratings of financed buildings in the illustrative portfolio between the base year 2020[21] and intermediate target year 2030. It is not sufficient to only upgrade the worst performing buildings from EPC rating G to F; financed buildings of the portfolio need to be transformed on a large scale to EPC rating A to C to be aligned with the overall decarbonization pathway. To make this transition actionable, the following sub-sections 4.3 and 4.4 provide appropriate sets of technical measures, as well as financial products and services required to meet the decarbonization targets.

Figure 13: Composition of illustrative portfolio in base year and intermediate target year



20 World Bank (2015)

21 The base year portfolio reflects the average EPC rating distribution across EU countries. Details can be found in Annex II.

4.3 Develop strategy: Menu of emission reduction measures

Following target setting and pathway development, financial institutions need to create an implementation strategy, including measures and milestones, on how to decarbonize their building portfolio in line with the identified pathway. Based on the characteristics of the building portfolio (financed building types, insulation levels, installed heating systems, etc.), corresponding decarbonization plans with appropriate emission reduction measures can be determined.

Figure 14 depicts a menu of emission reduction measures based on proven technologies that can be categorized around five pillars: (i) energy efficiency, (ii) renewable energy, (iii) embodied carbon[22], (iv) efficiency in operation[23] and (v) offsetting[24]. Aligned with the net-zero building definition and corresponding overarching pathway for a European building transition, these technical and soft abatement measures have been identified as both feasible for implementation as well as compatible with reaching net zero.

22 Further specifications on embodied impacts of buildings can be found in EN15978 at the building level and EN15804+A2 at the product level.

23 Measures to ensure the efficient operation of buildings and thus, contributing to continuous emission reduction should be considered throughout the lifecycle.

24 In case of any residual carbon emissions (max. 10%) that cannot yet be eliminated, offsetting in the form of carbon removals can be used to neutralize them.

Figure 14: Menu of emission reduction measures

Energy efficiency	***Building envelope*** • Best possible thermal insulation of façade, roof, windows, round floor • Effective shading • Air tightness and air leakage testing	***Heating, ventilation & air conditioning*** • Highly efficient heat pumps • Highly efficient biomass boilers • Building automation • Natural refrigerants or sorption cooling technologies • Highly efficient district heating • Mechanical ventilation heat recovery	***Lighting & appliances*** • Optimized lighting technology (LED) • Energy efficient appliances (A+++, Energy star) • Occupancy and daylight sensors
Renewable energy	***On-site renewable energy*** • Solar thermal • Solar photovoltaics (PV) • PV thermal • Geothermal • Storage	***Renewable energy procurement*** • Renewable Energy Certificates (RECs) • Guarantees of Origin (GOs) • Power Purchase Agreements (PPAs) conveying RECs or GOs • Direct procurement	
Embodied carbon	***Transform & reuse*** • Maximize use of existing assets • Refurbishment as preferred option • Reuse materials • Review of material efficiency	***Build low carbon*** • Whole life cycle assessment (WLCA) • Smart design (e.g. lean construction, smart floor plan) • Natural and renewable materials (fostering carbon storage) from sustainable forestry • Building site selection (e.g. availability of locally sourced materials/structures) • Streamline delivery processes	
Efficiency in operation	***Efficient use*** • Awareness raising campaigns on efficient user behavior • Energy managementsystem (incl. sensors, controls, smart meters)	***Monitoring & Maintenance*** • Monitoring and evaluation of consumption • Benchmarking and performance guarantees • Optimization of building operation • Timely maintenance	
Offsetting	***Carbon removal*** • Offsetting within the project or organizational boundary • Offsetting through verified schemes (e.g. Gold standard)		

There is no one-size-fits-all solution - modular combinations of the emission reduction measures in the menu are possible depending on the building type and conditions. It is crucial to understand the characteristics of the building portfolio to identify a window of opportunity to implement emission reduction measures (e.g. due to an upcoming renovation, required replacement of equipment, lease turnover or renewal). The decarbonization plans for the respective building types can include stepwise approaches which prioritize the most required emission reduction measures for the building conditions.

The following figures show how the menu can be applied, using the best possible abatement measures for renovation and new construction based on the building type and conditions. Corresponding CO_2 and cost savings are presented for the different cases. The first three cases consider operational carbon emissions, while case 4 extends to embodied carbon, in line with the scope of the aligned net-zero building definition. Further detailed results and assumptions used can be found in Annex III and IV, respectively.

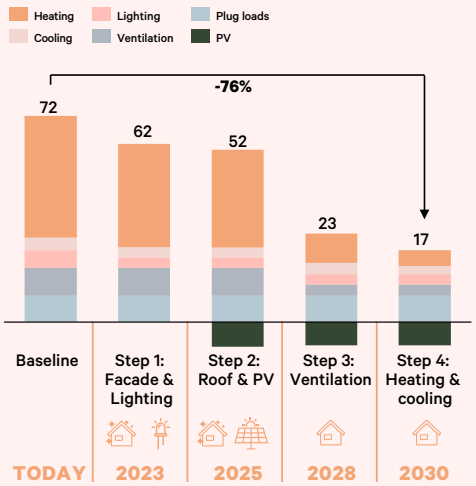
Figure 15: Case 1 - Renovation of an office building

Case 1: Renovation of an office building

Initial building conditions

- Existing office building in Frankfurt, Germany
- Construction year: 1984
- Double-glazing in 1984
- Old lighting system
- HVAC system renewed in 2008, no heat recovery

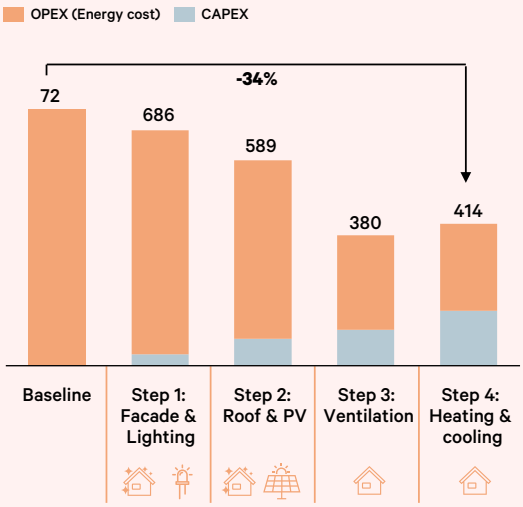
CO_2 savings (in $kgCO_2/m^2/a$)



Insights

The timing of renovation measures should depend on the building's condition. For instance, the illustrative office building possesses an old lighting system but a comparatively new HVAC system, thus, prioritization on emission reduction measures should be given to the outdated elements of the building. Improving the office building step-by-step results in 76% CO_2 reduction and 34% cost savings by 2030.

CO_2 savings (in $kgCO_2/m^2/a$)



Key figures

Measure	CO_2 savings ($kgCO_2/m^2/a$)	Cumulative CAPEX (EUR)[25] [26]	Cost savings (EUR)
Facade insulation, new windows + LED	-16,400	101,000	-74,000
Roof insulation & PV (42kW)	-19,800	186,000	-222,000
- 60% ventilation + heat recovery	-69,200	210,000	-590,000
Heat pump + improved cooling	-79,000	285,000	-530,000
Certified green electricity	-121,200	-	-483,000

25 Only energy related capital investments are considered.

26 The CAPEX is transformed into annual payments (=annuities) to make it comparable with the OPEX in the cost savings graph, e.g. 673 (OPEX) + 13 (annuity from CAPEX) = 686 cost savings.

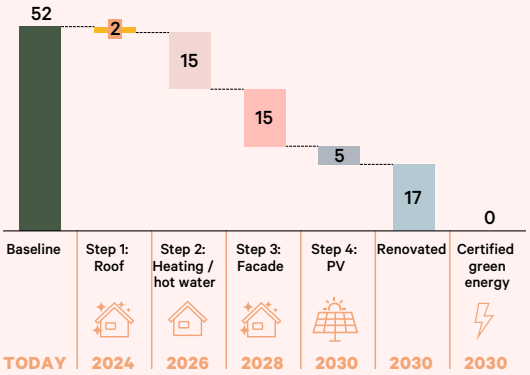
Figure 16: Case 2 - Renovation of a multi-family house

Case 2: Renovation of a multi-family house

Initial building conditions

- Apartment building in Amsterdam, Netherlands
- Construction year: 1965
- Leaky roof
- Uninsulated walls
- Windows exchanged in 1988
- Gas boiler renewed in 1994

CO_2 savings (in $kgCO_2/m^2/a$)



Insights

Due to the roof condition, renovation measures of the illustrative apartment building focus first on its insulation. Next, the gas boiler is replaced, followed by facade insulation in combination with the installation of new windows. In addition to on-site PV, the remaining energy demand is covered through certified green electricity. These measures lead to CO_2 savings of 68%.

Key figures

Measure	CO_2 savings ($kgCO_2/m^2/a$)	Cumulative CAPEX (EUR)	Cost savings (EUR)
Roof	-5,380	55,000	0
Replacement heating system + insulating pipes	-45,580	143,000	-68,000
Facade insulation + new windows	-95,580	406,000	-173,000
65 kWp PV (450 m^2) on roof	-103,680 (w/o feed in)	475,000	-190,000
Certified green electricity	-171,100	0	-118,000

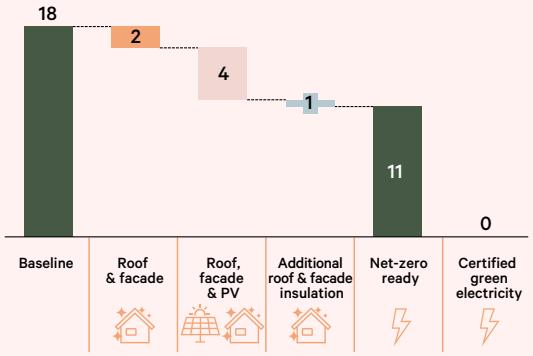
Figure 17: Case 3 - New construction of a multi-family house

Case 3: New construction of a multi-family house

Initial building conditions

- Newly constructed apartment building in Berlin, Germany
- Reference standard is the German building code for new buildings (EnEV 2014)
- Construction year: 2022

CO_2 savings (in $kgCO_2/m^2/a$)



Insights

New construction should be built directly as net-zero/net-zero ready buildings in a highly energy efficient manner without causing any on-site GHG emissions from fossil fuels. For the illustrative apartment building, this is achieved especially through the implementation of the best possible thermal insulation of the facade and roof. A combination of both on-site and off-site renewable energy covers its reduced energy use.

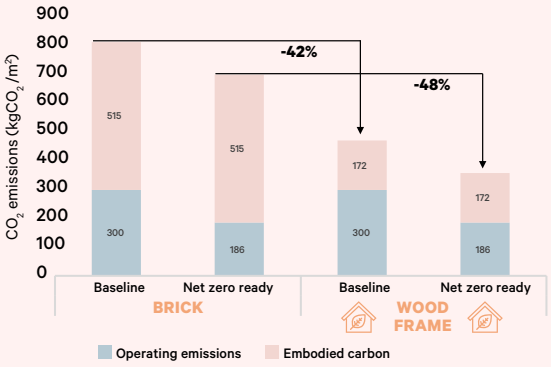
Key figures

Measure	CO_2 savings ($kgCO_2/m^2/a$)	Cumulative CAPEX (EUR)	Cost savings (EUR)
Roof & facade insulation	-5,000	72,000	-80,000
Roof & facade insulation & PV & triple glazing	-11,000	143,000	-377,000
Additional roof & façade insulation	-1,500	257,000	-341,000
Certified green electricity	-25,000	-	-268,000

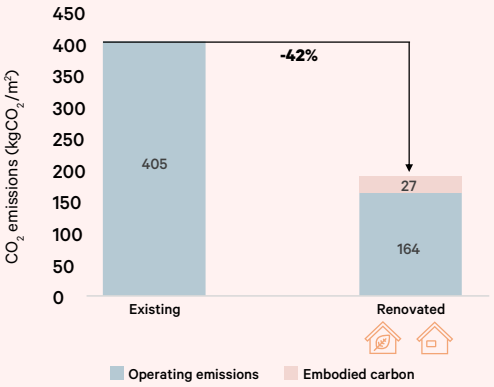
Figure 18: Case 4 - Embodied carbon in renovation and new construction of a multi-family house

Case 4: Embodied carbon in renovation and new construction of a multi-family house

NEW CONSTRUCTION

Insights	CO_2 savings (in $kgCO_2/m^2/a$)
In new construction, embodied carbon can be responsible for a large share of lifecycle emissions. The illustrative case of traditionally produced brick vs. wood frame building constructions shows the strong influence the choice of materials and their sourcing can have on emissions. To build low carbon, this also involves considerations of smart design, especially lean construction and smart floor plans. Moreover, a WLCA is best conducted at the design stage of a building.	

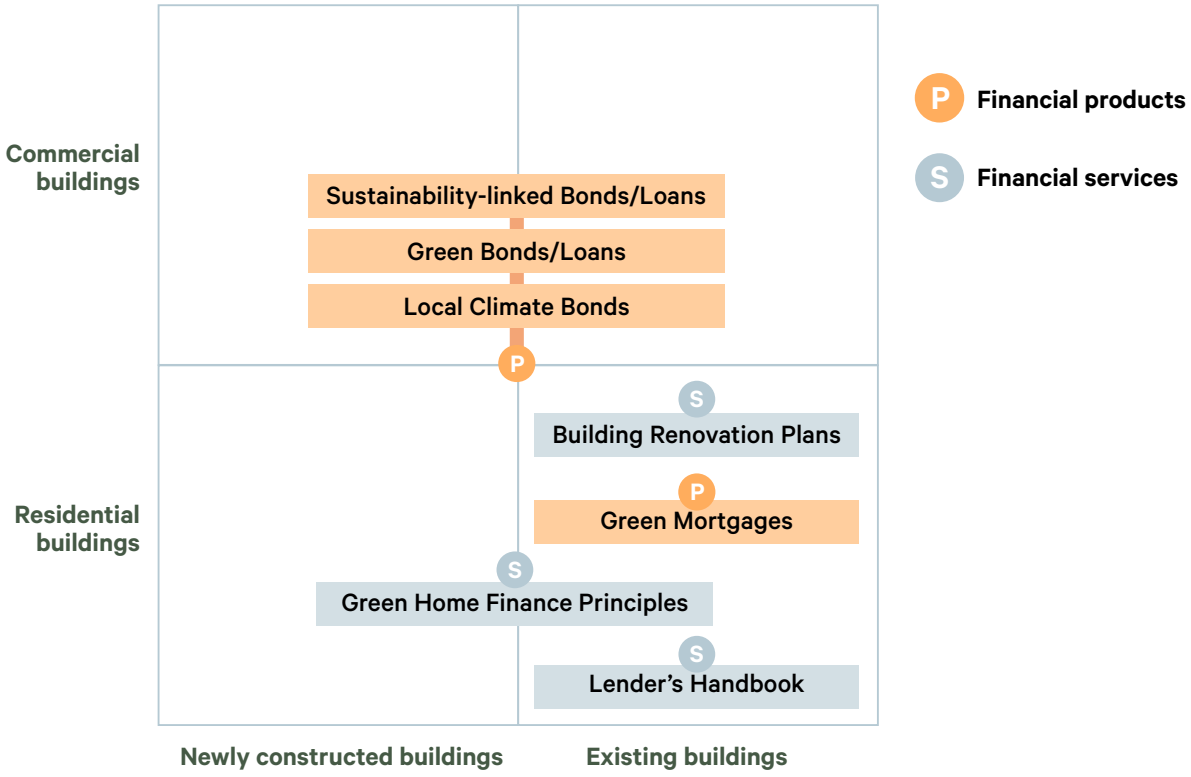
RENOVATION

Insights	CO_2 savings (in $kgCO_2/m^2/a$)
For renovation in an illustrative apartment building, insulating with mineral wool along with heating system change results in more than 50% CO_2 savings. This concerns mostly operational carbon; embodied carbon from introducing insulation material has a comparatively limited impact on the total emissions due to the existing structure. Still, throughout the renovation process, resource efficiency should be strongly considered, such as reuse of existing materials on or near the site as well as efficiency of planned materials.	

4.4 Take action: Financing the transition through new financial products and services

The last step of the net-zero journey is all about making the building transition actionable, particularly through the development and deployment of net-zero transition products and services. This sub-section presents a set of suitable financial products and services, highlighting their climate impact and compatibility with a net-zero pathway, as well as upscaling potential. They were identified together with the Green Finance Institute (GFI) based on their work and expertise in the field of financial products and services. Depending on the portfolio composition and financed building types, financial institutions are able to select and implement the corresponding financial products and services to decarbonize the European building stock.

Figure 19: Overview of potential financial products and services to finance the building transition



P Sustainability-linked Bonds/Loans

These instruments are intended to raise/borrow capital, respectively, for general purpose financing, tied to Key Performance Indicators (KPIs) and Sustainability Performance Targets (SPTs), and contingent on the achievement of these indicators. They should be assessed by Second Party Opinion providers.

Key features

- KPIs and SPTs can be tied to sustainable building metrics and/or targets.
- The ICMA Sustainability-linked Bonds/LSTA Sustainability-linked Loans Principles provide guidelines that recommend structuring features, disclosure and reporting, e.g. KPIs should be material to the issuer's overall business, SPTs should be in line with the issuer's overall sustainability strategy.

Read more on the ICMA website

Climate impact/compatibility to net zero	Upscaling potential
Sustainability-linked bonds/loans are able to encourage financial institutions to raise the ambition level of their sustainability efforts and tie them to KPIs and SPTs.	The sustainability bond market is growing rapidly, with an increase of issuers by 184% in 2021 compared to 2020. The corresponding guidelines help to establish the necessary components of a sustainability-linked bonds/loans framework.

P Local Climate Bonds

Local Climate Bonds have the potential to raise millions for sustainable building projects. It is a debt instrument issued by Local Authorities to access cost-effective funding for specific decarbonization projects, offering citizens an opportunity to invest in their area in a way similar to crowdfunding and to make a return doing so.

Key features

- Get local citizens interested and invested in sustainable projects in their local area.
- Example projects include retrofitting of buildings, rooftop solar provision, wind turbine farms, electric vehicle charging infrastructure and nature-based solutions, such as rewilding.

Read more on the GFI website

Climate impact/compatibility to net zero	Upscaling potential
Raised funds will only go to specified climate-related programs or assets. Community awareness on climate issues is raised.	Raising finance for climate change solutions can be done everywhere as long as communities are aware and willing.

P Green Bonds/Loans

Green bonds/loans are use of proceeds focused sustainable finance instruments, which are intended for project-specific financing, where capital raised/borrowed, respectively, is allocated to a specific use of proceeds that can be tied to sustainable buildings (e.g. financing the construction of sustainable new/existing buildings based on certain criteria). They should be assessed and certified by Second Party Opinion providers (see info box 1 on developing market confidence).

Key features

- Setting criteria related to sustainable buildings, e.g. building falls within the top 15% most energy efficient of the building stock within the local jurisdiction; building meets EPC rating A.
- The ICMA Green Bonds/LSTA Green Loans Principles provide guidance how proceeds should be used and how adequate projects should be selected.

Read more on the ICMA website

Climate impact/compatibility to net zero	**Upscaling potential**
These instruments are able to incentivize the investment in sustainable building projects and at the same time, enable financial institutions to meet their sustainability goals.	Green bonds and loans are widely used instruments by a variety of financial institutions. They are able to raise awareness on sustainable building improvements among financial market participants and correspondingly, attract further capital to support sustainable development.

BOX 1:

Developing market confidence in Climate Bonds

Confidence in the green credentials of green bonds is essential to the development of a sustainable market. Transparency to the underlying asset is important in allowing investor due diligence. Credible, science-based, and widely supported guidelines about what should and should not be considered a qualifying investment helps investors make informed decisions about the environmental credentials of a bond.

The Climate Bonds Initiative (CBI) is an investor-focused, not-for-profit organisation working to mobilize the $100 trillion bond market for climate action. They do this by helping to develop market confidence in green and transition bonds through the Climate Bonds Standard and Certification Scheme:

- The Standard contains criteria that have been developed to be consistent with the 1.5 degrees Celsius target declared in the 2015 Paris Agreement. Bonds and loans which are verified to conform with the Climate Bonds Standard are called Certified Climate Bonds.
- The certification scheme is a labelling scheme for bonds, assisting investors and Governments in prioritizing investments that truly contribute to addressing climate change, finance the transition to a net zero economy, and reducing the risk of greenwashing.

S Building Renovation Plans

Building Renovation Plans are digital tools to help landlords access decision-useful information to renovate their home. Like their EPBD counterpart Building Renovation Passports, they provide information on the current energy performance of a property, past renovations, and a long-term road map identifying future decarbonization measures (at best tied to the net-zero building requirements) along with links to contractors and finance options.

Key features

- Digital logbook' of building information.
- Connections to the supply chain and funding sources.
- Information about regulations, local initiatives, and benefits of energy efficiency.

Read more on the GFI website

Climate impact/compatibility to net zero
Though not a financial product, it is considered a key consumer tool that could go hand in hand with a Green Mortgage. Building Renovation Plans can raise awareness and capability of landlords to renovate their property considering future decarbonization measures. They also offer new opportunities for customer engagement as well as identifying risks of not retrofitting.

Upscaling potential
Standardized tool and already widely adopted in the UK, which could be easily expanded across Europe. There have already been several pilot schemes throughout the EU. Building renovation plans could also be adjusted for commercial buildings and extended to include further features, e.g. advisory services, information on available subsidies.

P Green Mortgages

Green Mortgage products come in a variety of different forms, but all aim to incentivize homeowners to invest in improving the energy efficiency of their properties. Customer incentives involve lower interest rates, additional borrowing capacity, cashback and/or refunds as well as non-financial benefits (e.g. free EPC assessments, advisory services). Eligible green activities concern the improvement of energy efficiency in existing homes and purchase of highly efficient homes.

Key features

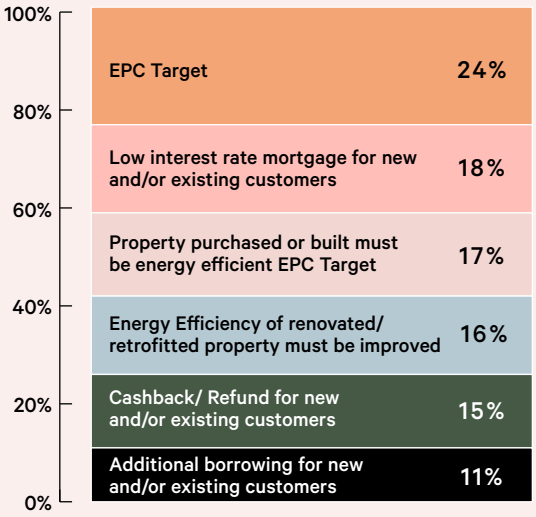
- Beneficial for both landlords and owner occupiers (decreased utility bills) and banks (meet regulation requirements, lower credit risk).
- Green Mortgages offer higher loan to value ratios compared to regular mortgages.

Read more on the GFI website

Climate impact/compatibility to net zero
A key tool to reaching net-zero as it incentivizes clients to either buy a sustainable building or renovate an existing one to make it more sustainable. It offers a standardized way for financial institutions to steer investments/loans to sustainable buildings and greening their mortgage portfolio. Green Mortgage products are also able to raise awareness amongst landlords and the construction and property development sector.

Upscaling potential
Green Mortgage products are already widely adopted by a variety of financial institutions (see info box 2 on the UK development). They offer standardized options that are applicable across Europe and therefore the potential to be adopted widely.

Figure 20: Percentage share of common features of UK Green Mortgage products (based on 36 products)[27]



BOX 2

Market development of Green Mortgages in the UK

In 2006, the first three green products were brought to the UK market by the Ecology Building Society, and it wasn't until twelve years later, in 2018, that a second provider, Barclays Bank, launched a Green Home Mortgage. By doing so, Barclays became the first high street bank to launch a green mortgage, demonstrating to other major mortgage lenders that structuring and launching such a product was both possible and commercially viable. In the four years since then, the market has seen over thirty green mortgage products launched by a minimum of twenty-five lenders (see figure 18 for key features). This has been helped in the UK by the Government's increased focus on lenders and the finance community, a critical factor in the campaign to net zero. Through various schemes and grants, and most recently in a reduction to 0% tax on energy efficiency works, the Government has sought to signal policy support for financial institutions and the entire built environment value chain to invest in this market.

The next challenge to overcome is that current green mortgages mostly focus on the small number of properties that are already highly energy efficient. With only 3% of UK homes with an EPC rating of B or higher, financing the transformation of the UK's existing housing stock through energy efficient retrofits, rather than rewarding buyers for purchasing the very small number of existing homes that are already green, is going to be crucial. For this, more mortgage and other innovative loan products must be launched with great urgency to both drive the development of the retrofit market as well as crucially reduce carbon. emissions in the built environment

27 Green Finance Institute (GFI) (2022)

Green Home Finance Principles

The Green Home Finance Principles (GHFP) seek to create an industry-recognized framework of market standards and guidelines, which provides a consistent and transparent methodology for the application of financial proceeds towards the purchase, renovation or construction of domestic buildings that achieves verifiable environmental benefits.

Key features

- The GHFPs may be applied by financial institutions on a product-by-product or deal-by-deal basis.
- The GHFPs are applicable to retrofitting and acquisition of domestic buildings, as well as self-build construction of domestic properties.

Read more on the GFI website

Climate impact/compatibility to net zero	Upscaling potential
A key step to allow banks to innovate supportive products. Supports activities that lower the environmental impact of housing through reducing energy consumption, carbon emissions and material use, as well as adapting homes to reflect the need for climate resilience.	The principles are standardized and applicable amongst building types European-wide. In addition, the GHFPs might become a market standard for Green Home Financings, e.g. green mortgages or retrofit loans.

Lender's Handbook

The Lender's Handbook on Green Home Retrofit and Technologies seeks to inform the financial professionals making lending decisions on different green home renovation solutions and technologies by providing a profile of the options available and their associated opportunities and risks, as well as quality assurance standards.

Key features

- Understanding customer drivers and motivations.
- Overview of low-carbon technologies (e.g. energy efficiency, heating and solar and storage systems).
- Overview of climate resiliency of certain measures.
- Financing options (e.g. (un)secured funding, etc.).

Read more on the GFI website

Climate impact/compatibility to net zero	Upscaling potential
Education is a key piece to driving market development. The Lender's Handbook offers a standardized guidance on the available options, existing technologies and the risks of inaction should encourage financial institutions accelerate action.	The handbook provides concise information on green home technologies for financial institutions to fund retrofit projects and develop new financial solutions to support net-zero ambitions of their clients.

Acronyms

ACEEE	American Council for an Energy-Efficient Economy
ASBP	Alliance for Sustainable Building Products
CAPEX	Capital expenditure
CBI	Climate Bonds Initiative
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CRE	Commercial Real Estate
CRREM	Carbon Risk Real Estate Monitor
CSLN	Climate Safe Lending Network
EBA	European Banking Authority
EC	European Commission
EEA	European Environment Agency
EEMI	Energy Efficient Mortgages Initiative
EF	Emission factor
ENEV	Energieeinsparverordnung - German Energy Saving Ordinance
EPBD	Energy Performance of Buildings Directive
EPC	Energy Performance Certificate
ESG	Environmental, Social, and Governance
EU	European Union
FI	Financial institution
GBPN	Global Buildings Performance Network
GFI	Green Finance Institute
GHG	Greenhouse gas
GHFP	Green Home Finance Principles
GlobalABC	Global Alliance for Buildings and Construction
GBPN	Global Buildings Performance Network
GO	Guarantee of Origin
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
HVAC	Heating, ventilation, and air conditioning
ICMA	International Capital Market Association
IEA	International Energy Agency
IIGCC	Institutional Investors Group on Climate Change
IPCC	Intergovernmental Panel on Climate Change
IPEEC	International Partnership for Energy Efficiency Cooperation
JRC	Joint Research Centre
KfW	Kreditanstalt für Wiederaufbau – German development bank
KPI	Key performance indicator
kWh	Kilowatt hour
LED	Light-emitting diode
LSTA	Loan Syndications and Trading Association
MWh	Megawatt hour
NZAOA	Net-Zero Asset Owner Alliance
OECD	Organisation for Economic Cooperation and Development

OPEX	Operating expenses
PCAF	Partnership for Carbon Accounting Financials
PHI	Passive House Institute
PPA	Power Purchase Agreement
PV	Photovoltaics
REC	Renewable Energy Certificate
SBTi	The Science Based Targets initiative
SDA	Sectoral Decarbonization Approach
SHASE.J	Society of Heating, Air-Conditioning and Sanitary Engineers of Japan
SPT	Sustainability Performance Target
UK	United Kingdom
UKGBC	United Kingdom Green Building Council
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WorldGBC	World Green Building Council
WLCA	Whole life carbon assessment

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Annex

Annex I – List of existing zero emission and zero energy building definitions

Annex I provides an overview of existing definitions of zero emission buildings and zero energy buildings which form the basis for the aligned net-zero building definition presented in section 3.

Table 1: Existing zero emission and zero energy building definitions (non-exhaustive list)

Source	Definition
Net-zero emissions	
SBTi[28] in line with the IPCC[29]	**Net-zero emissions** are achieved when anthropogenic emissions of GHGs to the atmosphere are balanced by anthropogenic removals over a specified period.
(Net-) Zero emission building	
EC[30]	**Zero emission building** means a building with a very high energy performance in line with the energy efficiency first principle, and where the very low amount of energy still required is fully covered by energy from renewable sources at the building or district or community level where technically feasible (notably those generated on-site, from a renewable energy community or from renewable energy or waste heat from a district heating and cooling system).
IEA[31]	A **zero-carbon-ready building** is highly energy efficient and either uses renewable energy directly or uses an energy supply that will be fully decarbonized by 2050, such as electricity or district heat. This means that a zero-carbon-ready building will become a zero-carbon building by 2050, without any further changes to the building or its equipment.
WorldGBC[32]	A **net-zero operational carbon building** is a highly energy efficient with all remaining energy from onsite and/or offsite renewable sources. A **net-zero embodied carbon building** (new or renovated) or infrastructure asset is highly resource-efficient with upfront carbon minimized to the greatest extent possible and all remaining embodied carbon reduced, or as a last resort, offset in order to achieve net zero across the lifecycle.
UKGBC[33]	**Net zero carbon – construction**: The embodied emissions associated with products and construction should be measured, reduced and offset to achieve net zero carbon. **Net zero carbon – operational energy**: The energy used by the building in operation should be reduced and where possible any demand met through renewable energy. Any remaining emissions from operational energy use should be offset to achieve net zero carbon.
GlobalABC/IEA/ UNEP[34]; OECD/IPEEC[35]	**Net-zero operational carbon buildings** are buildings whose carbon emissions resulting from electricity consumption and any other fuels consumed on-site are offset through renewable energy generation or other forms of carbon offsetting. Again, the offset may occur on- or off-site. **Whole-life net-zero carbon emissions buildings** are buildings whose carbon emissions from the materials used in their construction, or embodied carbon, are offset, as well as their operational carbon emissions.

28 Science Based Targets initiative (SBTi) (2021b)
29 Intergovernmental Panel on Climate Change (IPCC) (2018)
30 European Commission (EC) (2021b)
31 International Energy Agency (IEA) (2021)
32 World Green Building Council (WorldGBC) (2022)
33 UK Green Building Council (UKGBC) (2019)
34 Global Alliance for Buildings and Construction (GlobalABC) et al. (2020)
35 Organisation for Economic Cooperation and Development (OECD), and International Partnership for Energy Efficiency Cooperation (IPEEC) Building Energy Efficiency Taskgroup (2018)

The Norwegian Research, ZEB Centre[36]	A **zero-emission building** produces enough renewable energy to compensate for the building's greenhouse gas emissions over its life span which depends on how many phases of a building's lifespan are counted in.
Good et al.[37]	The overall goal of a **net-zero emission building** (NZEB) is that all emissions related to the energy use for operation as well as embodied emissions from materials should be offset by on-site renewable energy generation. The addition of the word "net" indicates that energy can be exported from and imported to the building, and that the net energy or emission balance is calculated over a specific period of time, usually a year. In practice, this usually means that the building is connected to the energy grid.
(Net-) Zero energy building definition	
GlobalABC/IEA/ UNEP[38]; **OECD/ IPEEC**[39]	**Net-zero operational energy buildings** are buildings whose energy consumption over the course of the year is offset by renewable energy generation. Depending on the definition boundary, the renewable energy generated can be on-site or off-site.
US Department of Energy[40]	A **zero energy building** is an energy-efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy.
SHASE.J[41]	A **zero energy building** is a building that has high energy saving through load reduction, natural energy use and efficient appliances without decreasing the environmental quality both indoors and outdoors. With the introduction of on-site renewable energies, the on-site energy generated will be equal to or greater than the actual energy consumed within the building in the course of a year.
EC[42]	**Nearly zero-energy building**: A building that has a very high energy performance and the nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby.
National Renewable Energy Laboratory[43]	At the heart of the **zero energy building** (ZEB concept) is the idea that buildings can meet all their energy requirements from low-cost, locally available, nonpolluting, renewable sources. At the strictest level, a ZEB generates enough renewable energy on site to equal or exceed its annual energy use.

36 Norwegian Research Centre for Zero Emission Buildings (ZEB) (2022)
37 Good et al. (2014)
38 Global Alliance for Buildings and Construction (GlobalABC) et al. (2020)
39 Organisation for Economic Cooperation and Development (OECD), and International Partnership for Energy Efficiency Cooperation (IPEEC) Building Energy Efficiency Taskgroup (2018)
40 American Council for an Energy-Efficient Economy (ACEEE) (2016)
41 Yoon et al. (2018)
42 European Commission (EC) (2021a)
43 National Renewable Energy Laboratory (2006)

Annex II – Assumptions on decarbonization of illustrative portfolio

Annex II presents the assumptions made to develop the decarbonization pathway of the illustrative CRE portfolio in section 4.2.

Regarding the average EPC rating distribution, the following assumptions were made:

- Considering the variety of EPC ratings across European countries, the most common and overlapping EPC ratings were used, i.e. EPC ratings A-G.
- All sub-versions of these ratings (e.g. A++, A1) were categorized in the corresponding main rating (e.g. EPC rating A).
- Sources used for the EPC rating distribution can be found in Annex I of the methodology document to the PCAF European building emission factor database.

Regarding the exemplary portfolio, the following assumptions were made:

- Property value as shown in base year is not subject to change and remains the same in the period between 2020-2050.
- Loans are not repaid and remain the same in the period between 2020-2050.
- The total m2 financed and total outstanding amount are not subject to change and remain the same in the period between 2020-2050. Both are reallocated across EPC ratings, but the total amount remains the same.
- Emission factors for "non-residential total" buildings were extracted from the PCAF European building emission factor database. The emission factors for Austria were used.

Regarding the expected grid electrification in 2030, the following assumptions were made for the emission factors:

- Regarding EPC rating C-G: A 60% reduction of power decarbonization was assumed up to 2030, based on the 2030 Climate Target Plan[44] for the power and building industry, announced by the European Commission. This results in a 15% reduction for the emission factors (based on 60% of a tenant split factor of 25%, i.e. 25% of the energy consumption relates to tenant activity). For assumptions on the tenant split factor, please see the methodology document to the PCAF European building emission factor database.
- Regarding EPC rating B: 60% reduction assumed for 50% electricity share, resulting in 30% reduction in emission intensity.
- Regarding EPC rating A: 60% reduction assumed for 75% electricity share, resulting in 45% reduction in emission intensity.
- A 50% and 95% heat pump contribution was assumed for EPC rating B and A, resulting in 50% and 75% electricity share, respectively.[45]

44 European Commission (EC) (2020d)

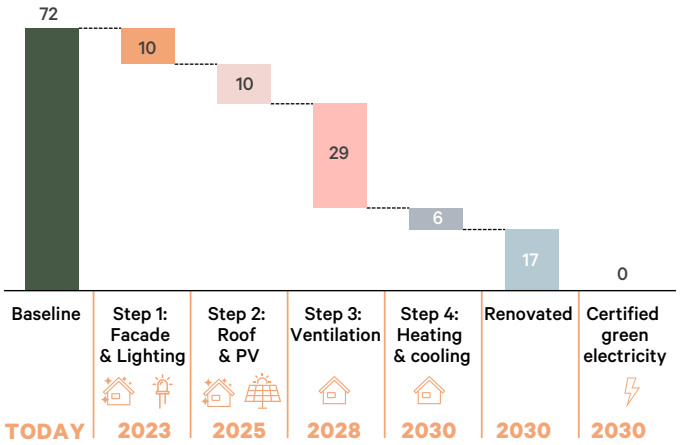
45 European Commission Joint Research Centre (JRC) (2017)

Annex III – Additional abatement measure results

Annex III shows further abatement measure results for cases 1 to 3, in addition to the findings presented in section 4.3.

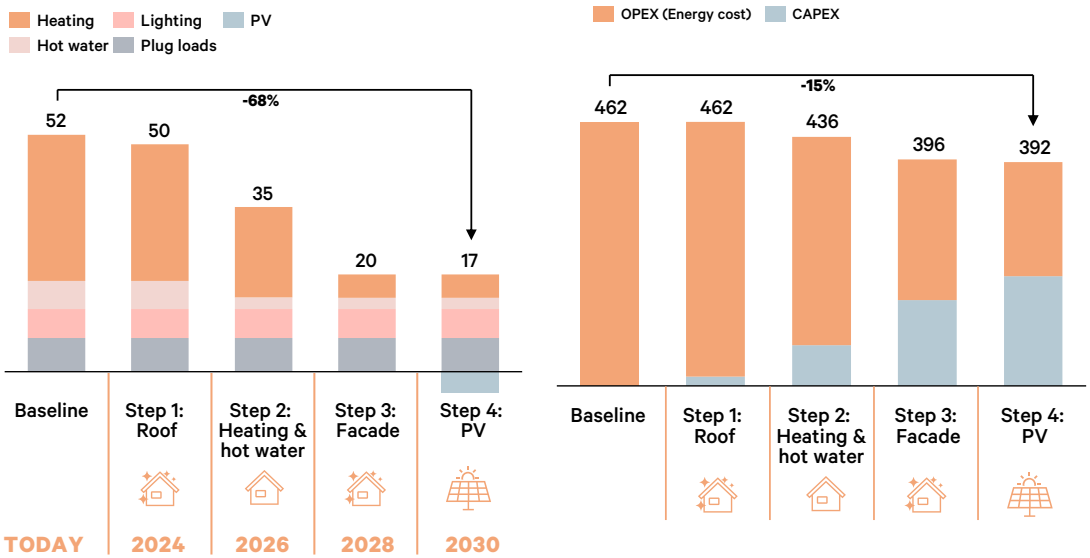
CASE 1 - RENOVATION OF AN OFFICE BUILDING

Figure 21: CO_2 emission savings in office building



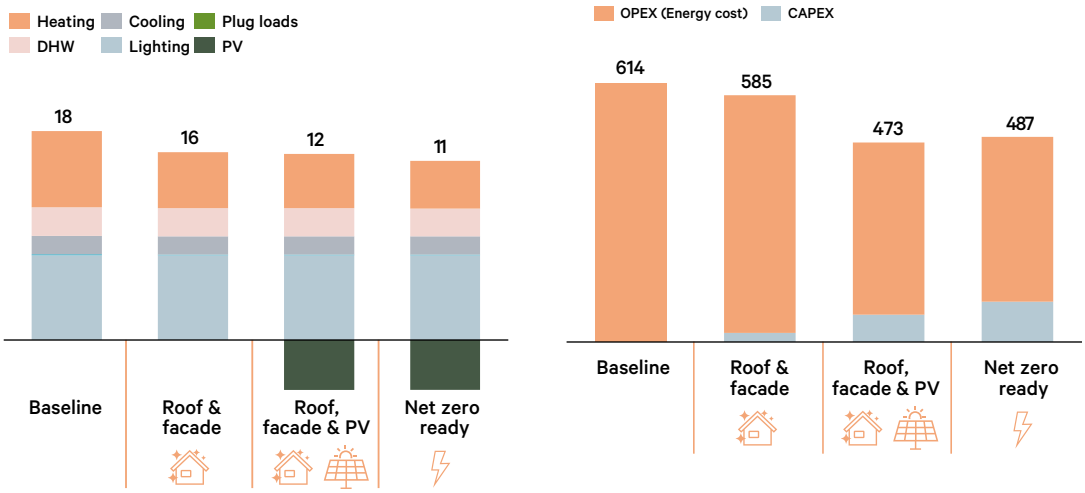
CASE 2 - RENOVATION OF A MULTI-FAMILY HOUSE

Figure 22: CO_2 emission and cost savings in multi-family house



CASE 3 - NEW CONSTRUCTION OF A MULTI-FAMILY HOUSE

Figure 23: CO_2 emission and cost savings in new construction



Annex IV – Assumptions on abatement measures

Annex IV presents the assumptions made to calculate the abatement measures for cases 1 to 4 in section 4.3.

CASE 1 AND 2 - RENOVATION OF AN OFFICE BUILDING AND MULTI-FAMILY HOUSE

Table 2: U-values used for case 1 – renovation

U-values in W/(m²K)	Office - not renovated	Facade & Lighting	Roof & PV	Ventilation	Heating & cooling	PV
Facade	0.28	0.15	0.15	0.15	0.15	0.15
Roof	0.56	0.56	0.15	0.15	0.15	0.15
Floor	0.52	0.52	0.52	0.52	0.52	0.52
Windows	2.60	0.80	0.80	0.80	0.80	0.80
Window G-value	0.70	0.55	0.55	0.55	0.55	0.55
Thermal heat bridge (average)	0.16	0.12	0.10	0.10	0.10	0.10

Table 3: G-values used for case 1 - renovation

G-values (-)	Office - not renovated	Facade & Lighting	Roof & PV	Ventilation	Heating & cooling	PV
Window	0.70	0.55	0.55	0.55	0.55	0.55

Table 4: U-values used for case 2 - renovation

U-values in W/(m²K)	MFH - not renovated	Roof	HS	Façade	PV
Facade	1.26	1.26	1.26	0.20	0.20
Roof	0.56	0.18	0.18	0.18	0.18
Floor	0.52	0.52	0.52	0.52	0.52
Windows	3.00	3.00	3.00	0.80	0.80
Thermal heat bridge (average)	0.16	0.15	0.15	0.12	0.12

Table 5: G-values used for case 2 - renovation

G-values (-)	MFH - not renovated	Roof	HS	Façade	PV
Window	0.70	0.70	0.70	0.55	0.55

Further assumptions:

- 20 years are considered for each step to account for resulting energy savings.
- CAPEX and OPEX are considered over the next 20 years after the measure is implemented.
- An additional cost of 3 ct/kWh for green electricity is assumed.
- Only PV used on-site is considered in the CO_2 emission savings.

CASE 3 - NEW CONSTRUCTION OF A MULTI-FAMILY HOUSE

Table 6: U-values used for case 3 – new construction

U-values in W/(m²K)	Baseline	Roof and facade	Roof, facade + PV	Net-zero ready
Facade	0.28	0.18	0.18	0.10
Roof	0.20	0.12	0.12	0.10
Floor	0.35	0.35	0.35	0.25
Windows	1.30	0.90	0.90	0.90
Thermal heat bridge (average)	0.05	0.03	0.03	0.03

Table 7: G-values used for case 3 – new construction

G-values (-)	Baseline	Roof and facade	Roof, facade + PV	Net-zero ready
Window	0.70	0.65	0.65	0.65

Further assumptions:

- Baseline is the German building code for new buildings (EnEV 2014); "Roof and façade" measures correspond to the reference efficiency house 55 by the German development bank KfW (KfW Effizienzhaus 55); "Roof, façade + PV" to KfW Effizienzhaus 55 + PV and "Net-zero ready" to KfW Effizienzhaus 40 + PV.
- 20 years are considered for each step to account for resulting energy savings.
- CAPEX and OPEX are considered over the next 20 years after the measure is implemented.
- An additional cost of 3 ct/kWh for green electricity is assumed.
- Only PV used on-site is considered in the CO_2 emission savings.

CASE 4: EMBODIED CARBON IN RENOVATION AND NEW CONSTRUCTION OF A MULTI-FAMILY HOUSE

NEW CONSTRUCTION

Table 8: U-values used for case 4 – new construction

U-values in W/(m²K)	Baseline	Net-zero ready
Facade	0.28	0.10
Roof	0.20	0.10
Floor	0.35	0.25
Windows	1.30	0.90
Thermal heat bridge (average)	0.05	0.03

Table 9: G-values used for case 4 – new construction

G-values (-)	Existing	Renovated
Window G-value	0.70	0.65

Further assumptions:

- Two building constructions, wood frame and brick, are compared.
- LCA values are based on the study "ASSET Study on Impact of Wooden Buildings on Climate, Embodied Energy and GHG-Emissions"' by Bettgenhäuser et. al.[46]
- Baseline is the German building code for new buildings (EnEV 2014) and "Net-zero ready" corresponds to KfW Effizienzhaus 40 + PV.
- The results were calculated with a CO_2 emissions factor of 400gCO_2 for electricity.
- A very efficient heat pump heated building with very efficient appliances is assumed, together with a reduction of the emission factor for electricity down to zero in a linear way until 2050.

RENOVATION

Table 10: U-values used for case 4 – renovation

U-values in W/(m²K)	Existing	Renovated
Facade	1.26	0.20
Roof	0.56	0.18
Floor	0.52	0.52
Windows	3.00	0.90
Thermal heat bridge (average)	0.16	0.05

Table 11: G-values used for case 4 – renovation

G-value (-)	Existing	Renovated
Window G-value	0.70	0.65

46 Bettgenhaeuser et al. (2020)

Further assumptions:

- Mineral wool is chosen as an insulation material.
- Based on the components' geometry and the building envelope U-values, the insulation volume was calculated.
- To estimate the corresponding embodied emissions from the insulation volume, CO_2 emissions per unit volume of insulation per component were adapted from ÖKOBAUDAT.[47] [48] [49]
- The operational carbon emissions were calculated for two different cases as follows: For the existing building, gas-based heating systems are assumed and adjusted to reflect the results of district heating with lower efficiency. For the renovation case, gas-based heating systems are assumed and adjusted to reflect the results of district heating with better efficiency.
- The results were calculated with a CO_2 emissions factor of 200gCO_2.

47 ÖKOBAUDAT (2018c)
48 ÖKOBAUDAT (2018b)
49 ÖKOBAUDAT (2018a)

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