“EU pathways to a decarbonised building sector”

How replacing inefficient heating systems can help reach the EU climate ambitions.

Final report

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Executive Summary

Heating and cooling today account for half of the EU energy consumption[1], but a large part of this energy is wasted because 65% of the installed stock of heaters in Europe is old and inefficient[2]. The carbon dioxide emissions from residential heating account for a significant share of the average individual's carbon dioxide emissions, and 30% of the EU overall carbon dioxide emissions.

The average replacement rate of the EU boiler is low, currently only 4% per year, which aggravates the problem. Without an ambitious change of pace, the European heating stock will continue to be old and inefficient for decades to come and the EU will fall behind on its pathway to a decarbonized building sector.

While representing a challenge, the inefficient installed stock may represent also an opportunity. If the trend of modernization of heating is accelerated, would carbon dioxide emissions from the heating sector decrease to such a level that can help achieve the EU 2030 climate targets?

In order to find the answer to this question, Ecofys was requested to conduct a scenario evaluation of the European residential heating sector. This study therefore explores the impact on EU carbon dioxide emissions of a 25% increase, from 2015 levels, of the replacement rate of installed heaters with a mix of state-of-the-art technologies.

We utilised the well-respected BEAM² model to perform the scenario calculation. The calculation builds on the realistic view of the industry, projecting how the future heating system mix may develop. Two elements are the pillars of the scenario: current market situation including sales figures for heating systems in Europe and current trends in the developments of low carbon heating systems in new and existing buildings.

The carbon dioxide emissions reduction in the scenario can be explained through two key elements. On the one hand, improving the building shell and the ventilation systems reduces the energy need of European residential buildings. On the other hand, installing highly efficient and low carbon heating systems reduces the energy delivered for the remaining energy needs for heating, and consequently carbon dioxide emissions.
The study finds that if the modernisation of the heating stock is accelerated from the current annual rate – in combination with an expected energy need reduction – carbon dioxide emissions will be in line with the EU 2030 targets. This means that a heating system change in 8.5 million households per year will contribute to a significant 18.5% drop in emissions in the upcoming fifteen years.

Can the current EU policy framework lead to achieving this scenario results in real life?

The current EU energy and climate policies are expected to lead to a significant reduction of carbon dioxide emissions in the coming years. In late 2015 the Ecodesign Directive introduced higher standards of efficiency for new heating appliances, de facto prohibiting the sale in the EU of any new heater which is less efficient than a condensing boiler. As of 2021 the Energy Performance of Buildings Directive will require all new buildings to be *nearly-zero energy*.

Yet, additional policy efforts are required.

This study's scenario builds on the contribution of several low carbon and renewable heating technologies. To deliver the resulting 18.5% carbon dioxide reduction will require at least an open policy approach to support the introduction and further development of these technologies. But the biggest contribution that Europe can make – with respect to heating systems – is to develop dedicated policies to accelerate the replacement rate of the 80 million old and inefficient heaters installed in EU homes. This combined with an energy need reduction will bring the EU on course to meet the carbon dioxide reduction goals set for 2030. For moving towards 2050 targets (-90% carbon dioxide emissions), exchange rates need to be kept high after 2030 with more or less exclusive implementation of low carbon/renewable energy systems and supply.

[1] COM(2016) 51 final, "An EU Strategy on Heating and Cooling", Brussels, 16.2.2016
[2] EHI, 2015

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1 Introduction

Half of the EU energy consumption today results from heating and cooling purposes[3]. About 85% of the energy consumed in buildings results from space heating and hot water supply[4]. Carbon dioxide emissions in Europe can be effectively reduced by lowering this consumption as the scenario calculation of this report will show.

In Europe the conditioned floor area increases by less than 1% of the current building stock per year. This means that new buildings are rather an exemption to the rule and that renovating the building stock and replacing the inefficient heating systems should become the main focus for reducing carbon dioxide emissions. Today about 120 million heaters are installed throughout Europe, whereof 65% are old and inefficient. With an average EU replacement rate of approximately 4%[5] per year the inefficient existing stock would be entirely replaced not before 25 years.

1.1 Objective

The Association of the European Heating Industry (EHI) represents 39 market leading companies and 14 associations in the European thermal comfort sector, covering about 90% of the heating needs of Europe. The heating industry appreciates the current activities of the European Commission in providing visibility to this important sector and developing an overarching policy approach on European level to reach EU climate targets.

To contribute to the political discussion, EHI asked Ecofys to conduct a scenario evaluation of the European residential heating sector. The scenario should clarify the role of an accelerated replacement of decentralised heating systems in existing buildings. It is based on a realistic view of the industry, projecting how the future heating system mix will develop, taking into account current trends in the developments of low carbon heating systems in new and existing buildings.

To show the relevance of accelerating replacement rates of decentralised heating systems for the EU climate targets, the scenario results are set in relation to the carbon dioxide emission targets of the EU "Roadmap for moving to a competitive low carbon economy in 2050".

1.2 Scope

The EU Roadmap sets targets for 2050 and presents a target corridor for 2030 (cf. 1.3). The developments in the next years will have significant impact on whether the EU will be able to achieve

[3] COM(2016) 51 final, "An EU Strategy on Heating and Cooling", Brussels, 16.2.2016
[4] http://www.eea.europa.eu/data-and-maps/indicators/energy-efficiency-and-energy-consumption-5/assessment
[5] EHI internal calculation, based on the average replacement rate of the four biggest EU markets: Italy, Germany, France and the UK.

its 2030 (and also 2050) energy and climate goals. Therefore this report focuses on setting the course in the years before 2030.

The industry has a high level of confidence in the types and performances of products that will be on the market over a 10-15 year time period. Beyond this we might expect to see new technologies beginning to emerge. There will also be developments in the availability and carbon content of supplied energy, which will also begin to impact the choice of heating system. The 15 to 20 year replacement cycle is important, because it provides ongoing opportunities to improve heating system efficiencies, as new cost-effective and widely accepted products become available.

To perform a realistic scenario, current developments of low carbon technologies as well as current sales numbers are considered. Therefore, all relevant options for heating systems that will be available in the market by 2030 are taken into account in the scenario, specifically:

- gas condensing boilers;
- oil condensing boilers;
- solar thermal systems;
- heat pumps[6] (electricity-/gas-driven);
- hybrid systems (heat pump combined with gas condensing boilers);
- biomass boilers;
- micro combined heat and power (mCHP) systems / fuel cells.

The study investigates the effect on European carbon emission targets of accelerating the replacement of inefficient heating systems with a mix of decentralised technologies. It considers increasing the rate of replacement by 25% by 2020 and then maintaining this new rate until 2030.

It assumes a stable policy framework which stimulates this higher replacement rates in a sustainable way, allowing a steady market development and at the same time avoiding a volatile demand for heating systems with large peaks in one year and dips in sales volume when certain incentives are cut. A sustainable market development allows long-term planning reliability for the heating industry to promote investments in low carbon technologies.

1.3 EU targets & policies

In February 2016, The European Commission has published its heating and cooling strategy to achieve the ambitious EU energy and climate targets[7]. This strategy is highly relevant, as the sector represents approximately half of the European energy consumption with a high share generated from fossil fuels.

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[6] Definition of heat pump: " 'heat pump' means a machine, a device or installation that transfers heat from natural surroundings such as air, water or ground to buildings or industrial applications by reversing the natural flow of heat such that it flows from a lower to a higher temperature. For reversible heat pumps, it may also move heat from the building to the natural surroundings" (EPBD 2010, Article 2, 18.)

[7] „An EU Strategy on Heating and Cooling", COM(2016) 51 final, Brussels 16.2.2016 (https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf)

Given the long lifetime of buildings, but also of heating and cooling technologies the change in the heating and cooling sector will take time and therefore developments of the current years have impact on whether the EU will be able to achieve its 2030 energy and climate goals, but also on the long term EU decarbonisation goals until 2050.

The EU "Roadmap for moving to a competitive low carbon economy in 2050", which is compatible with the EU 2050 energy and climate targets, defines a saving target "corridor" for 2030 carbon dioxide reductions compared to 1990 for the sector "residential and services"[8]. The following figure visualises this target corridor showing – from 2005 onwards[9] – a linear extrapolation to the two reduction targets of the roadmap for 2030 (upper line: -37% reduction compared to 1990, lower line: -53%).

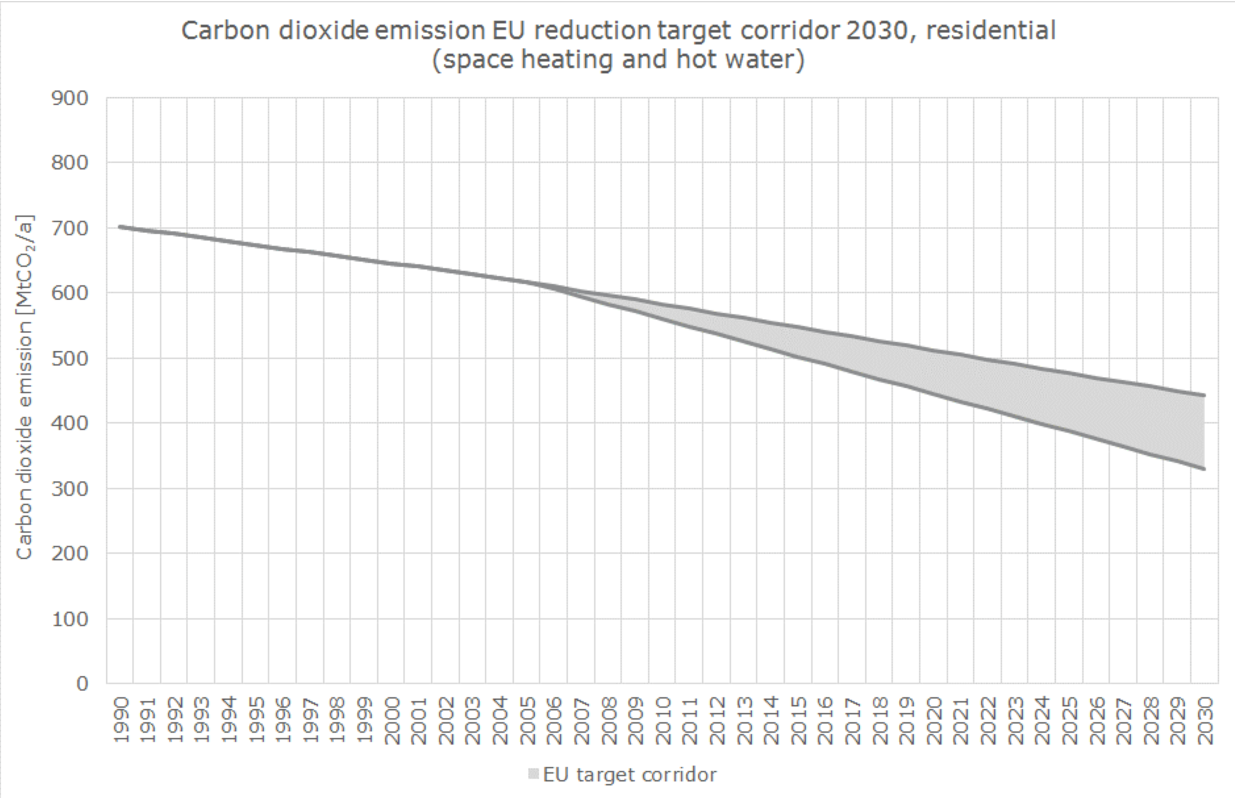

Figure 1: Carbon dioxide emission EU reduction target (heating and domestic hot water), residential buildings, $MtCO_2/a$ [10] [11] [12]

[8] Note: The focus in this study is set on the heating and domestic hot water part and not on the whole sector "residential and services". Therefore the figure shows the corridor for the heating and domestic hot water part.

[9] Note: Until 2005 no corridor but one single reduction target of 12% is mentioned in the EU "Roadmap for moving to a competitive low carbon economy in 2050".

[10] Source: Own calculation based on EU "Roadmap for moving to a competitive low carbon economy in 2050" and EUROSTAT "Complete energy balances - annual data [nrg_110a]"

[11] This study focuses on residential buildings and on the main carbon dioxide emission areas heating and domestic hot water (DHW). As the EU roadmap 2050 does not define specific sub targets and as the residential heating sector causes the largest share of direct carbon dioxide emissions of the „residential and services" sector, the same magnitude of reduction targets as for „residential and services" is used.

[12] As the heating sector strongly interacts with the power sector the direct and indirect emissions from the residential heating and hot water sector are investigated although they partly are "located" at the power sector.

Various EU instruments have been established to reduce energy consumption and Greenhouse Gas Emissions (GHG) emissions and are influencing the heating and cooling sector. The main instruments are the Energy Performance of Building Directive (EPBD), the Energy Efficiency Directive (EED), the EU Ecodesign and Energy labelling framework and the Renewable Energy Directive (RED). These instruments will be described in more detail in chapter 2.1.

Each instrument is addressing a specific area (e.g. requirements on the energy performance of buildings, EPBD; requirements to develop roadmaps for renovation, EED) but not the heating or cooling sector as a whole. Therefore, it is important that a European strategy is developed that provides a comprehensive, overarching approach to reach EU climate targets in the future. This becomes even more relevant since the COP21 climate conference in Paris which triggers further reduction of GHG emissions, as the current country pledges attached to the agreement still fall short of what is needed in order to keep global warming well below 2 °C.

The following report will focus on evaluating the detailed European political background and the potential developments for the heating market (cf. chapter 2). The methodology approach, including the specifications of the BEAM² scenario model and the main inputs for the scenario calculation, will be described in chapter 3. Chapter 4 of the report will present the most relevant outcomes of the scenario, followed by conclusions and policy recommendations (cf. chapter 5).

2 Background

This chapter aims to give an overview of the European policy regulatory framework (cf. 2.1) and to show the results of Ecofys/EHI workshops on the future developments in the heating market (cf. 2.2). These results serve as input to the scenario calculation presented in chapter 3.

2.1 Policy background

In order to be able to perform a realistic scenario analysis of the European building stock, we took into account the policy background in the European Union. For this reason, the following most important European legislative acts will be addressed:

- European Roadmap for moving to a competitive low carbon economy in 2050;
- Energy Performance of Buildings Directive (EPBD);
- Energy Efficiency Directive (EED);
- Ecodesign Directive;
- Energy Labelling Directive (ELD);
- Renewable Energy Directive (RED).

European Roadmap for moving to a competitive low carbon economy in 2050

The European "Roadmap for moving to a competitive low carbon economy in 2050"[13] defines a carbon dioxide target corridor for buildings that is to be reached by the Member States (MSs) by 2030. The sectors "residential and services" shall reduce their emissions by 37 to 55 % by 2030.

The results of the scenario calculation performed in this study will in the end be set in relation to the target corridor (cf. chapter 5) set in the Roadmap.

Energy Performance of Buildings Directive (EPBD)

The Energy Performance of Buildings Directive aims to improve the energy performance of, both, new buildings and existing buildings undergoing major renovations. According to EPBD, MSs need to follow a methodology framework to calculate cost-optimal levels of minimum performance requirements for new and existing buildings. Additionally, starting from 2021 (2019 for public buildings) each new building will have to be a nearly zero energy buildings (nZEBs[14]) The Directive introduces also the requirement for energy performance certificates (EPCs[15]) which should provide information for consumers on buildings they plan to purchase or rent. The certificates shall stimulate the path towards more energy efficient buildings in the future. However, the EPBD is not addressing renovation rates of building envelopes or replacement rates of heating technologies, which are – beside the ambition level

[13] "Roadmap for moving to a competitive low carbon economy in 2050", COM(2011) 112 final

[14] Definition: " 'nearly zero-energy building' means a building that has a very high energy performance, as determined in accordance with Annex I. 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" (EPBD 2010, Article 2, 2.)

[15] Definition: " 'energy performance certificate' means a certificate recognised by a Member State or by a legal person designated by it, which indicates the energy performance of a building or building unit" (EPBD 2010, Article 2, 12.)

of renovations – very critical if the related energy savings or GHG emission reductions are to be achieved.

Energy Efficiency Directive (EED)

The Energy Efficiency Directive aims to use energy more efficiently at all stages of the energy chain, with a view to meet the 20% EU energy saving target for 2020. Important to note is that MSs need to establish renovation roadmaps for their building stocks, which might impact the renovation rates.

Ecodesign Directive

The Ecodesign Directive aims to improve the environmental performance of energy related products and remove barriers to the internal market. One of the 24 product groups that are already covered are space heaters and combination heaters that are regulated in Regulation (EU) No 813/2013. The Ecodesign requirements in this regulation prohibit the sales of gas/oil non-condensing boiler from 2016 onwards (exception: gas non-condensing boiler in a shared open-flue system).

Energy Labelling Directive (ELD)

The Energy Labelling Directive aims to label appliances to show their energy consumption in such a manner that it is possible to compare the efficiency with that of other markets and models. Space and water heaters are one of the 16 product classes for which an EU energy label is mandatory. Hence, from 26 September 2015, heat generators, water heaters and tanks and package systems have to be labelled. Discussions are ongoing how the replacement of old and inefficient boilers with new low carbon heating technologies can be stimulated in the most effective way.

Renewable Energy Directive (RED)

The Renewable Energy Directive aims to achieve a 20% renewable share of gross final energy consumption in 2020. MSs need to submit National Renewable Energy Action Plans (NREAPs) and regular progress reports. Additionally, MSs need to:

- introduce in building regulations and codes appropriate measures to increase the share of all kinds of renewable energy systems in the building sector (Art. 13 (4));
- require the use of minimum levels of energy from renewable sources in new buildings and in existing buildings that are subject to major renovation (Art. 13 (4));
- promote the use of renewable energy heating and cooling systems and equipment that achieve significant reduction of energy consumption (Art. 13 (6)).

Based on this policy background, it was concluded that the key impacts on the scenario investigation performed in this study is:

- European GHG targets until 2030
    - Defining a corridor that shows how the carbon dioxide emissions of the heating sector should develop to contribute to reaching the EU 2030 goals
- Energy Performance of Buildings Directive (EPBD)
    - Cost optimality: Impact on future energy performance of all buildings through increased ambition levels of MSs (caused by the outcomes of mandatory cost optimality investigations of the MSs)

  - nZEB: Impact on energy performance of new buildings from 2021 onwards by improving building envelope to reduce heat loss and encouraging the use of non-fossil fuelled heating systems (building shell and renewable heating systems like heat pumps and biomass boilers)
- Energy Efficiency Directive (EED)
  - Renovation roadmaps of building stocks[16]: Impact on renovation rates
- Ecodesign Directive
  - Regulation (EU) No 813/2013: Impact on heating system sales as non-condensing boiler (gas/oil) cannot be sold from 2016 onwards
- Energy Labelling Directive (ELD)
  - Mandatory label for heaters: Impact on sales of heating systems
- Renewable Energy Directive (RED)
  - Impact on share of renewable heating systems

It can be concluded that GHG emission reduction, energy efficiency & renewable energies continue to be high on the European political agenda.

2.2 Developments in the heating market

Due to regional and local differences, climatic conditions, heat demands, but also different national electricity markets and consumer preferences, the European heating market is fragmented. Hence, the share of gas and oil boilers, district heating[17], direct electric heating systems, heat pumps, biomass, solar energy and other low carbon heating technologies varies depending on the local framework. Nevertheless, the overall European heating market is dominated by natural gas boilers. In 2014 gas boilers represented more than three quarters of the overall sales volume of approx. 7 million heating systems.

In general, the sales figures for heating systems show a decline following the financial crisis[18]. This is increasing the backlog in replacement, meaning that approximately 80 million[19] existing systems stay installed regardless of low efficiency. Accelerating the replacement of existing boilers offers a major opportunity to lower carbon dioxide emissions of the current heating system stock in Europe. It has to be recognised however that the heating market is driven by customer demand. Customers often chose cost effective solutions because of financial constraints and are resistant to new technologies that would often need larger structural construction measures. Although this means that customers will generally opt for a more efficient version of their current heating system e.g. replacing an old inefficient boiler with a condensing gas boiler, this still delivers significant efficiency improvements. According to the

[16] National long-term strategies for mobilising investment in the renovation of the national stock, as required under article 4 of the EED
[17] Definition: " 'district heating' or 'district cooling' means the distribution of thermal energy in the form of steam, hot water or chilled liquids, from a central source of production through a network to multiple buildings or sites, for the use of space or process heating or cooling" (EPBD 2010, Article 2, 19.)
[18] 2007-2014: approx. -10% (EHI, 2015)
[19] EHI, 2015

industry, replacing an old heat generator with a more efficient one (e.g. condensing technology) can reduce energy demand and carbon dioxide emissions by at least 25% compared to current levels.[20]

In case of major renovation and new buildings, a shift in the heating system technology is more likely to be considered. The penetration of low carbon technology in the market of replacements needs to be stimulated in all those cases where it is technically and economically feasible. If there is a market pull for low carbon technologies, the industry is keen to offer these technologies and further innovate and deliver higher efficiency products and systems.

EHI and Ecofys conducted several workshops on the potential future developments in the heating market. A major outcome of the workshops was the need to increase replacements of old inefficient boilers in the European Union. The heating industry considers an increase in total heating system sales by 25% until 2020 to be realistic. Concerning the heating system sales mix within this total sales, the following important developments are foreseen:

- **State-of-the-art technologies**
    - Gas, condensing boiler:
      Gas condensing boilers show a constant growth over the last years whilst non-condensing sales dropped in 2014 to 1/3 of the sales volume of 2005[21] The prohibition of most of the non-condensing gas boiler systems (Ecodesign regulation) will potentially lead to even increased sales of condensing boilers from 2016 onwards, especially if the replacement of old, inefficient boilers is increasing.
        - 2007-2014: approx. +20% (sales)[22]
    - Oil, condensing boiler:
      Oil condensing boiler sales increased especially until 2009, declined until 2012 and stagnated until 2014. At the same time the sales for non-condensing oil boiler declined in 2014 to 1/5 of the sales volume of 2005. As still many oil non-condensing boilers exist in the stock and due to the prohibition from 2016 onwards to sell non-condensing boiler (Ecodesign regulation) it is likely that oil condensing will increase in sales at least in replacements. The oil condensing boiler market is restricted to Western Europe but for at least 5 Member States (Germany, France, Belgium, Austria, United Kingdom) it is still an important market.
        - 2007-2009: approx. +70% (sales)[23]
        - 2009-2014: approx. -20% (sales)[24]
- **Renewable technologies**
    - Heat pumps:
      In new buildings previous years have already shown an increasing electrification of heating systems and it is likely that this trend will evolve especially from 2021 onwards when nearly zero energy buildings will be introduced by the EPBD.

[20] EHI, 2015
[21] EHI, 2015
[22] EHI, 2015
[23] EHI, 2015
[24] EHI, 2015

  - 2005-2014: approx. +40% (sales)[25]
- Hybrids[26]:
  Hybrids are perceived as a key technology for providing decarbonised heating especially of the existing building stock. They combine the high efficiencies of heat pumps with the additional flexibility to choose the energy carrier. This is of high importance for the future energy market with higher shares of renewable electricity[27] due to the need of flexibility options. Also heat pumps offer a certain flexibility especially on short term, as the heat can be stored in times of high energy prices. But especially in periods (typically a few weeks during the winter), when the heating demand is high but the share of renewables is moderate (due to low solar irradiation and a period of moderate wind) hybrid systems offer additional flexibility. Another main benefit is that they make maximum use of the heat pump under conditions when it can operate at optimum efficiency but allows a boiler to provide the peak heating demands e.g. under very cold conditions or fast heat up periods when the heart pump is less efficient. The heating industry is convinced that hybrids will grow significantly if the policy framework is adapted accordingly. Today hybrids represent a niche technology in sales with a high potential to evolve rapidly.
- Biomass boilers:
  Biomass boiler sales remained constant over the last 10 years having experienced some peaks (2006 and 2008) and dips (2007 and 2010). The demand for biomass boiler is likely to increase especially from 2021 onwards (introduction of nearly zero energy buildings by EPBD).
  - 2005-2014: approx. +10% (sales)[28]

- **Further technologies**
  - District heating:
    As district heating offers the possibility (especially in cities) to supply large shares of the population with renewable heat once the generation of the district heat uses more renewable sources, an increasing share of district heating connections will help to fulfil climate targets.
  - Micro combined heat and power (mCHP):
    A micro-CHP appliance allows you to generate heat and electricity from a single source, close to the place it is used, on a building level. CHP systems displace grid generated electricity. This means they are significantly more efficient than power stations, because energy isn't lost during transmission and transportation leading to considerably reduced carbon emissions. Further money savings can be made through the feed-in tariff, which pays a generation tariff for every kWh or electricity you generate and an export tariff for the power you don't use which is exported back to the

[25] EHPA, 2014; European Heat Pump Association (EHPA), "European Heat Pump Market and Statistics Report 2014", EU-11 including all heat pumps (exhaust air, sanitary hot water, H-ground/water, H-air/water, reversible other, reversible air-air w/heating)
[26] Heat pumps combined with gas condensing boilers
[27] cf. German government: "Energieeffizienzstrategie Gebäude" and ECOFYS report: "Vorbereitung und Begleitung bei der Erstellung eines Erfahrungsberichtes gemäß § 18 Erneuerbare-Energien-Wärmegesetz"
[28] EHI, 2015

grid. A moderate growth of micro combined heat and power installations can be expected if the political framework stimulates this development.

- The sales of micro combined heat and power installations are currently limited to Western Europe with only a few thousand systems installed in 2014 (compared to about 3 million gas condensing systems).

- Solar thermal systems:
  Although the past years show a declining trend for solar thermal systems in most EU MSs, a sales increase can be considered due to the prescription of the Renewable Energy Directive (RED) until 2020 and due to the nearly zero energy introduction from 2021 onwards (EPBD).

The detailed scenario parameters taking into account the above mentioned impacts can be found in the annex. The scenario parameters that are of the highest importance for this scenario calculation will be described in 3.4.

3 Methodology

This report shall contribute to the discussion about actions to deliver the objectives of the recently published EU Heating & Cooling Strategy by showing the effect of a realistic forward-looking scenario for residential buildings. The focus of the study is on determining to which degree decentralised heating technologies can contribute to achieving the 2030 EU climate and energy targets.

The following chapters are explaining and visualising the applied methodology approach (cf. 3.1), followed by a description of the scenario calculation tool "Built Environment Analysis Model (BEAM²)" (cf. 3.2) and main inputs to this model (cf. 3.3 and 3.4).

3.1 Methodology approach

For the scenario calculation of the whole European building stock the project team decided to choose the Built Environment Analysis Model (BEAM²) developed by Ecofys. The BEAM² model is well-respected, as it has been used in important projects for various associations and ministries and is currently used for the EPBD impact assessment for the European Commission[29].

The following figure shows the methodology approach of the study.

[29] Selection of clients: European Commission, German Federal Ministry for Economic Affairs and Energy (BMWi), German Federal Ministry of Transport, Building and Urban Affairs (BMVBS), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), European Insulation Manufacturers Association (EURIMA), European alliance of companies for energy efficiency in buildings (EuroACE), Aalborg University

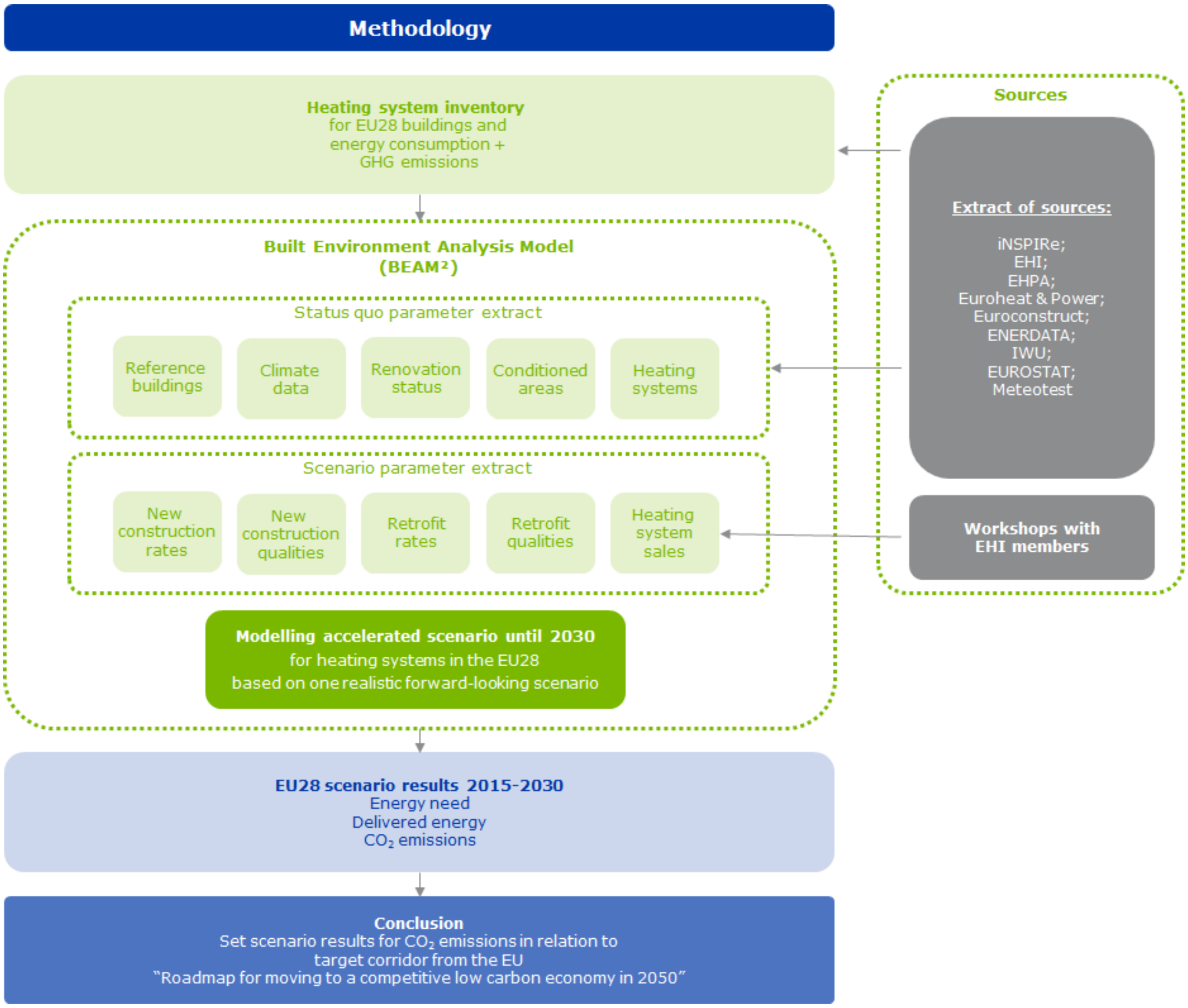

Figure 2: Methodology and major sources

The analysis is based on extensive data research and makes use of the best possible data sources of the European building stock (cf. Figure 2, "Status quo parameter extract").As input into the BEAM² model[30], a variety of actors provided data: EHI, EHPA, Euroheat & Power, Euroconstruct, iNSPIRe, ENERDATA, IWU, EUROSTAT, Meteotest and Ecofys have been utilised. These data concern information on reference buildings, climate, renovation status of buildings, conditioned floor areas and in particular on heating systems.

In the second phase, the scenario parameters have been defined (cf. Figure 2, "Scenario parameter extract"). Especially the workshops between EHI and Ecofys, where the potential future developments of heating systems have been discussed, resulted in a realistic view of the future heating system mix

[30] Although the overall model is structured as a bottom-up model also a top-down calibration of the status quo with energy consumption data of the Member States was conducted to end up with results being as close to reality as possible.

for replacements and new buildings. Furthermore, new construction and demolition rates and the qualities of buildings (built or retrofitted) until 2030 have been researched and developed.

After having defined all input parameters for the BEAM² model, a scenario run has been performed and has generated results regarding energy need, delivered energy and carbon dioxide emissions (cf. Figure 2, "EU28 scenario results 2015-2030").

Finally, concluding the outcomes of the scenario run, the scenario results have been set in relation to the EU target corridor from the EU Roadmap 2050 (cf. 1.3 and Figure 2, "Conclusion").

In the following chapters the chosen scenario calculation tool BEAM² (cf. 3.2) and main inputs concerning the status quo (cf. 3.3) and the scenario calculation (cf. 3.4) will be presented.

3.2 Built Environment Analysis Model (BEAM²)

The **B**uilt **E**nvironment **A**nalysis **M**odel (BEAM²) has been developed by Ecofys to be able to perform scenario analysis of the EU28 building stock. A detailed explanation of the model can be accessed in the dissertation by Bettgenhäuser.[31]

The model setup and calculation process is based on the energy demand calculations for space heating and cooling from the ISO Standard 13790:2008 (DIN EN ISO 13790). Basic input to the model are data on the building stock such as building types, floor area, age groups, retrofit levels and heating, ventilation and air-conditioning (HVAC) systems in stock. Furthermore the climate data such as temperature and irradiation is required. Based on this data a status-quo inventory of the building stock can be constructed.
For the scenario analysis as central part of the model, additional input data with respect to new building, demolition and retrofit activities, thermal insulation standards, heating, ventilation and air conditioning equipment, renewable energy systems is required. With respect to the overall energy performance the greenhouse gas emissions factors and primary energy factors are required per fuel type.

As the BEAM² model is also used to assess the impact of the European Energy Performance of Buildings Directive (EPBD), the general terms and definitions are aligned with it.

A detailed description of the BEAM² model can be found in the Annex.

3.3 Main BEAM² status quo inputs

This section describes the status quo of the building stock in the EU which is clustered into different reference buildings, building age groups, retrofit levels and HVAC systems. An in-depth understanding

[31] Bettgenhäuser, 2013

of these characteristics and their distributions is required as a starting point for the scenario calculation.[32]

The BEAM² model is based on building stock data that has been collected for all EU28 countries and clustered to reference zones, for modelling purposes. All countries are assigned to one of the five reference zones based on the criteria of (i) climate conditions, (ii) building stock characteristics and (iii) cost structures and level of investment costs/energy costs. The countries within the respective reference zones are shown in the following figure. A scenario calculation is carried out for the Northern, North-Eastern, Western, South-Eastern and Southern zone.

Figure 3: Five reference zones for Europe

In a next step, a definition of reference buildings as representative average building types for all buildings in stock is required. The reference buildings are typical representatives with regard to the geometry of a building. Major parameters determining the energy demand of buildings are the size and

[32] Please note that in this section only the main status quo inputs are briefly described. More details can be accessed in the Annex.

the quality of the buildings. In order to create representative reference buildings for the five reference zones the statistical data of the amount of single-family and two multi-family building types (cf. size) and the thermal qualities of the building shell components for a renovated[33] and not renovated[34] case have been researched (cf. quality).

Concerning the reference building geometries of the internationally respected iNSPIRe[35] study are used which are:

- Single Family House (SFH);
- Small Multi Family House (SMFH);
- Large Multi Family House (LMFH).

The parameters and geometries for the chosen reference buildings are shown in the Annex.

Additionally the current thermal qualities of the European buildings stock have been researched (see Annex). For modelling purposes the buildings are categorised into buildings that have been "renovated" and "not renovated". The share of buildings that are considered as "renovated" is less than 50% of the European building stock.

The conditioned floor area[36] distribution within the building stock is the starting point for any kind of scenario calculation. Following the definition of reference buildings the conditioned floor areas have been researched for all EU28 countries and clustered to reference zones and reference buildings for the scenario calculation (cf. Figure 4).

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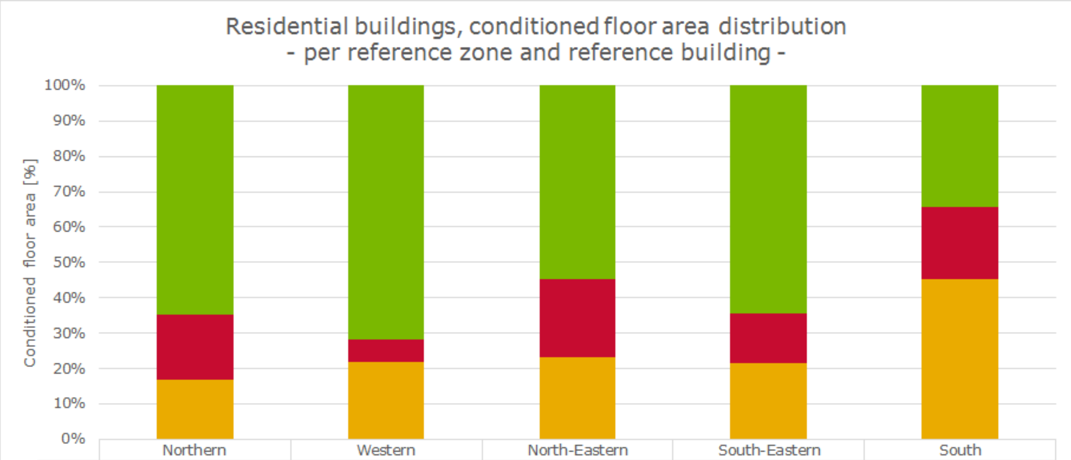
[33] ECOFYS, 2012
[34] iNSPIRe, 2014
[35] iNSPIRe, 2014
[36] Definition of conditioned floor area: "Floor area of conditioned spaces excluding non-habitable cellars or non-habitable parts of a space, including the floor area on all storeys if more than one." [EN ISO 13790:2008]



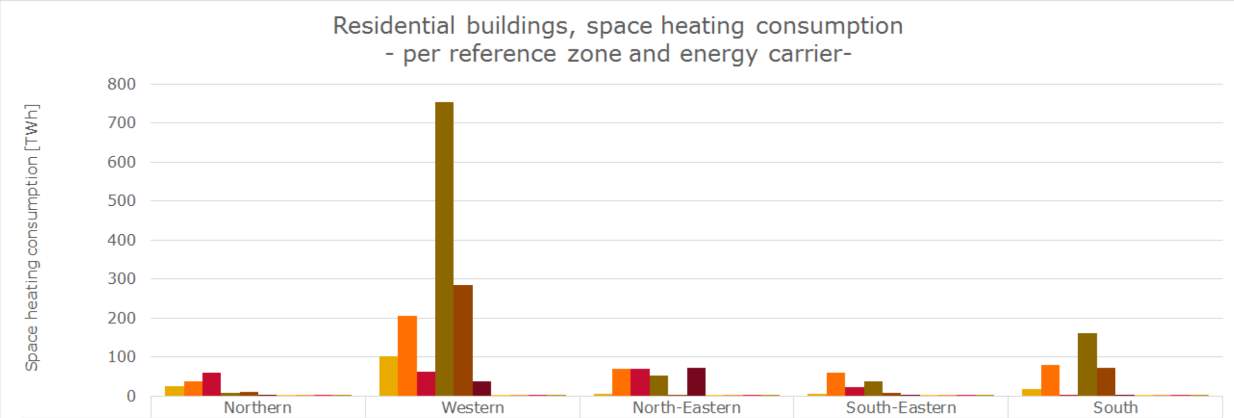
	Northern	Western	North-Eastern	South-Eastern	South
SFH	65%	72%	55%	65%	34%
LMFH	19%	6%	22%	14%	20%
SMFH	17%	22%	23%	21%	45%

Figure 4: Conditioned floor area distribution in residential buildings, per reference zone and reference building, [%] [37] [38] [39] [40] [41]

It is evident, that single-family buildings account for the largest share in conditioned floor area for each zone, even though there is a large variation in the relative shares across the zones. In the Western zone, for example, the single-family houses account for more than 70% of all conditioned floor area, whereas in the Southern zone they represent only about 35%.

Finally the energy carrier consumptions for space heating across the reference zones are highly important for the BEAM² model inputs. On the one hand the consumption distribution between the energy carriers serves as one of the sources to build up the status quo of the heating system stock in Europe. On the other hand the absolute top-down consumptions serve to calibrate the BEAM² model. The following figure shows the space heating consumption distribution per reference zone and per energy carrier.

[37] iNSPIRe, 2014
[38] IWU, 2015
[39] ENERDATA, 2013-2015
[40] BPIE, 2015
[41] Schimschar, 2015



	Northern	Western	North-Eastern	South-Eastern	South
Electricity	25	102	5	6	19
Biomass	38	205	71	59	80
District heat	61	63	70	22	2
Gas	9	754	54	37	161
Oil	11	286	1	7	73
Coal	0	38	73	3	2
Solar thermal	0	1	0	0	0
Geothermal	0	0	0	0	0
Other biofuels	0	0	0	0	0
Waste	0	0	0	0	0

Figure 5: Space heating energy consumption, per reference zone and energy carrier, %[42] [43] [44] [45]

It becomes clear, that fossil fuels (gas, oil, coal) still dominate the heating consumption in all reference zones. The most frequent energy carriers/systems per zone for single-family houses are:

- Northern: District heating (> 40%)
- Western: Gas (> 50%)
- North-Eastern: Coal (> 25%)
- South-Eastern: Biomass (> 40%)
- Southern: Gas (> 40%)

Regardless the energy carrier distribution, the efficiency of boilers that are currently installed throughout Europe is highly important for the European energy and climate targets. Approximately 80 million[46] low efficient boilers are still in operation today. The efficiencies considered in the scenario calculation can be found in the Annex[47]. Also the assumptions concerning the distribution of ventilation systems with heat recovery in case of major renovation of a building and in new buildings can be found in the Annex[48].

In the following chapter the main inputs to the scenario calculation (cf. 3.4) will be presented.

[42] iNSPIRe, 2014
[43] Eurostat, 2015a
[44] Schimschar, 2015
[45] IWU, 2015
[46] EHI, 2015
[47] Annex > Building stock > Heating and hot water systems
[48] Annex > Specific scenario parameters > HVAC systems > Ventilation systems

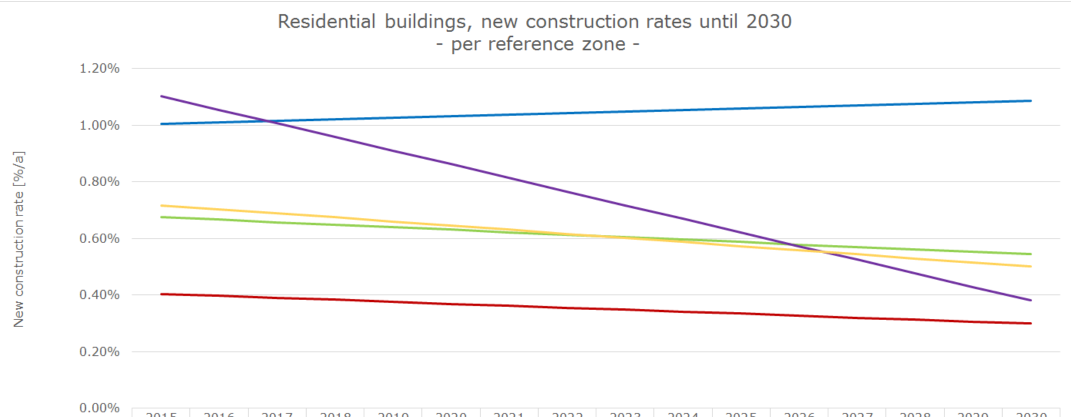
3.4 Main BEAM² scenario inputs

This section describes the main scenario inputs needed to perform a realistic scenario calculation with the BEAM² model. An evaluation of the future new construction rates (cf. 3.4.1) is essential to be able to anticipate the development of conditioned floor areas in Europe (cf. 3.4.3). Retrofit rates determine the amount of buildings that will be renovated with the quality of the retrofit (cf. 3.4.2). The following section evaluates the conditioned floor area development within the scenario calculation (cf. 3.4.3). Finally, the most important topic of this study is described: Heating system replacement rates and system distributions over the scenario period (cf. 3.4.4).

3.4.1 New construction rates and standards

The evaluation of new construction rates in Europe is important, as they influence the conditioned floor area development and thereby have impact on the overall energy need (cf. 4.1).

The new construction rate prognosis in the GLOBUS model is based on the prediction of the gross domestic product and on the population. The new construction rates from 2015-2030 are shown in the following figure for each of the five reference zones.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Northern	1.01%	1.01%	1.02%	1.02%	1.03%	1.03%	1.04%	1.04%	1.05%	1.05%	1.06%	1.07%	1.07%	1.08%	1.08%	1.09%
Western	0.67%	0.67%	0.66%	0.65%	0.64%	0.63%	0.62%	0.61%	0.60%	0.60%	0.59%	0.58%	0.57%	0.56%	0.55%	0.54%
North-Eastern	1.10%	1.05%	1.01%	0.96%	0.91%	0.86%	0.81%	0.77%	0.72%	0.67%	0.62%	0.57%	0.53%	0.48%	0.43%	0.38%
South-Eastern	0.40%	0.40%	0.39%	0.38%	0.38%	0.37%	0.36%	0.36%	0.35%	0.34%	0.33%	0.33%	0.32%	0.31%	0.31%	0.30%
South	0.72%	0.70%	0.69%	0.67%	0.66%	0.65%	0.63%	0.62%	0.60%	0.59%	0.57%	0.56%	0.54%	0.53%	0.51%	0.50%

Figure 6: New construction rates per reference zone, residential, 2015-2030[49]

Solely the new construction rates for the Northern Zone increase whereas in the North-Eastern Zone less buildings will be built in the scenario period until 2030. In the Western, South-Eastern and Southern Zone also a slight decline in new construction rates can be observed. The weighted average new construction rate from 2015-2030 for EU28 is 0.63 %/a[50].

[49] Schimschar, 2015
[50] i.e. 100 m² in 2015 would increase to approx. 110 m² in 2030

The following table shows the thermal qualities of the building shell components for new buildings per reference zone. As from 2021 onwards nearly zero energy buildings are prescribed by the EPBD. An improved building shell for new buildings is anticipated.

Table 1: Heat transfer coefficients (U-values), 2015-2020 and 2021-2030, new buildings[51]

	North	Western	North-Eastern	South-Eastern	South
New buildings 2015-2020					
Wall	0.21	0.23	0.21	0.25	0.68
Window	1.00	1.47	1.24	1.14	3.71
Floor	0.31	0.28	0.32	0.30	0.64
Roof	0.15	0.19	0.16	0.25	0.68
New buildings 2021-2030					
Wall	0.19	0.20	0.19	0.21	0.60
Window	0.88	1.28	1.08	0.99	3.25
Floor	0.27	0.25	0.28	0.26	0.56
Roof	0.13	0.17	0.14	0.22	0.60

The following section describes the retrofit rates and standards used in the scenario calculation.

3.4.2 Retrofit rates and standards

The evaluation on retrofit rates in Europe is important as they influence the energy need development of the building stock (cf. 4.1).

The retrofit rates from 2015-2030 are shown in the following figure where the starting point results from a current equivalent retrofit rate[52]. The equivalent thermal retrofit rate takes into account buildings being partly renovated and aggregate this to an amount of full thermal retrofit equivalents for the building envelope. I.e. if four buildings each received a 25% retrofit this would be the equivalent of one building being fully retrofitted. The recast of the EPBD will introduce a further strengthening of the new building standard and renovation requirements concerning the energy performance of the building. An uptake of the renovation rate (as assumed here) is expected under the future revised EPBD.

[51] ECOFYS, 2015b
[52] ECOFYS, 2015a

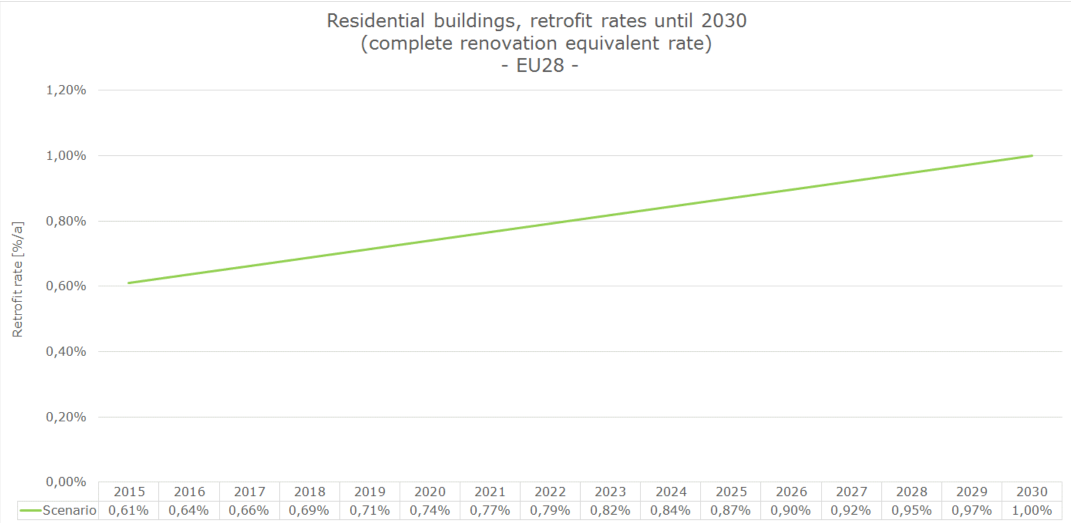


Figure 7: Retrofit rates for EU28, residential, 2015-2030

The following table shows the thermal qualities of the building shell components for the full retrofit equivalents (see above) per reference zone.

Table 2: Heat transfer coefficients (U-values), 2015-2020 and 2021-2030, retrofit[53]

	North	Western	North-Eastern	South-Eastern	South
Retrofit 2015-2020					
Wall	0.24	0.26	0.24	0.27	0.76
Window	1.00	1.47	1.24	1.14	3.71
Floor	0.31	0.28	0.32	0.30	0.64
Roof	0.15	0.19	0.16	0.25	0.68
Retrofit 2021-2030					
Wall	0.21	0.23	0.21	0.25	0.68
Window	0.90	1.32	1.11	1.02	3.34
Floor	0.28	0.25	0.29	0.27	0.57
Roof	0.14	0.17	0.14	0.22	0.62

The following section shows the conditioned floor areas used in the scenario calculation.

3.4.3 Conditioned floor area

The evaluation of the conditioned floor area development is important for the study as it has an impact on the overall energy need (cf. 4.1).

[53] update cost optimality calculations, average improvement 2020-2030

The conditioned floor area[54] development depends on two main developments:

- New construction rates;
- Demolition rates.

As described in 3.4.1, the new construction rate prognosis in the GLOBUS model is based on the prediction of the gross domestic product and on the population. The weighted average new construction rate from 2015-2030 for EU28 is therefore 0.63 %/a[55]. The demolition rates are assumed to be 0.10 %/year and will be applied to the two age groups containing the oldest buildings (pre 1945, 1945-1970). Therefore, the total building stock will increase each year by about 0.5 %. Figure 8 shows this effect as a sum of the reference zone per year.

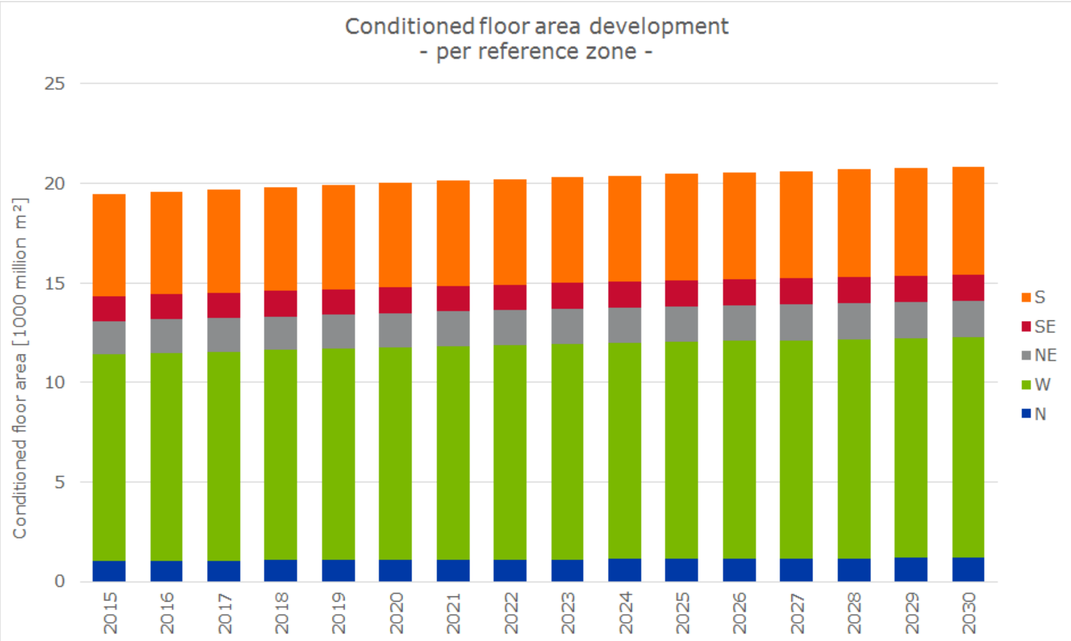


Figure 8: Conditioned floor area development, per reference zone, TWh/a

The buildings with the largest conditioned floor areas are located in the Western (AT, BE, FR, DE, IE, LU, NL, UK) and Southern (CY, GR, IT, MT, PT, ES) zone. A detailed distribution within the EU28 Member States to the reference zones is shown in 3.3.

The following section shows the most important inputs to the scenario calculation: Heating system replacement rates and system distributions over the scenario period.

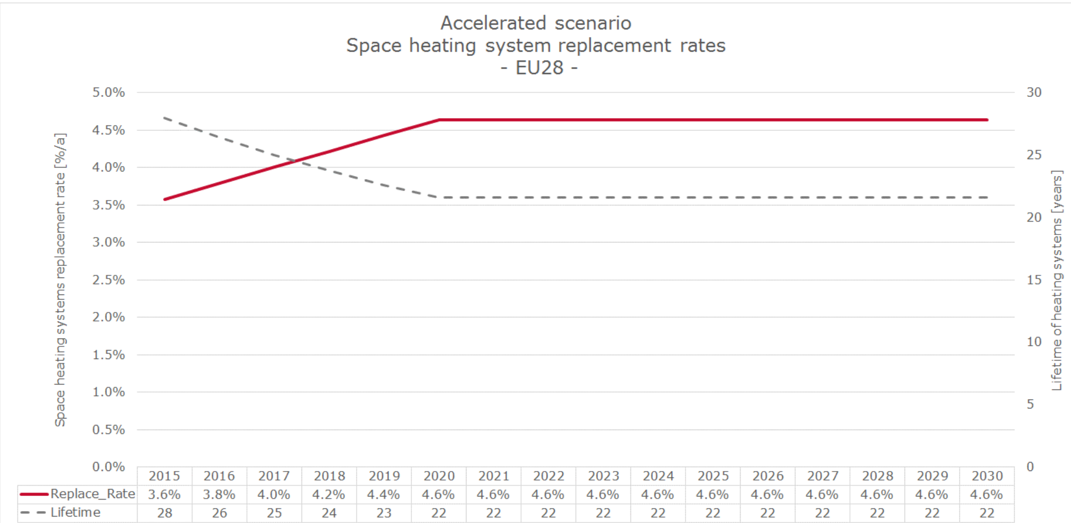
[54] Definition of conditioned floor area: "Floor area of conditioned spaces excluding non-habitable cellars or non-habitable parts of a space, including the floor area on all storeys if more than one." [EN ISO 13790:2008]

[55] i.e. 100 m² in 2015 would increase to approx. 110 m² in 2030

3.4.4 Heating systems: replacement rate and system distribution

This study aims to evaluate how an increase of the modernisation volume of heating systems (cf. Figure 9) in combination with a realistic heating system mix (cf. Figure 10) can contribute to achieve the EU 2030 emission reduction targets from the EU Roadmap 2050[56].

Accelerating the replacement of old and inefficient heating systems is expected to produce significant reductions in energy use and carbon dioxide emissions. The backlog in the replacement of old and inefficient heating systems also makes this opportunity even more imperative. To address this, a primary assumption within this scenario is that the total heating system sales volume shall increase by 25% until 2020 and remain on this level until 2030 (from 7.0 to 8.8 Mio. sales/year[57]). When considering the new construction rates for EU28 in the near future (cf. 3.4.1) this equates to an increase of the heating system replacement rates of approx. 30% (3.6% to 4.6%) - as the amount of sales in new buildings cannot be varied. This leads to a reduction of the average lifetime of heating systems from 28 to 22 years from 2020 onwards (cf. Figure 9).

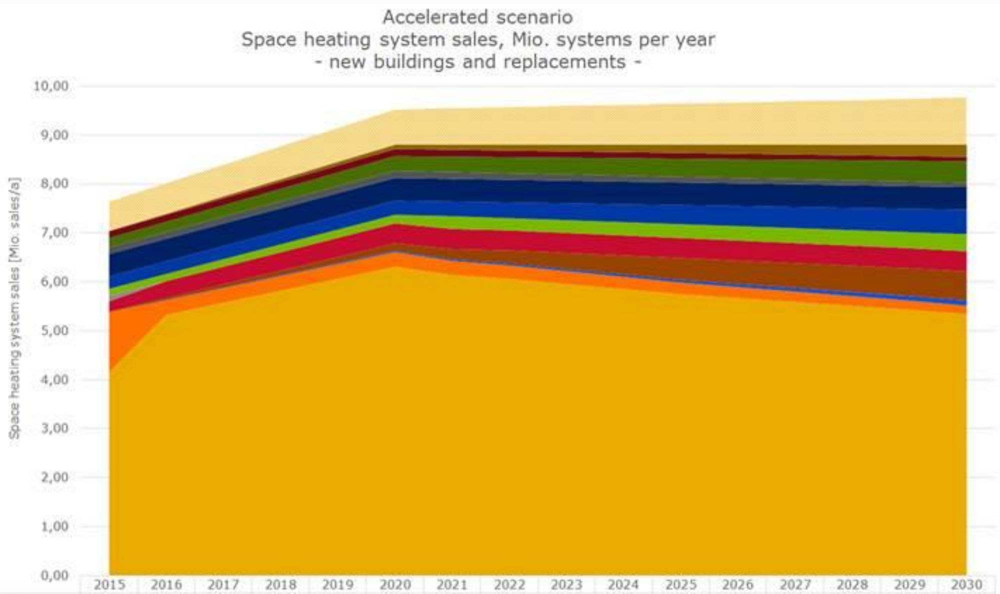


	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Replace_Rate	3.6%	3.8%	4.0%	4.2%	4.4%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%
Lifetime	28	26	25	24	23	22	22	22	22	22	22	22	22	22	22	22

Figure 9: Space heating system replacement rates, EU28, %/a

To understand the impact of changes in the heating system, an increase in the number of heating system sales alone cannot generate a complete picture. To achieve a more fine-grained analysis, this study also takes into account the mix of different heating technologies, which will be installed and incorporates these data to produce the scenario results. .Figure 10 shows the resulting heating system sales distribution within the limits of the above mentioned sales volume per year. They result from the workshops EHI and Ecofys conducted on the potential future developments in the heating market (cf. 2.2).

[56] "Roadmap for moving to a competitive low carbon economy in 2050"
[57] Sources: EHPA, EUROHEAT, EHI, ECOFYS



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ST (DHW)	0,60	0,62	0,65	0,67	0,70	0,72	0,74	0,77	0,79	0,82	0,84	0,86	0,89	0,91	0,94	0,96
mCHP+fuel cells	0,01	0,03	0,04	0,06	0,07	0,09	0,11	0,12	0,14	0,15	0,17	0,19	0,20	0,22	0,23	0,25
Coal	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,13	0,13	0,12	0,12	0,11	0,10	0,10	0,09	0,09
DH	0,19	0,21	0,23	0,25	0,28	0,30	0,32	0,33	0,34	0,36	0,37	0,39	0,40	0,41	0,43	0,44
EL	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,13	0,13	0,12	0,12	0,11	0,10	0,10	0,09	0,09
HP, air/air	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46
HP, hydronic	0,25	0,26	0,27	0,27	0,28	0,29	0,30	0,32	0,34	0,37	0,39	0,41	0,43	0,46	0,48	0,50
Wood	0,14	0,15	0,15	0,16	0,17	0,18	0,26	0,25	0,26	0,27	0,28	0,30	0,31	0,32	0,33	0,35
Oil, nc	0,11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Oil, c	0,21	0,34	0,36	0,38	0,39	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41
Hybrids (gas+HP)	0,01	0,04	0,07	0,09	0,12	0,15	0,21	0,27	0,33	0,39	0,45	0,48	0,51	0,54	0,57	0,60
HP, gas	0,00	0,01	0,01	0,02	0,02	0,03	0,03	0,04	0,04	0,05	0,05	0,06	0,07	0,08	0,09	0,10
Gas, nc	1,22	0,30	0,30	0,30	0,30	0,30	0,29	0,28	0,26	0,25	0,24	0,23	0,21	0,20	0,19	0,18
Gas, c	4,16	5,33	5,58	5,82	6,06	6,31	6,14	6,06	5,96	5,85	5,75	5,67	5,59	5,51	5,43	5,34

Notes:
- district heating (DH) considers only new connections
- heat pumps (HP, hydronic) do not include sanitary heat pumps and heat pumps for cooling purposes

Figure 10: Total space heating system sales, million sales/year (Source: own assumptions based on information from EHI[58]) [59] [60]

Figure 10 shows the heating system sales distribution, as projected by the heating industry. These estimates of potential growth and changes in the future sales volumes and product mix are also based on market developments, performance, product developments, customer acceptance and policies. The developments in the heating market have already been described in chapter 2.2. Therefore, only the main sales developments will be summarised here:

- Growth in sales:
  - Micro combined heat and power
  - District heating
  - Heat pump, hydronic
  - Biomass boiler
  - Oil, condensing boiler
  - Gas, condensing boiler

[58] Delta-EE, 2015

[59] The following abbreviations are used: c = condensing; nc = non-condensing; HP = heat pump; mCHP = micro combined heat and power; DH = district heating; EL = electric direct, ST = solar thermal system

[60] Note: Solar thermal system sales figures (ST (DHW)) are added for visualisation purposes although it is not a space heating system but a domestic hot water system.

    - Hybrids
    - Heat pump, gas
- Constant in sales:
    - Heat pump, air/air
- Decline in sales:
    - Coal boiler
    - Direct electric heating
    - Oil, non-condensing boiler
    - Gas, non-condensing boiler

The following chapter outlines the most relevant outcomes of the scenario calculation (energy need, delivered energy and carbon dioxide emissions).

4 Scenario results

The scenario results presented in this chapter result from a scenario calculation run with the BEAM² model. The scenario has been developed in close cooperation with EHI. The main input parameters used to reproduce the status quo in the model, as well as the main inputs being relevant for the scenario development until 2030 are described in the previous chapter (cf. 3.3 and 3.4). Further scenario parameters and model inputs are to be found in the Annex.

The following chapters show the outcomes for the three most important areas when evaluating energy and climate saving targets on European level:

- Energy need (for heating[61] and domestic hot water[62]), cf. 4.1;
- Delivered energy[63], cf. 4.2;
- Carbon dioxide emission[64], cf. 4.3.

When evaluating the following results, it is important to bear in mind that the assumed increase of conditioned floor area in Europe – derived from a new construction rate prognosis in the GLOBUS model (cf. 3.4.3) – means that the underlying energy use and carbon dioxide emissions are actually increasing.

---

[61] Definition of energy need for heating: "Heat to be delivered to or extracted from a conditioned space to maintain the intended temperature conditions during a given period of time." [EN 15603:2008]
[62] Definition of energy need for domestic hot water: "Heat to be delivered to the needed amount of domestic hot water to raise its temperature from the cold network temperature to the prefixed delivery temperature at the delivery point." [EN 15603:2008]
[63] Definition of delivered energy: "Energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, appliances etc.) or to produce electricity" [EN 15603:2008]
[64] Definition of carbon dioxide (CO_2): „Carbon dioxide (CO_2) is a naturally occurring greenhouse gas in the atmosphere, composed of two oxygen atoms covalently bonded to an individual carbon atom."

4.1 Energy need

Energy need for heating by definition is "Heat to be delivered to or extracted from a conditioned space to maintain the intended temperature conditions during a given period of time"[EN 15603:2008]. In other words energy need is the amount of heat added to a building to keep it adequately warm. Hence, only heat losses through the building envelope (transmission and ventilation) as well as heat gains (solar and internal) are considered for the energy need. Energy need does not include heat generation, distribution, transfer or storage losses.

The energy need development is relevant for the study as the ambitious EU targets (cf. 1.3) cannot be achieved simply by increasing the heating system replacement rate. An overarching approach that also addresses the building shell and the buildings' ventilation system will be required.

In the scenario calculation the energy needs for heating and domestic hot water (DHW) systems depend mainly on the following parameters for existing and new buildings.
Existing buildings:

- retrofit rate (amount of retrofits taking place);
- retrofit level (energy performance after retrofit);
- share of ventilation systems[65] with heat recovery[66] in existing and retrofitted buildings.[67]

New buildings:

- new construction rate (amount of newly constructed buildings);
- new building level (energy performance of new building);
- share of ventilation systems with heat recovery in new buildings.

The scenario inputs are described in detail in 3.4 and in the Annex. Overall the energy need for heating and the need for domestic hot water decrease in the scenario calculation until 2030 (cf. Figure 11) even though the conditioned floor area in total increases (cf. 3.4.3).

[65] Definition of ventilation system: "Combination of appliances designed to supply interior spaces with outdoor air and to extract polluted indoor air." [EN 15615:2007]
[66] Definition of heat recovery unit: "Mechanical component that recover waste heat from another system and use it to replace heat that would otherwise come from a primary energy source." [EN 15603:2008]
[67] The scenario assumptions concerning the distribution of ventilation systems with heat recovery in case of major renovation of a building and in new buildings can be found in the Annex (Annex > Specific scenario parameters > HVAC systems > Ventilation systems).

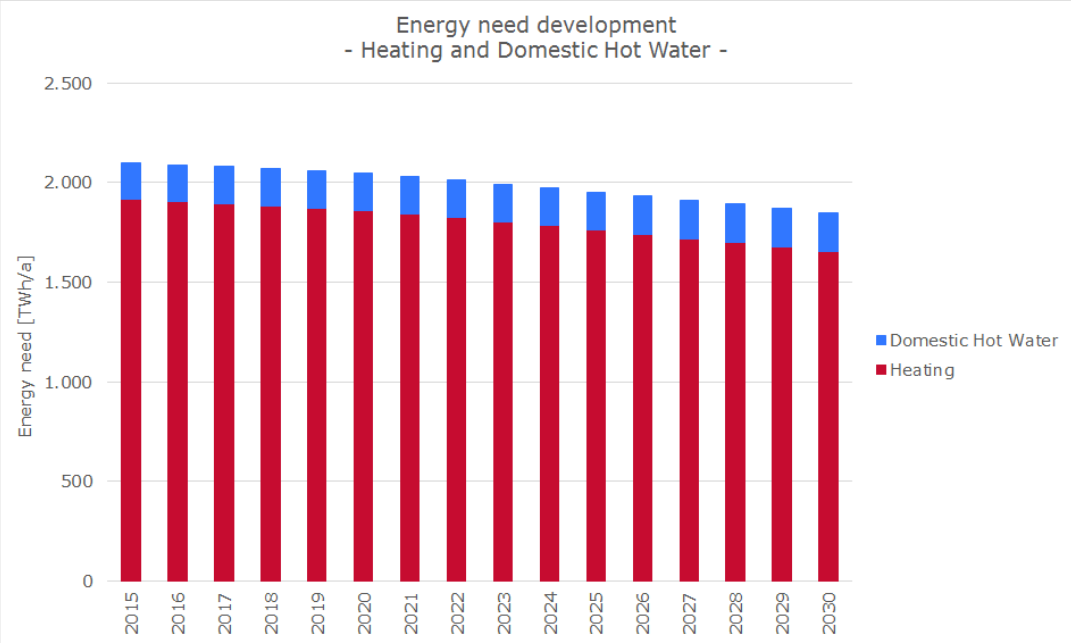


Figure 11: Energy need development, Heating and Domestic Hot Water (DHW), TWh/a

This reduction in the energy need for heating results from the combination of the retrofit rate, more ambitious levels of insulation both for new buildings and for retrofits together with a higher share of especially new buildings equipped with ventilation systems with heat recovery systems.

Figure 12 shows the energy need distribution per heating system as an outcome of the scenario calculation concerning the accelerated heating system replacement rates and the choice concerning the types of heating systems when a system is replaced or installed (cf. 3.4.4).

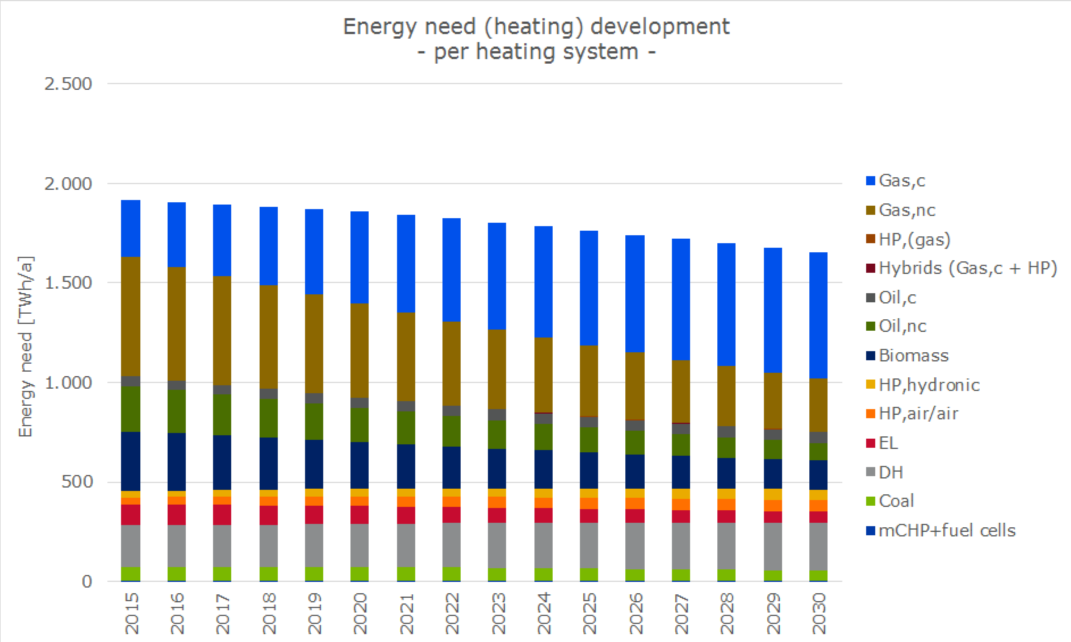


Figure 12: Energy need development, per heating system, TWh/a [68]

Based on the initial heating system distributions in 2015, the stock of all EU28 countries contains a high share of especially gas and oil non-condensing boiler (approx. 50%). By 2030, a significant reduction to approx. 25 % is achieved in the scenario. Especially the old non-condensing boilers are mainly replaced by highly efficient boilers of the same energy carrier (e.g. gas) but also by heat pumps or new technologies (switch in energy source). Although new technologies are assumed to develop in the market, their share of the whole stock will still remain low compared to conventional technologies (incl. heat pumps).

In total the energy need for heating and domestic hot water purposes could be reduced in the scenario calculation by approx. 12 % from 2015 to 2030 even though the conditioned floor area in Europe in total increases (cf. 3.4.3).

[68] The following abbreviations are used: c = condensing; nc = non-condensing; HP = heat pump; mCHP = micro combined heat and power; DH = district heating; EL = electric direct

4.2 Delivered energy

Delivered energy by definition is "Energy, expressed per energy carrier, supplied to the technical building systems through the system boundary, to satisfy the uses taken into account (heating, cooling, ventilation, domestic hot water, lighting, appliances etc.) or to produce electricity" [EN 15603:2008]. In other words delivered energy for heating purposes is the amount of energy that needs to be provided to the heating appliance (boiler, heat pump etc.) to keep a building adequately warm. Delivered energy includes heat generation, distribution, storage and transfer losses.

The delivered energy development is relevant for the study as the ambitious EU targets (cf. 1.3) cannot solely be achieved by improving the building shell and the buildings' ventilation system. Increasing the heating system replacement rate and the heating system efficiency – but also installing a higher capacity of solar thermal collectors – adds to an overarching approach to reach the EU climate targets.

Figure 13 shows the delivered energy development until 2030 for heating and domestic hot water, illustrating also the share of the domestic hot water energy covered by solar thermal collectors (yellow bar). The outcome mainly depends on the heating and domestic hot water efficiencies and the amount of solar thermal systems installed (cf. Annex).

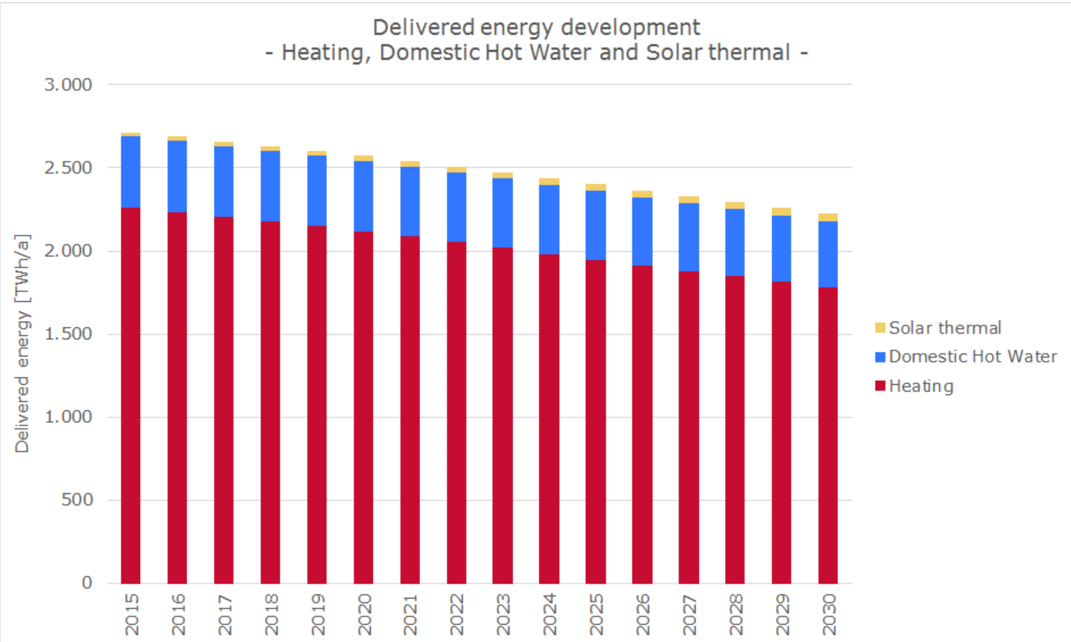


Figure 13: Delivered energy development, Heating and Domestic Hot Water (DHW), TWh/a

As the shares of highly efficient heating systems increase with every year of the scenario (cf. sales assumptions in 3.4.4) the decline in delivered energy becomes greater than that of the energy need.

Figure 14 shows the distribution among the energy carriers[69] for heating and domestic hot water purposes in order to illustrate the energy carrier usage.

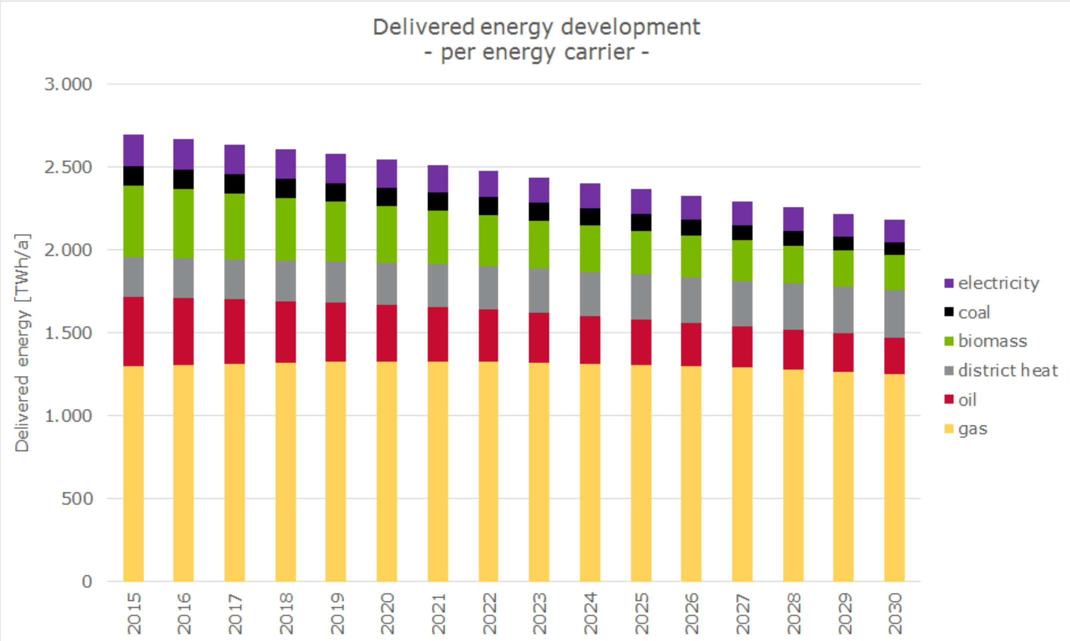


Figure 14: Delivered energy development, per energy carrier, TWh/a

In absolute figures, only the energy delivered by district heating systems increases, while the energy delivered by gas driven systems remain constant. All other energy carriers decrease in absolute as well as in relative terms. This effect can be explained on the one hand by more efficient systems and a different heating system mix in sales (cf. chapter 3.4.4). On the other hand, the energy need of buildings decreases (cf. 4.1).

In the case of e.g. electric heat pumps, more systems will be installed in the scenario calculation (cf. chapter 4.1, Figure 12). However, the absolute part of delivered electricity decrease in the scenario calculation. The main reasons for a decrease in electricity consumption until 2030 are:

- The overall energy need of the buildings decrease;
- Direct electric heating systems will be rarely sold in the future which decreases the electricity consumption (cf. 3.4.4);
- The electricity need decreases due to higher efficiencies when stock heat pumps are replaced by new ones;

In total the delivered energy could be reduced in the scenario calculation by approx. 19.0% from 2015 to 2030 although the conditioned floor area in Europe in total increases (cf. 3.4.3).

[69] Definition of energy carrier: "Substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes" [EN 15615:2007; EN 15603:2008]

4.3 Carbon dioxide emissions

The European Union set targets to reduce carbon dioxide emissions in Europe by 2030 (cf. 1.3). The outcomes of the scenario calculation presented in this chapter will be set in relation to these targets in the conclusion section (cf. chapter 5).

The carbon dioxide emission development depends on the amount of delivered energy (cf. 4.2) and the carbon dioxide emission factors of the energy carriers used to deliver the energy (cf. Annex, Carbon dioxide emission factors). Figure 15 reveals the development in relation to heating and domestic hot water.

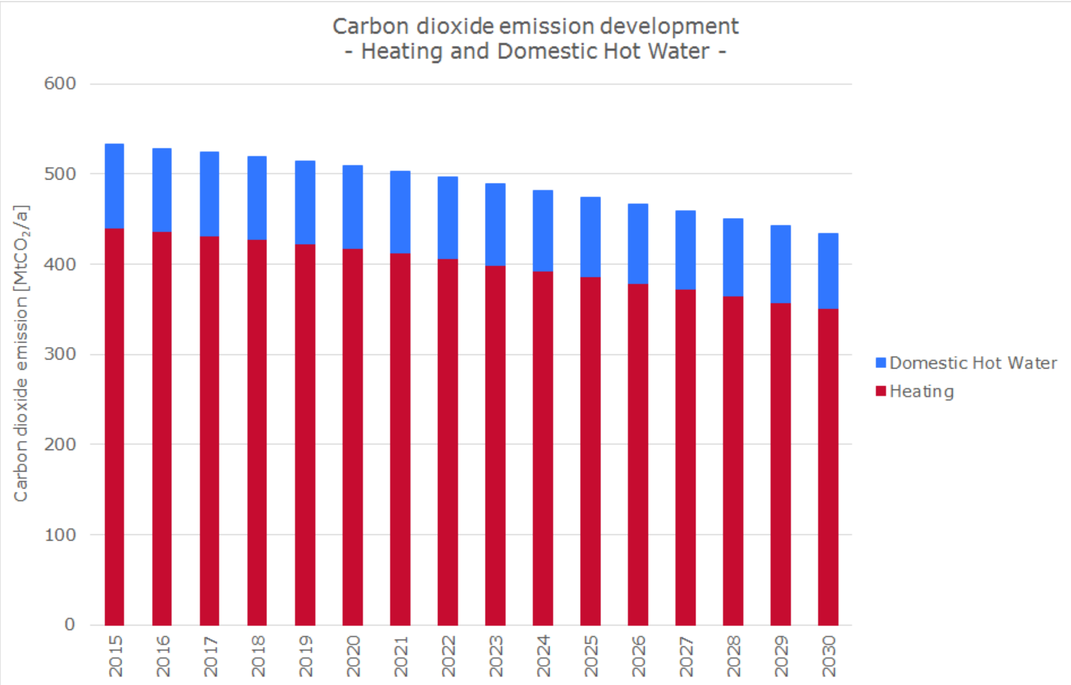


Figure 15: Carbon dioxide emission development, Heating and Domestic Hot Water (DHW), $MtCO_2/a$

It is evident that the carbon dioxide reductions resulting from the scenario calculation are similar to the ones observed for delivered energy (cf. Figure 13). This can be explained by the fact that the shares between the energy carriers remain relatively stable. Figure 16 shows the energy carrier proportions for heating and domestic hot water purposes over the scenario period to illustrate the energy carrier developments.

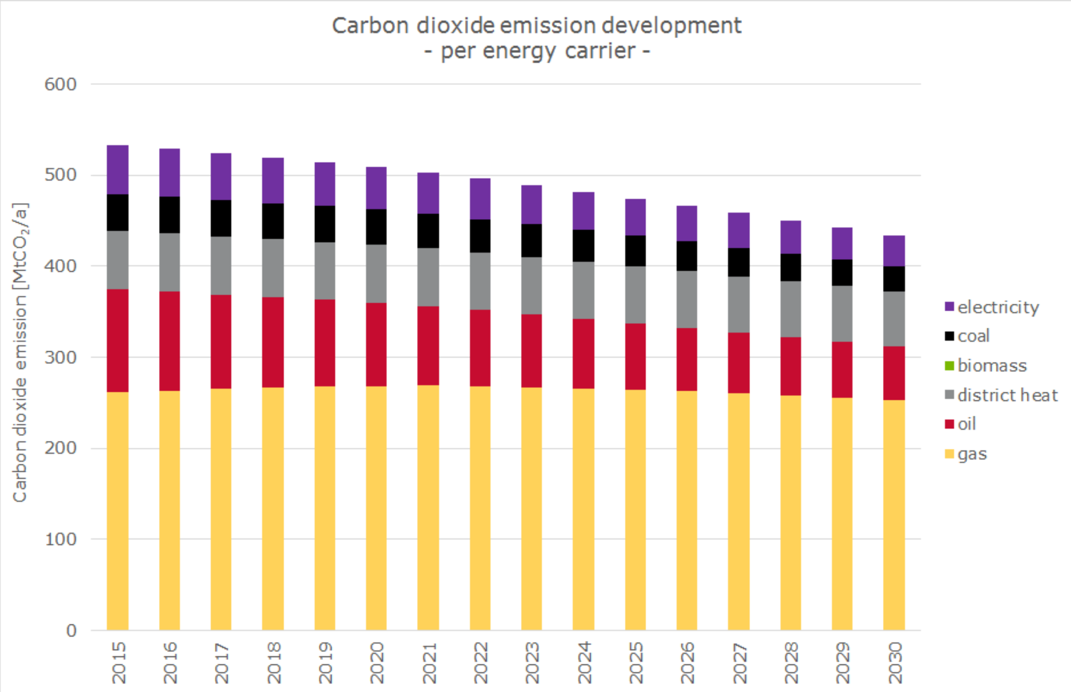


Figure 16: Carbon dioxide emission development, per energy carrier, $MtCO_2/a$

The main difference to the respective delivered energy figure in the previous chapter (cf. Figure 13) is that the different energy carriers causes different carbon dioxide emissions. E.g. biomass has an emission factor of zero gCO_2/kWh (cf. Annex, Carbon dioxide emission factors) and therefore is no longer visible in Figure 16 whereas electricity, district heat and coal shares increase in comparison to the delivered energy as those are energy carriers with comparably high emission factors. Overall the absolute carbon dioxide emissions of the electricity consumption reduce according to the reasons highlighted in 4.2 and due to reduced carbon dioxide emission factors as the supply mix to produce electricity will change in the future[70].

Since the ultimate target is the reduction of carbon dioxide emissions, the heating systems with its corresponding energy carrier is very relevant.

In total the carbon dioxide emissions could be reduced in the scenario calculation by approx. 18.5% from 2015 to 2030 although the conditioned floor area in Europe in total increases (cf. 3.4.3). The reduction equals the carbon dioxide emissions of approximately 13.3 million European inhabitants[71] which corresponds to more than 10 times the population of Brussels.

[70] Annex > Building stock > Carbon dioxide emission factors
[71] Source of Data (2012): European Environmental Agency (EEA), International Energy Agency (IEA), Eurostat (http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tsdgp410&plugin=1, EU28: 7.4 tCO_2/inhabitant, Last update: 25/01/16)

5 Conclusions and recommendations

The heating industry supports a development of an overarching policy approach on European level to reach EU climate targets. To help quantify the contribution from heating, EHI asked Ecofys to perform a scenario evaluation of the European (residential) heating sector to evaluate how an accelerated replacement of decentralised heating systems in existing buildings and future developments in low carbon heating technologies can contribute to reach EU energy and climate saving targets.

Approximately 80 million low efficient heating systems are still installed in Europe. This has not improved during the financial crisis as sales figures for heating systems show a decline over the last years. Therefore accelerating the replacement of existing boilers currently offers a significant opportunity to lower carbon dioxide emissions of the current heating system stock in Europe.

The scenario starts from current sales figures for heating systems as well as current new construction and renovation rates and assumes continuous development of the heating market following current trends to show realistic developments.

Scenario results

The scenario outcomes show that the energy need of European residential buildings can be reduced by 12%, the delivered energy by 19% and that carbon dioxide emissions can be lowered by 18.5% with realistic assumptions from the heating industry on future developments in the heating market in 2030 compared to 2015.

Figure 17 compares the scenario results to the EU carbon reduction target for 2030 based on the EU "Roadmap for moving to a competitive low carbon economy in 2050". It can be concluded that the acceleration of heating system replacements and the heating system mix developments – in combination with an energy need reduction – lead to carbon dioxide emissions in 2030 ranging within the EU target corridor.

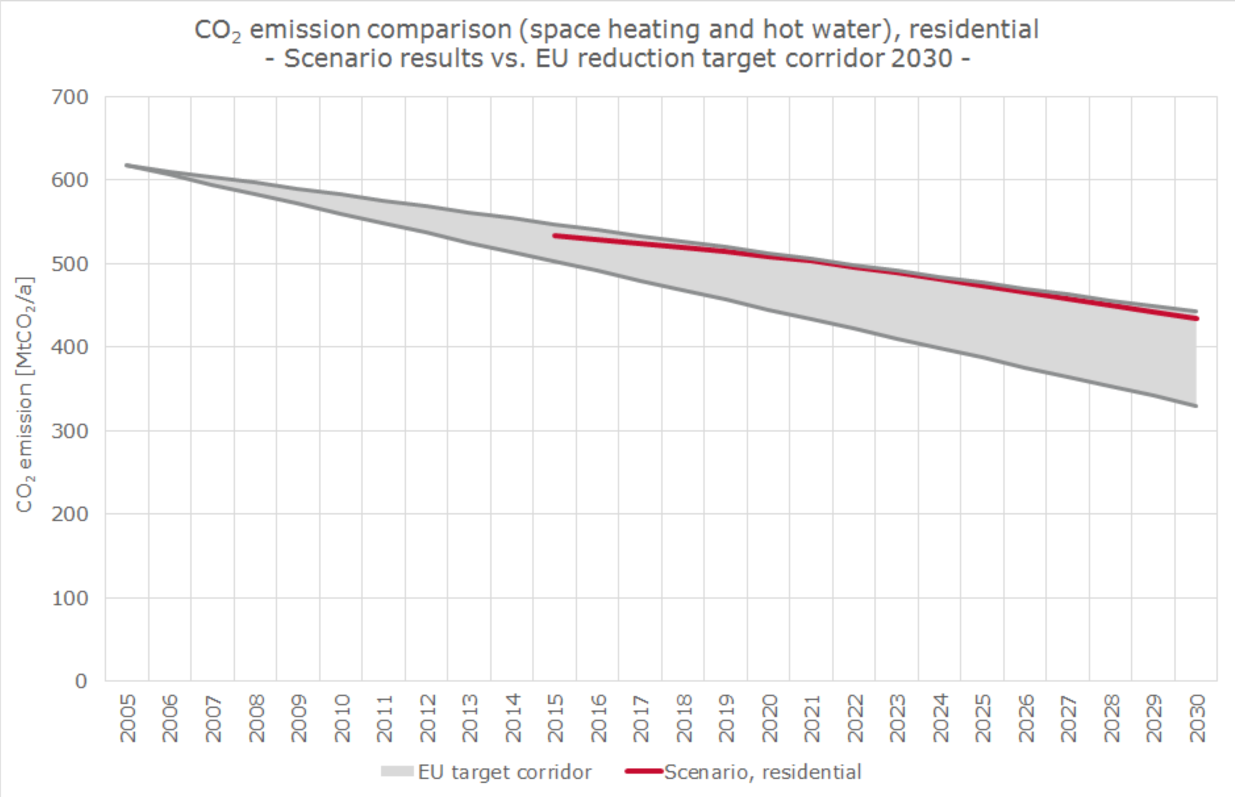


Figure 17: Carbon dioxide emission comparison (heating and domestic hot water), scenario results vs. EU reduction target, residential buildings, $MtCO_2/a$ [72] [73]

The corridor would not be met if:

(i) the heating system replacement would not be accelerated and

(ii) no low carbon technologies will enter the market.

The scenario evaluation showed that key elements to reduce carbon dioxide emissions are on the one hand reduction of delivered energy and carbon dioxide emissions by installing higher efficient heating systems with low carbon energy carriers and a reduction of energy need by improving the building shell and the ventilation systems. Therefore, these 2 key elements need to be addressed by the future EU policy framework.

Policy recommendations

The scenario proves that the installation of low carbon heating systems and an accelerated replacement of old heating systems can largely contribute to achieve the EU 2030 targets. For the acceleration an appropriate policy framework is required, allowing a sustainable market development of the heating industry and at the same time avoiding a volatile demand for heating systems.

[72] Source: Own calculation based on EU "Roadmap for moving to a competitive low carbon economy in 2050" and EUROSTAT "Complete energy balances - annual data [nrg_110a]"

[73] The calculated starting point from the BEAM² model fits well with the actual emission developments of the last years (EUROSTAT "Complete energy balances - annual data [nrg_110a]").

The current policy framework already contains policies that can be expected to have positive impacts on the heating sector – e.g. by the Ecodesign interdiction of non-condensing boiler sales from 2016 onwards and the EPBD's implementation of nearly zero energy buildings from 2021. These policies will already play an important role on the path to significant carbon dioxide reductions in the future. Nevertheless even more political activities will be needed to increase overall heating system replacements, introduce sustainably low carbon technologies into the market, while putting efforts on increasing retrofit rates and qualities.

This study's scenario builds on the contribution of several low carbon and renewable heating technologies. To deliver the resulting carbon dioxide reduction will require at least an open policy approach to support the introduction and further development of these technologies.

But the biggest contribution that Europe can make – with respect to heating systems – is to develop dedicated policies to accelerate the replacement rate of the 80 million old and inefficient heaters installed in EU homes. This combined with an energy need reduction will bring the EU on course to meet the carbon dioxide reduction goals set for 2030. For moving towards 2050 targets (-90% carbon dioxide emissions), exchange rates need to be kept high after 2030 with more or less exclusive implementation of low carbon/renewable energy systems and supply.

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Annex

Built Environment Analysis Model (BEAM²)

This section gives an overview on the methodology used for the ex-ante assessment of policy option, which is the BEAM² model.

Terms and definitions

As the Built Environment Analysis Model BEAM² is set up in the framework of the European Energy Performance of Buildings Directive (EPBD), the general terms and definitions are aligned with it. The relevant document in that context is the umbrella document for all European standards within the EPBD, which is the Technical Report (TR): Explanation of the general relationship between various CEN standards and the Energy Performance of Buildings Directive (EPBD), see (CEN/TR 15615)[74]. They are also valid for the energy demand calculations for space heating and cooling from (DIN EN ISO 13790)[75], which are also referred to.

Scope of model

The scope of the model is described in this section. General references for the energy-related calculations are CEN/TR 15615 and a report by Ecofys for the ECEE[76].

The calculation methodology follows the framework set out in the annex to the EPBD. For useful heating and cooling demand calculations the methodology in EN ISO 13790 (DIN EN ISO 13790) allows a simplified monthly calculation based on building characteristics. It is not dependent on heating and cooling equipment (except heat recovery) and results in the heating energy that is required to maintain the temperature level of the building. Based on the energy demand the delivered energy (final energy) for heating, cooling, hot water and ventilation are calculated per fuel type.
In a last step the overall energy performance in terms of primary energy and carbon dioxide emissions is calculated. An overview of the calculation process is given in Figure 18, based on the umbrella document (CEN/TR 15615). It implies following the energy flows from the left to the right.

The three steps of the energy performance calculation are always done for reference buildings for a sector, age group, retrofit level and HVAC systems. Subsequently the energy costs per year and the investment costs in case of a new buildings or retrofit are calculated.

[74] CEN/TR 15615. Technical Report - Explanation of the general relationship between various European standards and the Energy Performance of Buildings Directive (EPBD) - Umbrella Document, CEN April 2008 (English).
[75] DIN EN ISO 13790. Energy performance of buildings - Calculation of energy use for space heating and cooling (ISO 13790:2008), Beuth Verlag Berlin 1999 (German version EN ISO 13790:2008).
[76] ECOFYS, 2011a

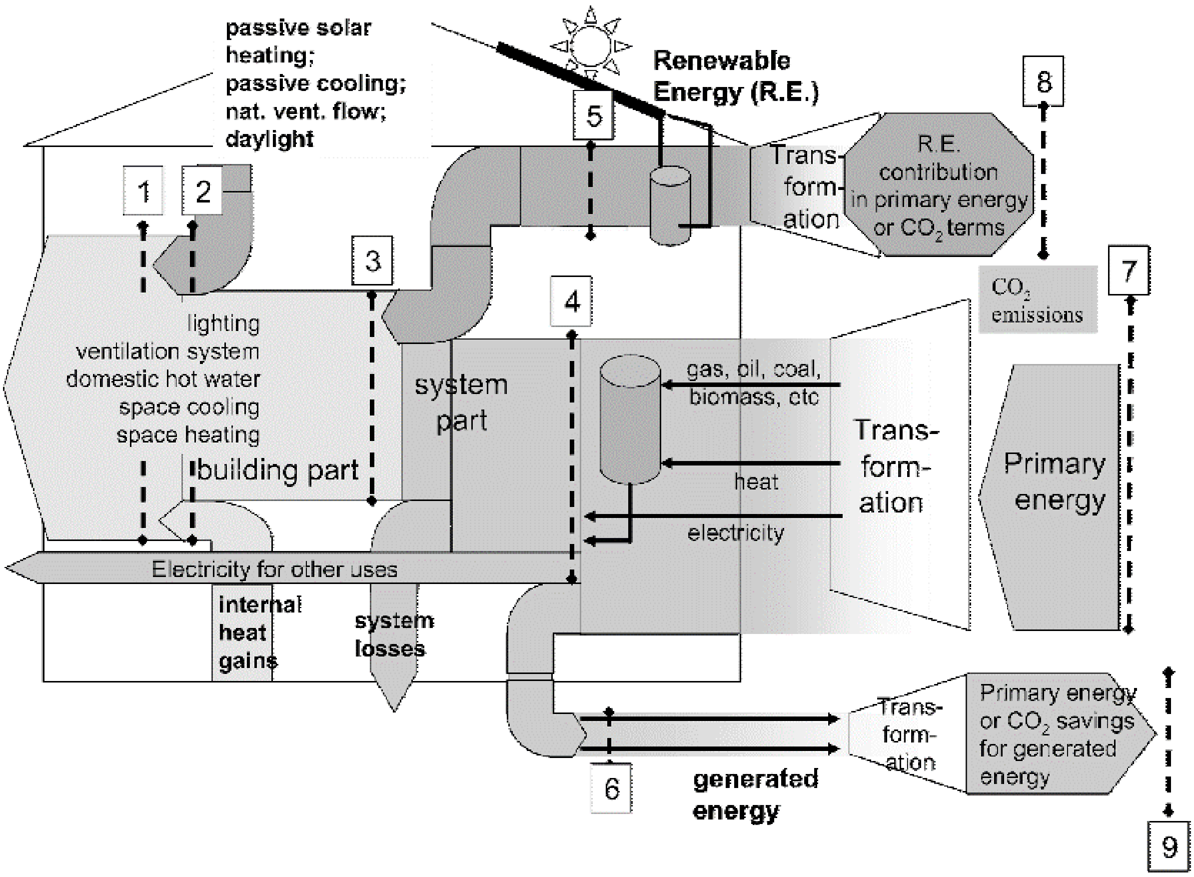


Figure 18: Schematic Illustration of the scope for the newly developed Built-Environment-Analysis-Model BEAM2, Source:(CEN/TR 15615)[77]

Key for Figure 18
(1) represents the energy needed to fulfil the users requirements for heating, cooling, lighting etc, according to levels that are specified for the purposes of the calculation.
(2) represents the "natural" energy gains - passive solar heating, passive cooling, natural ventilation, daylighting ˝U together with internal gains (occupants, lighting, electrical equipment, etc)
(3) represents the building's energy needs, obtained from (1) and (2) along with the characteristics of the building itself.
(4) represents the delivered energy, recorded separately for each energy carrier and inclusive of auxiliary energy, used by space heating, cooling, ventilation, domestic hot water and lighting systems, taking into account renewable energy sources and co-generation. This may be expressed in energy units or in units of the energy ware (kg, m3, kWh, etc).
(5) represents renewable energy produced on the building premises.
(6) represents generated energy, produced on the premises and exported to the market; this can include part of (5).
(7) represents the primary energy usage or the carbon dioxide emissions associated with the building.

Structure and methodology

The model setup and calculation process is based on the energy demand calculations for space heating and cooling from the ISO Standard 13790:2008 (DIN EN ISO 13790).

[77] The figure is a schematic illustration and is not intended to cover all possible combinations of energy supply, on-site energy production and energy use. For example, a ground-source heat pump uses both electricity and renewable energy from the ground; and electricity generated on site by photovoltaic could be used entirely within the building, or it could be exported entirely, or a combination of the two. Renewable energy wares like biomass are included in [7], but are distinguished from non-renewable energy wares by low carbon dioxide emissions. In the case of cooling, the direction of energy flow is from the building to the system.

Basic input to the model are data on the building stock such as building types, conditioned floor areas, age groups, retrofit levels and HVAC systems in stock. Furthermore the climate data such as temperature and irradiation is required. Based on this data a status-quo inventory of the building stock can be constructed.

For the scenario analysis as central part of the model, additional input data with respect to new building, demolition and retrofit activities, thermal insulation standards, heating, ventilation and air conditioning equipment, renewable energy systems is required. Furthermore energy costs, costs for energy efficiency measures at the building envelope and costs for heating, cooling and ventilation systems are processed. With respect to the overall energy performance the greenhouse gas emissions factors and primary energy factors are required per fuel type.

The calculation process over the scenario time frame is organised as follows. Based on the initial conditioned floor area distribution along the reference buildings (RB), age groups (AG), retrofit levels (RL), heating systems (HS)[78], hot water systems (DHW)[79] and cooling systems (CS) a forecast for the conditioned floor area is done taking into account new building, demolition and retrofit programs for all or parts of these combinations.

All activities in year i have an effect starting in year i+1.
The useful energy demand for heating and cooling is derived from an integrated calculation algorithm based on (DIN EN ISO 13790). The energy demands for hot water and auxiliary energy. The final energy is calculated based on the parameters of the HVAC systems.

The delivered energy together with the primary energy and GHG emission factors are combined to the overall primary energy and GHG emissions. For the economic assessment heating and cooling loads per single building type are derived, which are relevant to the systems sizes and investment costs. The economic evaluation takes in addition to the investment costs also the energy costs into consideration.

Scenario results

Main outputs of the model are the conditioned floor area developments for RB, AG, RL, HS, DHW and CS in the first place. Next step is the calculation of the useful energy demands for heating, cooling and hot water. From this the final energy/ delivered energy for heating, cooling, hot water, ventilation and auxiliary energy is derived. For the overall energy performance the greenhouse gas emissions and primary energy is calculated.

For the economic evaluation energy costs per year are provided as well as investment costs in new buildings and retrofits. In order to compare yearly costs the investments are broken down along the lifetime of components to yearly costs by use of annuities.

[78] Heating systems (HS) also include ventilation systems (VS) and solar thermal systems (STS) for HS support if applicable.
[79] Hot water systems (DHW) also include solar thermal systems (STS) for hot water if applicable.

All results are given in specific units (e.g. per m^2) and for the overall building stock in the respective scenario.

A more detailed description of the BEAM² model is available in the dissertation by Bettgenhaeuser[80].

[80] Bettgenhäuser, 2013

Model inputs

Building stock

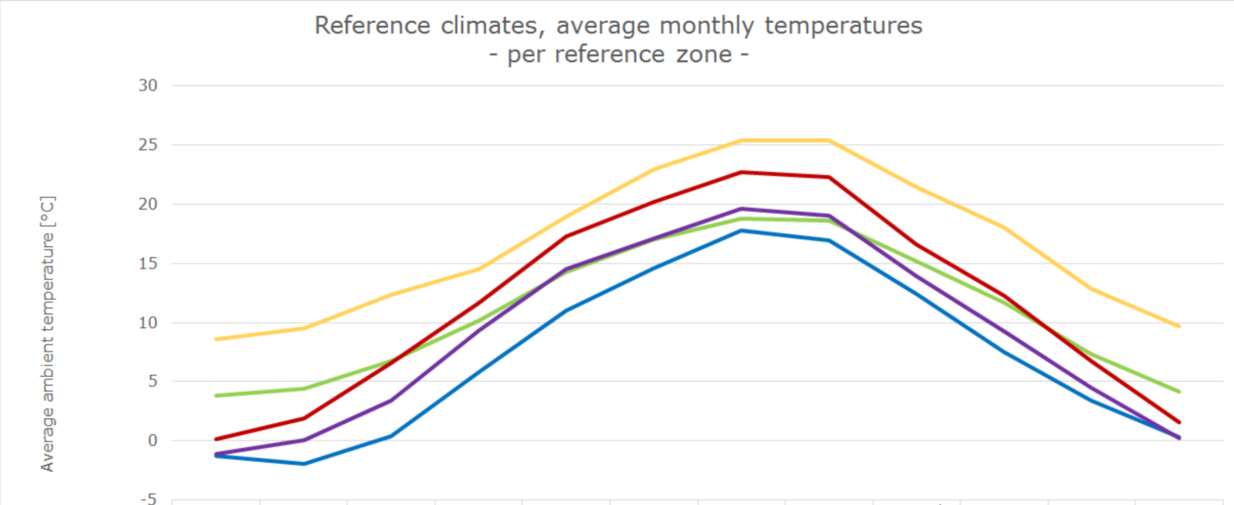
Reference zones and climates

The assessment is divided into five climate zones for Europe. The countries within the respective reference zones[81] are shown in Figure 19. A scenario calculation is carried out for each zone.

Figure 19: Five reference zones for Europe[82]

Figure 20 shows the reference climate conditions in terms of weighted average ambient temperatures of the reference zones.

[81] All countries are assigned to one of the reference zones concerning the criteria of (i) climate conditions, (ii) building stock characteristics and (iii) cost structures and level of investment costs/energy costs.
[82] ECOFYS, 2012



	January	February	March	April	May	June	July	August	September	October	November	December
Northern	-1	-2	0	6	11	15	18	17	12	8	3	0
Western	4	4	7	10	14	17	19	19	15	12	7	4
North-Eastern	-1	0	3	9	15	17	20	19	14	9	4	0
South-Eastern	0	2	7	12	17	20	23	22	17	12	7	2
South	9	10	12	15	19	23	25	25	22	18	13	10

Figure 20 Average ambient temperatures of the reference zones per month[83]

Reference buildings

The definition of reference buildings as representative average building types for all buildings in stock is required. The reference buildings are typical representatives with regard to the geometry of a building.

The reference buildings of the internationally respected iNSPIRe[84] are used which are:

- Single Family House (SFH);
- Small Multi Family House (SMFH);
- Large Multi Family House (LMFH).

The parameters and geometries for the chosen reference buildings are shown in the following figures.

The distribution of the reference buildings for the five reference zones is presented in the conditioned floor area distribution chapter.

[83] Meteotest, 2012
[84] iNSPIRe, 2014

Table 3: Single Family House (SFH)[85]

Parameter	Values	Unit
Total conditioned floor area	96	m²
A/V ratio	0.90	1/m
Average room height	2.5	m
Exterior building volume	281	m³
Exterior walls	128	m²
Windows	26	m²
Cellar ceiling	52	m²
Roof / Upper Ceiling	52	m²

Table 4: Small Multi Family House (SMFH)[85]

Parameter	Values	Unit
Total conditioned floor area	500	m²
A/V ratio	0.5	1/m
Average room height	2.5	m
Exterior building volume	1,672	m³
Exterior walls	513	m²
Windows	128	m²
Cellar ceiling	124	m²
Roof / Upper Ceiling	124	m²

Table 5: Large Multi Family House (SMFH)[85]

Parameter	Values	Unit
Total conditioned floor area	2,340	m²
A/V ratio	0.3	1/m
Average room height	2.5	m
Exterior building volume	7,484	m³
Exterior walls	699	m²
Windows	699	m²
Cellar ceiling	462	m²
Roof / Upper Ceiling	462	m²

Age groups

The definition of age groups in stock is required to distinguish between different construction periods of buildings.

The chosen age groups are:

[85] iNSPIRe, 2014

- Pre 1945;
- 1945-1970;
- 1971-1990;
- 1991-2014;
- From 2015.

The distribution of the age groups for the five reference zones is presented in the conditioned floor area distribution chapter.

Retrofit levels

In the scenario calculation for each reference zone two retrofit levels (major renovation before/after 2020) will be used. The fact that not every renovation is a major renovation will be considered in the retrofit rates per year (cf. chapter "specific scenario parameters").

The thermal qualities of the renovated/not renovated case and for the retrofit/new building cases are shown in the following chapter.

Figure 21 shows the share of already retrofitted residential buildings per reference zone. The already retrofitted buildings are not excluded from further renovations, but not renovated buildings are retrofitted first.[86]

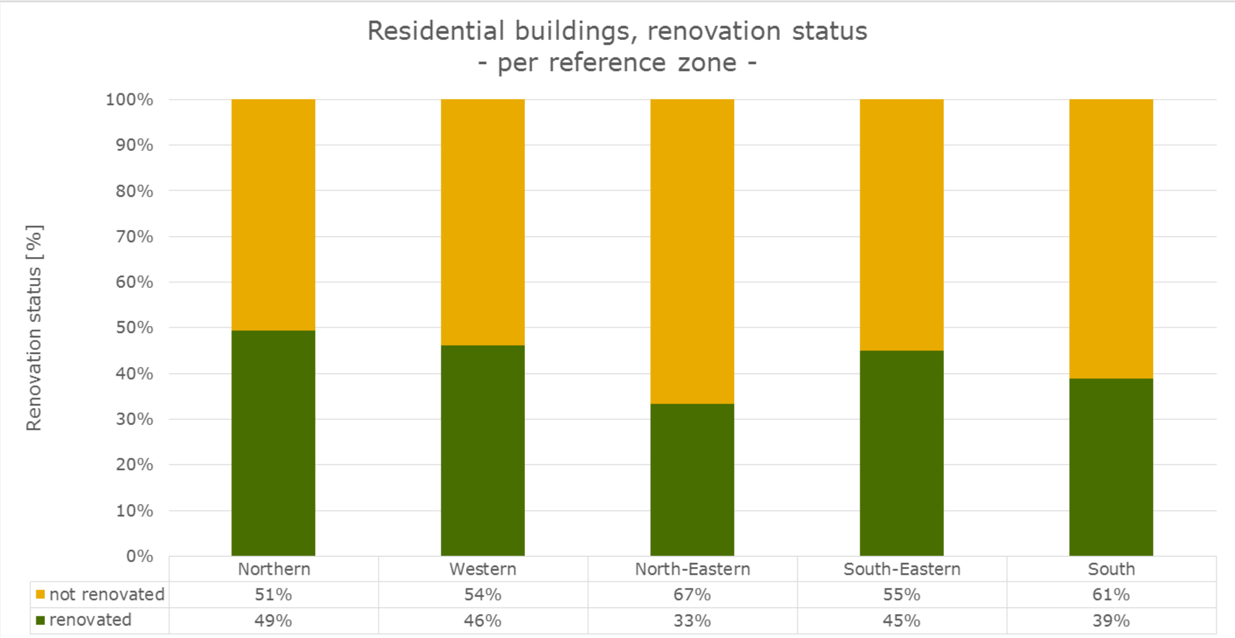


Figure 21: Share of already retrofitted residential buildings[87]

[86] Information is available only for the split up in renovated and not renovated buildings, no further details. For each period typical renovation levels are assumed. Already renovated buildings are not excluded from renovation, but the not renovated buildings undergo renovation first.
[87] ECOFYS, 2012 (based on Euroconstruct, 2005) with further updates and assumptions for period 2005-2013.

Thermal qualities

As described in the previous chapter of the retrofit levels, renovated and not renovated buildings are distinguished per reference zone.

In the scenario calculations the influence of cold bridges will also be taken into account (0.05 W/(m²K) for new buildings and 0.10 W/(m²K) for renovated buildings).

Table 6 shows the thermal qualities of the building shell components (wall, window, floor and roof) for all age groups for the "not renovated" case whereas Table 7 shows the "renovated" case[88].

Table 6: Thermal Qualities per Reference Zone – Residential Buildings, not renovated[89]

	North	Western	North-Eastern	South-Eastern	South
Pre 1945 Not renovated					
Wall	0.70	1.90	1.40	1.68	1.80
Window	2.82	4.13	3.91	2.57	5.32
Floor	0.55	1.72	1.66	1.21	1.94
Roof	0.46	2.08	0.99	1.29	2.21
1945-1970 Not renovated					
Wall	0.64	1.77	1.25	1.64	1.75
Window	2.70	4.04	3.35	2.52	5.37
Floor	0.45	1.62	1.31	1.20	2.05
Roof	0.38	1.89	0.83	1.26	1.88
1971-1990 Not renovated					
Wall	0.36	0.86	0.85	1.32	1.50
Window	2.29	3.50	2.58	2.46	4.35
Floor	0.28	0.94	1.07	1.00	1.67
Roof	0.23	0.70	0.63	1.02	1.50
1991-2014 Not renovated					
Wall	0.26	0.44	0.48	0.80	1.08
Window	1.75	2.02	2.05	1.76	3.45
Floor	0.26	0.42	0.70	0.72	1.06
Roof	0.16	0.32	0.31	0.48	0.95

[88] Note: The thermal qualities will be calibrated with top-down space heating consumption data in the course of the scenario calculation.
[89] iNSPIRe, 2014

Table 7: Thermal Qualities per Reference Zone – Residential Buildings, renovated[90] [91]

	North	Western	North-Eastern	South-Eastern	South
Pre 1945 Renovated					
Wall	0.24	0.55	0.52	0.72	1.63
Window	1.75	2.24	3.91	2.57	4.70
Floor	0.25	0.54	0.56	0.60	1.27
Roof	0.17	0.35	0.37	0.46	1.20
1945-1970 Renovated					
Wall	0.24	0.55	0.52	0.72	1.63
Window	1.75	2.24	3.35	2.52	4.70
Floor	0.25	0.54	0.56	0.60	1.27
Roof	0.17	0.35	0.37	0.46	1.20
1971-1990 Renovated					
Wall	0.17	0.33	0.33	0.50	0.84
Window	1.00	1.20	1.90	1.90	2.00
Floor	0.17	0.38	0.50	0.39	0.56
Roof	0.17	0.20	0.28	0.28	0.45
1991-2014 Renovated					
Wall	0.17	0.33	0.33	0.50	0.84
Window	1.00	1.20	1.90	1.76	2.00
Floor	0.17	0.38	0.50	0.39	0.56
Roof	0.16	0.20	0.28	0.28	0.45

Heating and hot water systems

The figures on the next pages show the existing stock of heating systems and domestic hot water systems for single-family houses (cf. Figure 22 and Figure 24) and for multi-family houses (cf. Figure 23 and Figure 25) referring to the heating energy consumption in the five reference zones.

The implementation of the heating system distribution into the BEAM² model will be performed according to the square meter distribution across the different reference building types and ages.

The following efficiencies will be assumed per heating system for residential buildings (cf. Table 8).

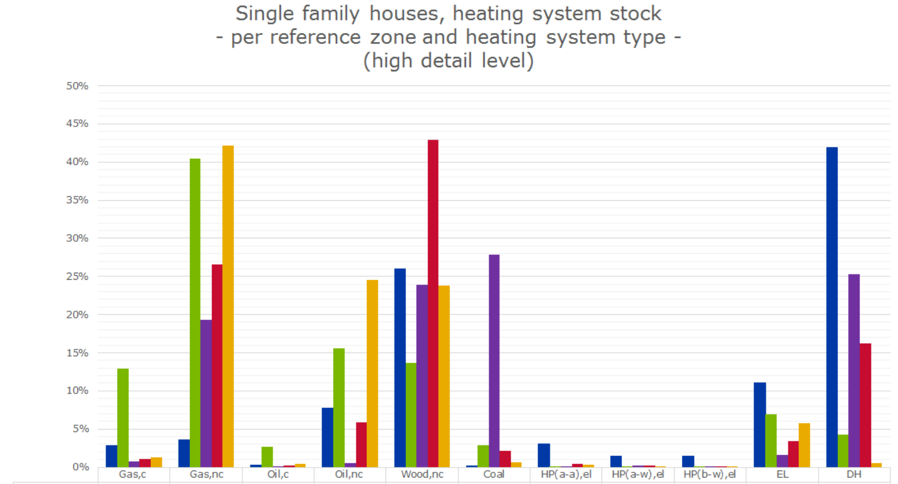
[90] ECOFYS, 2012
[91] Note: The thermal qualities will be calibrated with top-down space heating consumption data in the course of the scenario calculation.

Table 8: Conversion efficiencies per heating systems for residential (Source: several sources[92] [93] [94] [95])

System[96]	Annual system efficiency[97] [%]
s_Gas,c	90%
s_Gas,nc	80%
s_Oil,c	86%
s_Oil,nc	76%
s_Wood	76%
s_Coal	63%
s_HP,(b-w)	388%
s_HP,(a-w)_N	288%
s_HP,(a-w)_S	350%
s_HP,(a-a)_N	289%
s_HP,(a-a)_S	351%
s/n_CHP	95%
s/n_DH	99%
s/n_EL-direct	99%
n_Gas,c	95%
n_Oil,c	91%
n_Wood	81%
n_HP,(b-w)	463%
n_HP,(a-w)_N	308%
n_HP,(a-w)_S	375%
n_HP,(a-a)_N	361%
n_HP,(a-a)_S	439%
n_HP,(gas)	143%

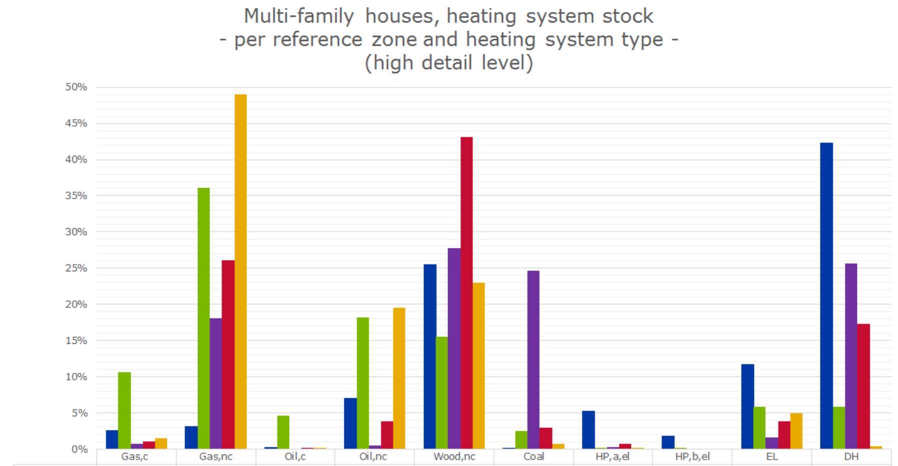
For domestic hot water systems the same magnitude of efficiencies for heat generation is set[98]. A top down adjustment of the total system efficiencies has been performed to take into consideration the high distribution losses.

[92] Ecodesign Regulation No 813/2013 (ecodesign requirements for space heaters and combination heaters)
[93] Fraunhofer heat pump monitoring report, http://wp-effizienz.ise.fraunhofer.de/download/wp_effizienz_endbericht_kurzfassung.pdf
[94] Eco efficiency directive
[95] Ecofys heat pump report (for EHPA), http://www.ehpa.org/media/studies-and-reports/?eID=dam_frontend_push&docID=1204
[96] The following abbreviations are used: s = stock; n = new; s/n = stock / new; c = condensing; nc = non-condensing; N = North; S = South; HP = heat pump; CHP = combined heat and power; DH = district heating; EL-direct = electric direct
[97] Based on low calorific value and inclusive all losses (annual system efficiency = energy need / delivered energy)
[98] Exception: Sanitary hot water heat pump with efficiencies between 1.9 and 2.1 depending on the climate



	Gas,c	Gas,nc	Oil,c	Oil,nc	Wood,nc	Coal	HP(a-a),el	HP(a-w),el	HP(b-w),el	EL	DH
Northern	3%	4%	0%	8%	26%	0%	3%	1%	1%	11%	42%
Western	13%	40%	3%	16%	14%	3%	0%	0%	0%	7%	4%
North-Eastern	1%	19%	0%	1%	24%	28%	0%	0%	0%	2%	25%
South-Eastern	1%	27%	0%	6%	43%	2%	0%	0%	0%	3%	16%
South	1%	42%	0%	25%	24%	1%	0%	0%	0%	6%	1%

Figure 22: Heating system stock for single family houses, per reference zone and heating system type (Source: own calculation based on several sources[99] [100] [101]), consumption-based



	Gas,c	Gas,nc	Oil,c	Oil,nc	Wood,nc	Coal	HP,a,el	HP,b,el	EL	DH
Northern	3%	3%	0%	7%	25%	0%	5%	2%	12%	42%
Western	11%	36%	5%	18%	16%	2%	0%	0%	6%	6%
North-Eastern	1%	18%	0%	1%	28%	25%	0%	0%	2%	26%
South-Eastern	1%	26%	0%	4%	43%	3%	1%	0%	4%	17%
South	2%	49%	0%	20%	23%	1%	0%	0%	5%	0%

Figure 23: Heating system stock for multi-family houses, per reference zone and heating system type (Source: own calculation based on several sources[102] [103] [104]), consumption-based

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[99] ECOFYS, 2015c
[100] ECOFYS, 2013
[101] ECOFYS and IEEJ, 2015
[102] ECOFYS, 2015c
[103] ECOFYS, 2013
[104] ECOFYS and IEEJ, 2015

The distribution per reference zone of the different domestic hot water systems for residential buildings are shown in the following tables.

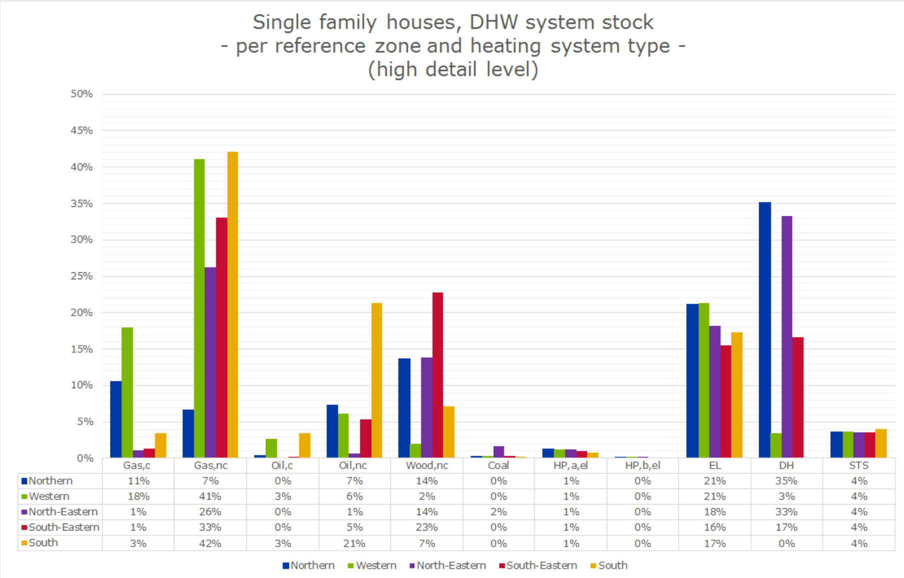

Figure 24 Domestic hot water system stock for single family houses, per reference zone and heating system type (Source: own calculation based on several sources[105] [106] [107]), consumption-based

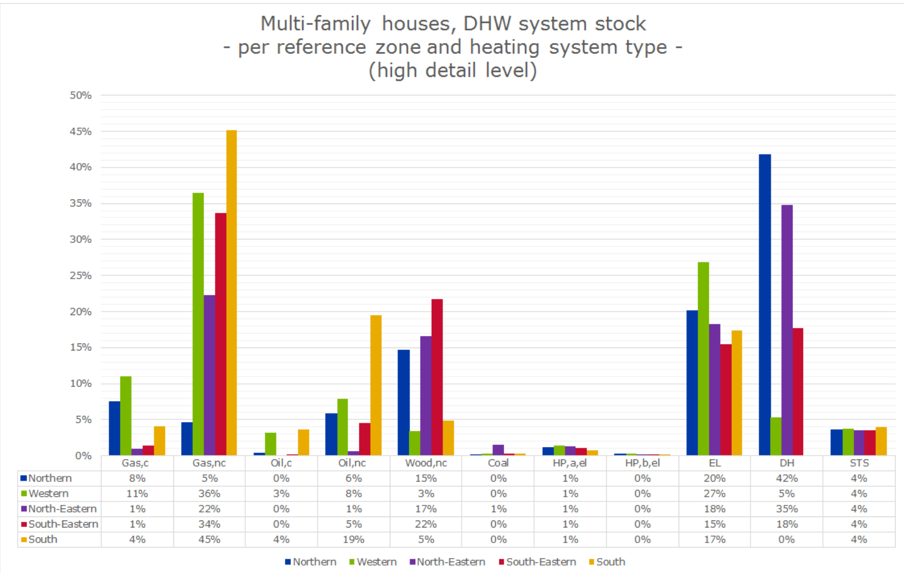

Figure 25 Domestic hot water system stock for Multi-family houses, per reference zone and heating system type (Source: own calculation based on several sources[108] [109] [110]), consumption-based

[105] ECOFYS, 2015c
[106] ECOFYS, 2013
[107] ECOFYS and IEEJ, 2015
[108] ECOFYS, 2015c
[109] ECOFYS, 2013
[110] ECOFYS and IEEJ, 2015

Conditioned floor areas

The following figures give an overview on the conditioned floor area distribution along the reference zones of the study (per reference buildings: cf. Figure 26 and Figure 27, per age group: cf. Figure 28).

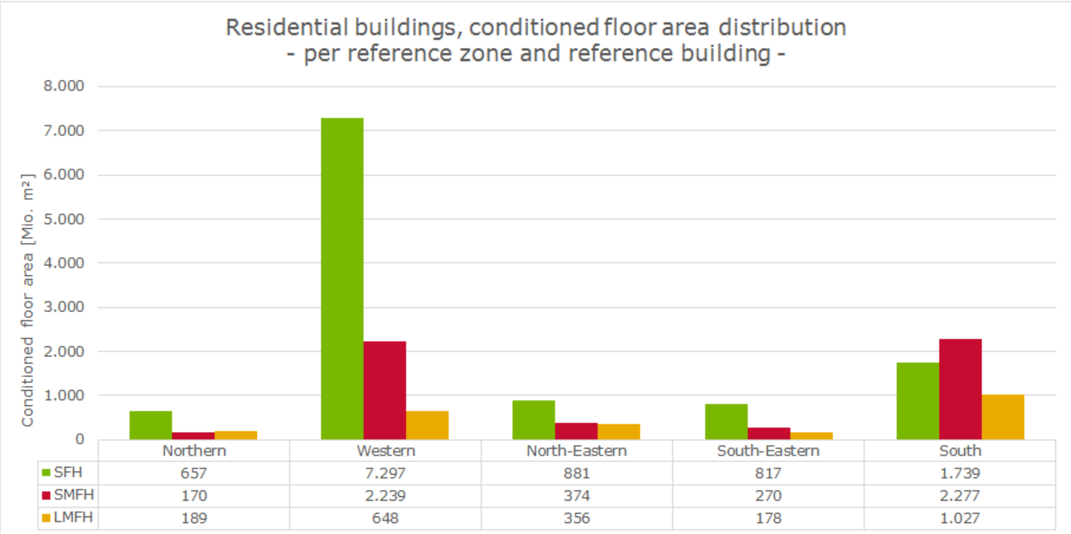

Figure 26: Conditioned floor area distribution in residential buildings, per reference zone and reference building, [Mio. m²] [111] [112] [113] [114] [115]

[111] iNSPIRe, 2014
[112] IWU, 2015
[113] ENERDATA, 2013-2015
[114] BPIE, 2015
[115] Schimschar, 2015

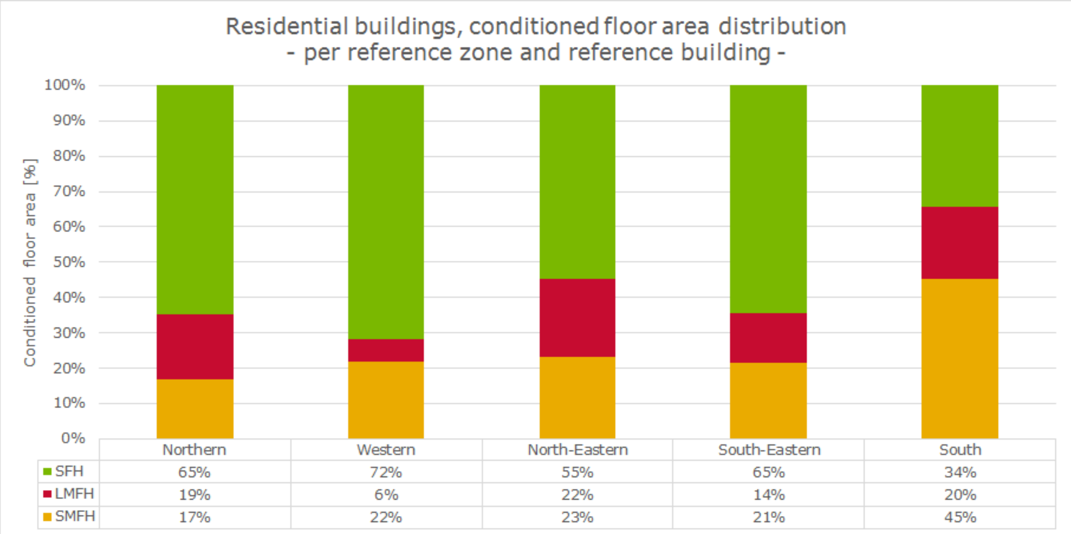

Figure 27: Conditioned floor area distribution in residential buildings, per reference zone and reference building, [%] [116] [117] [118] [119] [120]

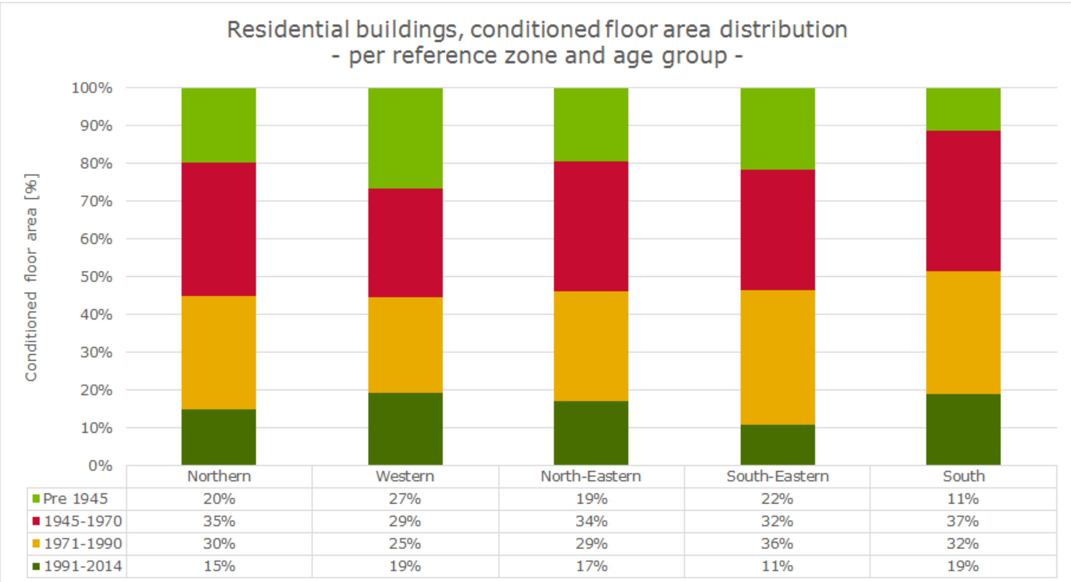

Figure 28: Conditioned floor area distribution in residential buildings, per reference zone and age group, [%] [121] [122] [123] [124] [125]

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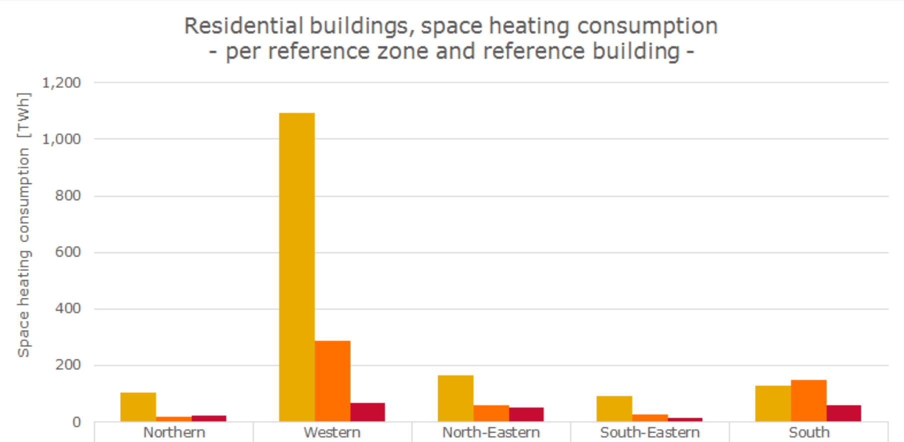
[116] iNSPIRe, 2014
[117] IWU, 2015
[118] ENERDATA, 2013-2015
[119] BPIE, 2015
[120] Schimschar, 2015
[121] iNSPIRe, 2014
[122] IWU, 2015
[123] ENERDATA, 2013-2015
[124] BPIE, 2015
[125] Schimschar, 2015

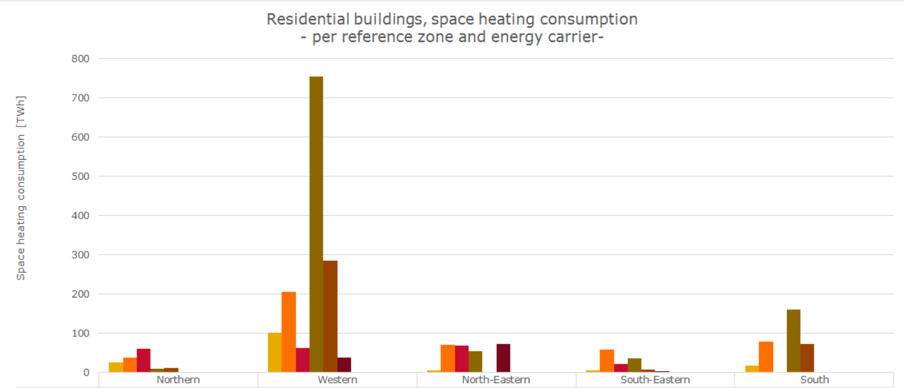
Space heating energy consumptions

The following figures give an overview on the space heating energy consumptions in the reference zones per reference buildings (cf. Figure 29) and per energy carrier (cf. Figure 30).



	Northern	Western	North-Eastern	South-Eastern	South
SFH	106	1,094	166	93	130
SMFH	18	286	57	28	149
LMFH	21	69	52	15	58

Figure 29: Space heating consumption in residential buildings, per reference zone and reference building, [TWh] [126] [127] [128] [129]



	Northern	Western	North-Eastern	South-Eastern	South
Electricity	25	102	5	6	19
Biomass	38	205	71	59	80
District heat	61	63	70	22	2
Gas	9	754	54	37	161
Oil	11	286	1	7	73
Coal	0	38	73	3	2
Solar thermal	0	1	0	0	0
Geothermal	0	0	0	0	0
Other biofuels	0	0	0	0	0
Waste	0	0	0	0	0

Figure 30: Space heating consumption in residential buildings, per reference zone and energy carrier, [TWh] [130] [131] [132] [133]

[126] iNSPIRe, 2014
[127] Eurostat, 2015a
[128] Schimschar, 2015
[129] IWU, 2015
[130] iNSPIRe, 2014
[131] Eurostat, 2015a
[132] Schimschar, 2015
[133] IWU, 2015

It is evident, that fossil fuels (gas, oil, coal) still dominate the heating consumption in all reference zones. The most frequent energy carriers/systems per zone for single-family houses are:

- Northern: District heating (> 40%)
- Western: Gas (> 50%)
- North-Eastern: Coal (> 25%)
- South-Eastern: Biomass (> 40%)
- Southern: Gas (> 40%)

Regardless of the energy carrier distribution the efficiency of the boilers that are currently installed is highly important for the European energy and climate targets. Approximately 80 million[134] low efficient boilers are still in operation today.

Carbon dioxide emission factors

The following table shows the carbon dioxide emission factors for the reference zones per energy carrier for 2013.

Table 9 Carbon dioxide emission factors per energy carrier for 2013 [135]

Reference Zone	Electricity [gCO_2/kWh]	Biomass [gCO_2/kWh]	District heat [gCO_2/kWh]	Gas [gCO_2/kWh]	Oil [gCO_2/kWh]	Coal [gCO_2/kWh]
Northern	80	0	173	202	267	341
Western	262	0	307	202	267	341
North-Eastern	700	0	318	202	267	341
South-Eastern	482	0	368	202	267	341
Southern	419	0	362	202	267	341

Until 2030 the average annual decrease of carbon dioxide emission factors is 1.10 % for electricity[136] and 1.68 % for district heat.

[134] EHI, 2015
[135] For district heat: Own calculations based on Eurostat Complete Energy Balances, for electricity: IEA Energy Statistics - CO_2 per kWh of electricity (gCO_2 per kWh) - Memo EU-28
[136] IEA Energy Statistics - CO_2 per kWh of electricity (gCO_2 per kWh) - Memo EU-28

Specific scenario parameters

The following paragraphs describe briefly the main scenario parameters and the following subchapters show the detailed scenario parameters (thermal qualities, new building/demolition/retrofit rates and HVAC).

The scenario assumes an implementation of the EPBD recast from 2010, without further changes on the Directive. This includes already built-in provisions for future actions, namely the requirement for all new buildings to be built as nearly zero energy buildings as from 2021 on and the update cycles of the assessments of MSs on cost optimal building performance requirements.
It is also assumed that the further implementation of the provisions on energy performance certificates, and inspections of heating and air-conditioning systems and technical building systems lead to an increase in the renovation rate and of the heating system exchange rate (developing from an average lifetime of 28[137] to an average lifetime of 22 years until 2030).

We set the following parameter for the scenario calculation:

- Thermal qualities
  - New buildings
    - 2015-2020: Cost optimal U-values according to MS reports
    - 2021-2030: 12.5 % improvement compared to 2015-2020, reflecting introduction of nZEBs
  - Existing buildings
    - 2015-2020: Cost optimal U-values from MS reports
    - 2021-2030: 10 % improvement[138] compared to 2015-2020
- Retrofit rates (complete renovation equivalent rate)
  - Residential (2015-2030): 0.61[139] - 1.00 %
- Heating systems
  - Replacement rates (2015-2030): 3.6 - 4.6 %

[137] Own assumption, based on market data
[138] Update cost optimality calculations, average improvement 2020-2030
[139] Own calculations based on the building stock model Invert/EE-Lab, TU Vienna

Thermal qualities

The following table shows the thermal qualities of the building shell components for new buildings per reference zone.

Table 10 Heat transfer coefficients (U-values), 2015-2020 and 2021-2030, new buildings[140]

	North	Western	North-Eastern	South-Eastern	South
New buildings 2015-2020					
Wall	0.21	0.23	0.21	0.25	0.68
Window	1.00	1.47	1.24	1.14	3.71
Floor	0.31	0.28	0.32	0.30	0.64
Roof	0.15	0.19	0.16	0.25	0.68
New buildings 2021-2030					
Wall	0.19	0.20	0.19	0.21	0.60
Window	0.88	1.28	1.08	0.99	3.25
Floor	0.27	0.25	0.28	0.26	0.56
Roof	0.13	0.17	0.14	0.22	0.60

The following table shows the thermal qualities of the building shell components for retrofits per reference zone.

Table 11: Heat transfer coefficients (U-values), 2015-2020 and 2021-2030, retrofit[141]

	North	Western	North-Eastern	South-Eastern	South
Retrofit 2015-2020					
Wall	0.24	0.26	0.24	0.27	0.76
Window	1.00	1.47	1.24	1.14	3.71
Floor	0.31	0.28	0.32	0.30	0.64
Roof	0.15	0.19	0.16	0.25	0.68
Retrofit 2021-2030					
Wall	0.21	0.23	0.21	0.25	0.68
Window	0.90	1.32	1.11	1.02	3.34
Floor	0.28	0.25	0.29	0.27	0.57
Roof	0.14	0.17	0.14	0.22	0.62

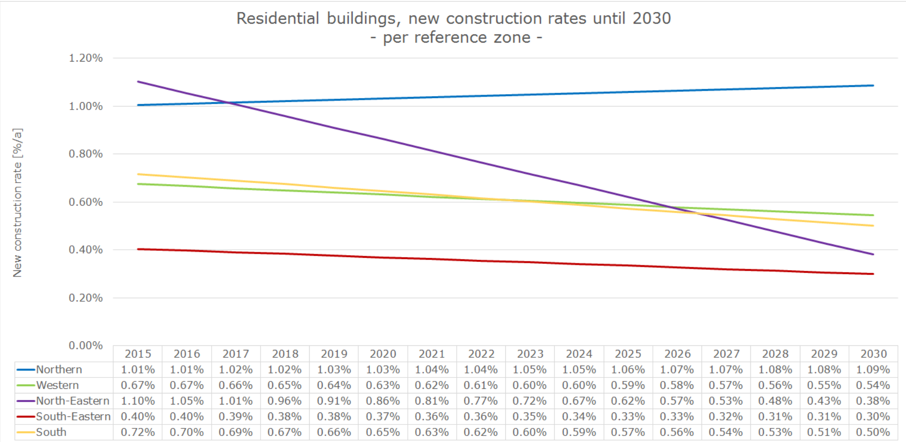
[140] ECOFYS, 2015b

[141] update cost optimality calculations, average improvement 2020-2030

New construction, demolition and retrofit rates

This chapter shows the different developments for new construction, demolition and retrofit rates from 2015 to 2030.

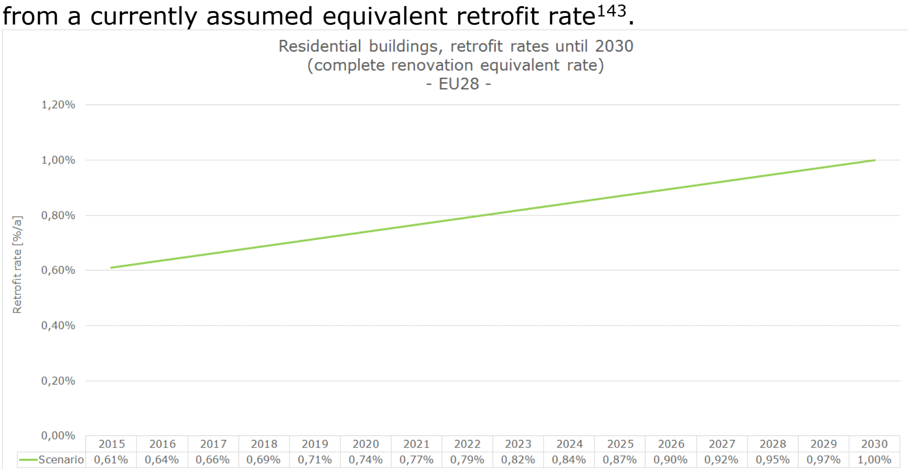
The new construction rate prognosis in the GLOBUS model is based on the prediction of the gross domestic product and on the population. The new construction rates from 2015-2030 are shown in the following figure.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Northern	1.01%	1.01%	1.02%	1.02%	1.03%	1.03%	1.04%	1.04%	1.05%	1.05%	1.06%	1.07%	1.07%	1.08%	1.08%	1.09%
Western	0.67%	0.67%	0.66%	0.65%	0.64%	0.63%	0.62%	0.61%	0.60%	0.60%	0.59%	0.58%	0.57%	0.56%	0.55%	0.54%
North-Eastern	1.10%	1.05%	1.01%	0.96%	0.91%	0.86%	0.81%	0.77%	0.72%	0.67%	0.62%	0.57%	0.53%	0.48%	0.43%	0.38%
South-Eastern	0.40%	0.40%	0.39%	0.38%	0.38%	0.37%	0.36%	0.36%	0.35%	0.34%	0.33%	0.33%	0.32%	0.31%	0.31%	0.30%
South	0.72%	0.70%	0.69%	0.67%	0.66%	0.65%	0.63%	0.62%	0.60%	0.59%	0.57%	0.56%	0.54%	0.53%	0.51%	0.50%

Figure 31: New construction rates per reference zone, residential, 2015-2030[142]

The retrofit rates from 2015-2030 are shown in the following figure where the starting point results from a currently assumed equivalent retrofit rate[143].



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Scenario	0,61%	0,64%	0,66%	0,69%	0,71%	0,74%	0,77%	0,79%	0,82%	0,84%	0,87%	0,90%	0,92%	0,95%	0,97%	1,00%

Figure 32: Retrofit rates for EU28, residential, 2015-2030

The demolition rates are assumed to be 0.10 %/year and will be applied to the two age groups containing the oldest buildings (pre 1945, 1945-1970).

[142] Schimschar, 2015
[143] ECOFYS, 2015a

HVAC systems

Heating systems

The heating system assumptions are presented in chapter 3.4.4.

Ventilation systems

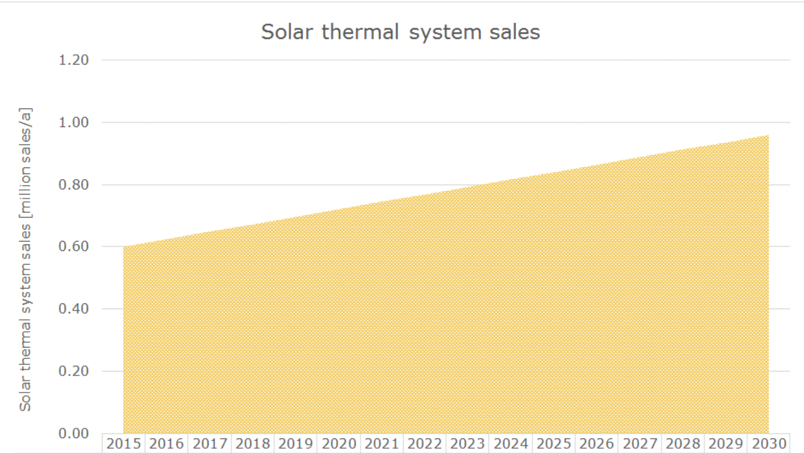
Ventilation systems with heat recovery are assumed to be distributed in case of major renovation of a building and in new buildings according to the following table.

Table 12: Scenario input, ventilation systems with heat recovery, residential, all zones

	Ventilation systems with heat recovery [%]
	Residential
Retrofit 2015-2030	3 %
New buildings 2015-2020	25 %
New buildings 2021-2030	45 %

Solar thermal systems

Solar thermal systems in residential buildings are considered to support only domestic hot water supply. The EU28 information from the European Solar Thermal Industry Federation (ESTIF[144]) has been used as a starting point for the scenario calculation.



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ST (DHW)	0.60	0.62	0.65	0.67	0.70	0.72	0.74	0.77	0.79	0.82	0.84	0.86	0.89	0.91	0.94	0.96

Figure 33: Solar thermal system sales, million systems per year

[144] http://www.estif.org/fileadmin/estif/content/market_data/downloads/2014_solar_thermal_markets_LR.pdf

Although the past years show a declining trend in some EU MSs the following sales increase has been considered due to the prescription of the Renewable Energy Directive (RED) until 2020 and due to the nearly zero energy introduction from 2021 onwards (EPBD).

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