2024

DRIVERS TO HEAT PUMP ADOPTION BY EUROPEAN HOUSEHOLDS

DAIKIN EUROPE

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Foreword

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With this paper we aim to provide complete and fact-based information about the benefits of heat pumps from the user perspective. This is intended to be a living document and we will update it regularly.

The increased demand for heat pumps in recent years has triggered manufacturers to widen their product offer. Based on a sample from October 2018 to September 2022 of 124,000 heat pump selections (52 % in existing homes and 48 % in new builds), in the United Kingdom, France and Germany, the Daikin product offer of air-to-water heat pumps fits in 89 % of existing homes and 95 % of new build homes[2].

Though the heat pump offer covers the need of the vast majority of homes in terms of heat load and heat emitters[3] used in the property, the decision to swap from a combustion boiler to a heat pump is not easy. Users are first-time users, who have no past experience with the comfort level and reliability of the equipment. Additionally, the macro conditions are complex and volatile. Since the outbreak of war in Ukraine, energy prices have been subject to a steep increase, followed by a fall to a level close to pre-war times. Local authorities offer a wide range of incentives, often product-specific, sometimes combining multiple measures. Authorities intend to, and in some cases already have plans to, ban conventional, combustion-based technology. These are often application-specific and sometimes region-specific.

In such a complicated macro environment, the first-time heat pump user needs to know whether a heat pump is the right investment decision for their specific needs.

With this paper, we aim to offer objective, fact-based information and insights to help citizen reach their own conclusions.

The paper explores six elements:

1. **To what extent does a heat pump impact the value of your property, in capital value and rental fee?**
   Installing a heat pump in a home has a positive effect on the property's energy label, which in turn has an effect on the value of the property.

2. **What savings on energy costs can be expected when replacing a combustion boiler with a heat pump?**
   Oil, gas and electricity prices have shown big fluctuations in 2022 and 2023. With such fluctuations, the mid- to long-term projections on savings of heat pumps versus combustion boilers are significant. In chapter 2, a model suggests the most plausible view of savings within a 10-year horizon.

3. **Future ban on gas and oil boilers**
   A map is drawn that clarifies possible or certain restrictions on the usage of gas or oil boilers in specific applications and regions.

4. **Incentive schemes for air-to-water heat pumps**
   An overview of the incentive schemes in place per country/region and type of technology.
5. **Synergies between solar PV and heat pumps**
   Heat pumps are electrically powered devices and thus have the potential to increase the self-consumption ratio[4]. PV energy is mainly produced during the summer while the heat pump mainly operates in winter. Nevertheless, an increase of the self-consumption ratio can be achieved and a case study is explored in

[1] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions REPowerEU Plan COM/2022/230 final
[2] Single family home applications, excluding multi-family buildings.
[3] Heat emitters: e.g. radiators, underfloor heating etc.
[4] The self-consumption ratio is the ratio between the PV production and the portion of the PV production consumed by the loads. This ratio can vary between 0 % and 100 % and is most often between 30 % and 50 %. The higher the value, the more PV energy is consumed by the loads in the home and the less energy is sent back to the grid.

chapter 5.

6. **Environmental impact of heat pumps**
Heat pumps can, by avoiding the combustion of natural gas or oil, substantially contribute to reducing carbon emissions in homes. In chapter 6 we take a holistic view of the carbon emissions of heat pumps. By applying an LCA[5] methodology, all stages are taken into consideration and benchmarked against conventional technology.

Based on the six-point argumentation, and considering the medium- to long term projections, for many people a heat pump is a valuable alternative to a gas or oil boiler and will be beneficial from both a life cycle cost and environmental impact point of view.

Although the authors have tried to be complete in the answers given in this document, some questions may not have been answered. Please share your questions or thoughts on heatpumpadoptioneuhsbu@daikin.eu.

[5] LCA: Life cycle assessment

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Section 1: Impact of heat pump installation on property value

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"This section showcases the positive impact of heat pumps installation on the energy classes of dwellings in the EU. Additionally, in several countries, installing a HP increases the value of the property"

1.1 The European Energy Performance Label framework

The Energy Performance of Buildings Directive (EPBD), last reviewed in 2018, sets out minimum requirements and a common framework for calculating energy performance in an effort to improve the energy performance of buildings in the European Union (EU)[6].

Under this framework, energy performance certificates became compulsory in 2019 when selling or renting a building. Similarly, inspection schemes for heating and air conditioning systems must be established[7].

Energy performance certificates (EPCs) assign buildings a label ranging from A (most energy efficient) to G (least energy efficient). The certificate is valid for 10 years. In case of renovations, a new certification must be issued that takes into account improvements before selling or leasing the property.

Energy class	Energy index: kWhPE/m²/year
A++	less than zero
A+	from 0 to 15
A	from 16 to 30
A-	from 31 to 45
B+	from 46 to 62
B	from 63 to 78
B-	from 79 to 95
C+	from 96 to 113
C	from 114 to 132
C-	from 133 to 150
D+	from 151 to 170
D	from 171 to 190
D-	from 191 to 210
E+	from 211 to 232
E	from 233 to 253
E-	from 254 to 275
F	from 276 to 345
G	346 and above

FIGURE 1.1 SOURCE: CERTIBRU THE ENERGY PERFORMANCE OF BUILDINGS

Following the directive, all 27 member states and the UK have implemented the EPBD requirements in their national legislations.

[6] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)
[7] European Commission – DG Energy: Certificates and inspections;

1.2 Impact of heat pump installation on a building's Energy Performance Certificate

To isolate the energy-saving effect of a heat pump on the EPC label, we have calculated the energy consumption of an existing house with a certain EPC class rating, which we assume is representative of the entire building stock in that class. Within this existing house space, heating and domestic hot water are for example provided by means of electricity, gas or oil fuel. An EPC simulation is then carried out for each of these houses to calculate the new EPC label that could be reached when the existing installation is replaced by a heat pump to power space heating and domestic hot water.

For the purpose of this study, we have decided not to change emitters whenever possible. For example: if radiators are installed, it is assumed the same type of emitter is kept after the installation of the heat pump. Whether or not the same radiators can be reused depends on the situation. However, radiators can be replaced easily at a low cost especially compared to the alternative of installing underfloor heating. Conversely, if the house features an underfloor heating system, that system was considered for the installation of the heat pump.

Furthermore, the exact reduction in a house's energy consumption per square metre per year (kWh/(m^2/year)) varies depending on heterogeneous factors. A house with a very efficient heating installation but poorly insulated roof and walls has a certain energy consumption of X kWh/(m^2/year) – corresponding with a certain EPC label. Suppose that we now have a completely different house with the opposite situation, i.e. good insulation of the roof and walls but a very inefficient heating system. It may be that this completely different house has a similar energy consumption and thus falls in the same EPC class. In these two imaginary cases, installing a heat pump will have a greater effect on the house with the more inefficient heating system. This difference will perhaps become clearer with the aid of a practical example (see the following section).

The effect of a heat pump is also relative to the combined effect of other renovation measures. Many such measures can achieve a reduction in yearly energy consumption of a residential building, and hence an improvement in EPC label. However, even without other renovation measures, a heat pump can still result in a significant reduction of the yearly energy consumption (for more on this topic, see Section 2).

All the following simulations, which will be referred to in the country-specific section, were carried out where possible by, or at least with input from, recognised energy experts with the expertise and assets to perform such calculations.

1.2.1 Germany

EPC framework

The EPBD regulations are also applied in Germany and evaluations take place according to the procedures for calculation of annual heat and energy use[8] and heating, domestic hot water supply and ventilation[9] . With the DIN V 18599[10] calculation method, a planned building is always compared directly to a reference building with the same geometry but with specified quality standards for the building shell and a specified heating system and building equipment.

The building is evaluated by assessing its shell and the primary energy requirement, depending on the heat generator, the heat transfer medium and all other energies required for heating, cooling, lighting, etc.

Depending on what is changed in the building or in the system technology, these evaluations must be re-reported and a new assessment must be carried out.

For the replacement of a heat generator, legal regulations regarding the use of regenerative energies must be observed as follows and the proportional use for heating the building must be documented.

The German Buildings Energy Act (Gebäudeenergiegesetz, GEG)[11] is a summary of several ordinances that were issued individually until 2020 and in this context regulates the content of this legal basis for standards in the construction and renovation of buildings in order to implement energy efficiency requirements and optimise the use of energies. The GEG contains requirements for the energy efficiency of buildings and the use of energy certificates and renewable energies.

[8] DIN V 4108-6 Wärmeschutz und Energie-Einsparung in Gebäuden - Teil 6: Berechnung des Jahresheizwärme- und des Jahresheizenergiebedarfs
[9] DIN V 4701-10 Energetische Bewertung heiz- und raumlufttechnischer Anlagen - Teil 10: Heizung, Trinkwassererwärmung, Lüftung
[10] DIN V 18599 Energetische Bewertung von Gebäuden - Berechnung des Nutz-, End- und Primärenergiebedarfs für Heizung, Kühlung, Lüftung, Trinkwarmwasser und Beleuchtung - Teil 1: Allgemeine Bilanzierungsverfahren, Begriffe, Zonierung und Bewertung der Energieträger
[11] Gesetz zur Vereinheitlichung des Energieeinsparrechts für Gebäude und zur Änderung weiterer Gesetze Vom 8. August 2020

Energy performance certificates are issued by experts who are qualified according to the GEG. Energy classes range from H to A+

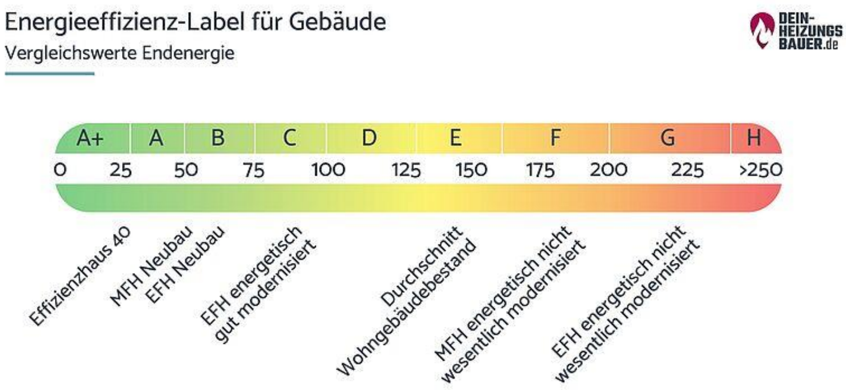


FIGURE 1.2 SOURCE: DEIN-HEIZUNGS BAUER

The Bundesförderung für Effiziente Gebäude (BEG)[12] is a technical set of rules that is required to obtain government funding to replace a heat generator. Funding is provided for the construction, conversion or expansion of a building network, provided that at least 65 % of the heat generation that feeds the building network after the measure has been carried out comes from energy-efficient systems, including heat pumps with a seasonal performance factor of at least 2.7.

Requirements for the sound power level will also be relevant from 2024. The refrigerants used will also be regulated: from 2028 only natural refrigerants will be permitted.

Effect of the installation of a heat pump on a building's energy class

Daikin Germany has performed simulations to assess the effect of changing the existing heat generator to a heat pump without any further adjustments to the building to reduce the heat requirement.

The heat pump effect is summarised below[13]:

Project	Year of construction	Heat source	Starting energy class	Energy class after heat pump installation
Heidelberg Building	1958	Oil BoilerNT '84	H	D
Heidelberg Building	1967	Oil BoilerNT '87	G	C
Karlsruhe Building	1983	Gas condensing boiler 2005 incl Solar hot water	D	C
Hamburg Building	2008	Gas condensing boiler 2008	D	A

In each simulation, the installation of a heat pump results in improved energy efficiency and higher energy class.

[12] Richtlinie für die Bundesförderung für effiziente Gebäude – Einzelmaßnahmen (BEG EM) vom 9. Dezember 2022 (Fundstelle: BAnz AT 30.12.2022 B1)

[13] Please note that the simulations aim to showcase the effect of heat pump installation and do not always reflect feasible renovation projects. To receive tailored advice, please refer to professional energy advisors.

1.2.2 France

Context, regulations and target

The 2015 Energy Transition Act for Green Growth sets a target of 2050 for the housing stock to include all buildings are renovated to low-energy building standards. The Énergie et Climat (Energy and Climate) and Climat et Résilience (Climate and Resilience) laws have introduced a minimum energy performance requirement in the definition of decent housing.

For reference, there are an estimated 5.2 million low-energy homes in France*. A passoire énergétique is a dwelling with very high energy consumption for heating, domestic hot water and cooling and/or high greenhouse gas emissions. These homes have a very poor energy rating.

Diagnostique de Performance Energetique (DPE)

Since 2006, the DPE has provided information about the energy performance of a dwelling or building, by assessing its primary energy consumption. The DPE is compulsory for all sales and rentals of properties in mainland France, with some exceptions (see article R126-15 of the French Construction and Housing Code[14]).

In 2022, new changes came into force to further limit the impact of the most energy-intensive homes. In accordance with the Loi de l'Evolution du logement, de l'aménégament et du numérique (ELAN)[15], the DPE became fully enforceable on this date. Previously issued for information purposes, the DPE now has legal force. This means that anyone involved – tenant, buyer, seller or landlord – can take legal action in the event of a fault, error or omission in the assessment.

The DPE must be carried out at the initiative and expense of the owner or lessor, and incorporated in the Technical Diagnostic File (DDT), which contains all the reports and statements that must be included in the preliminary contract of sale or lease. The DPE must be carried out by a certified diagnostician with professional insurance cover.

The DPE is given to the buyer or tenant, who can then estimate their housing budget (heating costs, insulation performance, etc.), with the diagnosis indicating the property's estimated annual energy costs.

Since April 2023[16,17], increasing the rents of housing classified F or G has been prohibited and an energy audit is compulsory for owners wanting to sell properties rated F or G.

From 2025, it will be prohibited to rent accommodation classified G; from 2028, this ban will be extended to F-rated housing. From 2034, the ban will also apply to E-classified properties.

The DPE has been the subject of numerous updates. Today it is presented as follows:

- the relevant characteristics of the dwelling and a description of its equipment;
- an indication of the annual quantity of energy consumed or estimated for each category of equipment, and an estimate of the annual consumption costs;
- an assessment of the greenhouse gas emissions associated with the annual energy consumed or estimated;
- the classification of the home according to a reference scale (energy label);
- recommendations for improving the property's energy performance, with an assessment of their cost and effectiveness. (The recommendations are for guidance only on the correct use of the home and its equipment.)

[14] Code de la construction et de l'habitation
[15] LOI n° 2018-1021 du 23 novembre 2018 portant évolution du logement, de l'aménagement et du numérique
[16] Décret n° 2021-19 du 11 janvier 2021 relatif au critère de performance énergétique dans la définition du logement décent en France métropolitaine
[17] Décret n° 2002-120 du 30 janvier 2002 relatif aux caractéristiques du logement décent pris pour l'application de l'article 187 de la loi n° 2000-1208 du 13 décembre 2000 relative à la solidarité et au renouvellement urbains

Below is an example of an energy label, from the French Ministry of the Ecological Transition and Territorial Cohesion[18] :

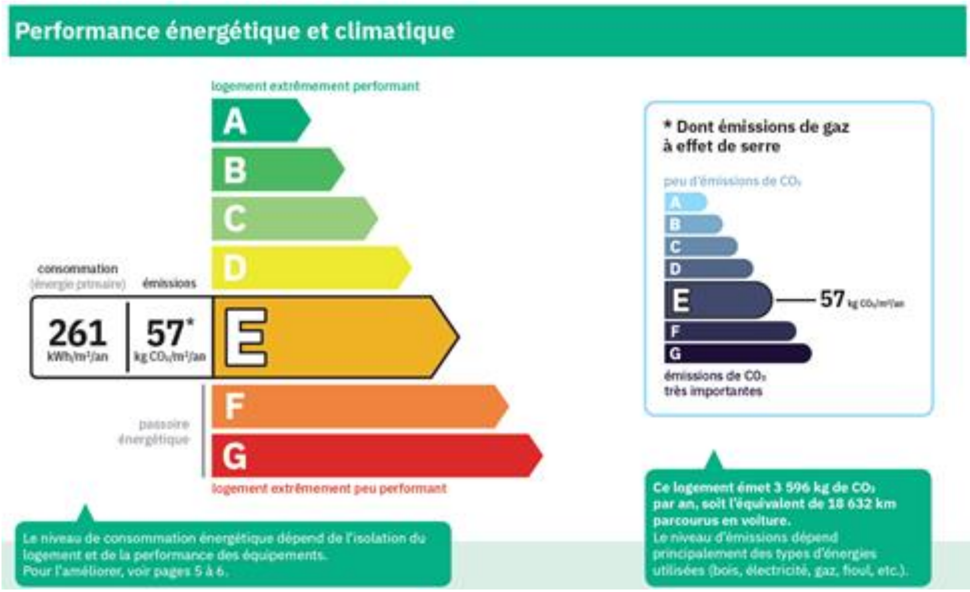
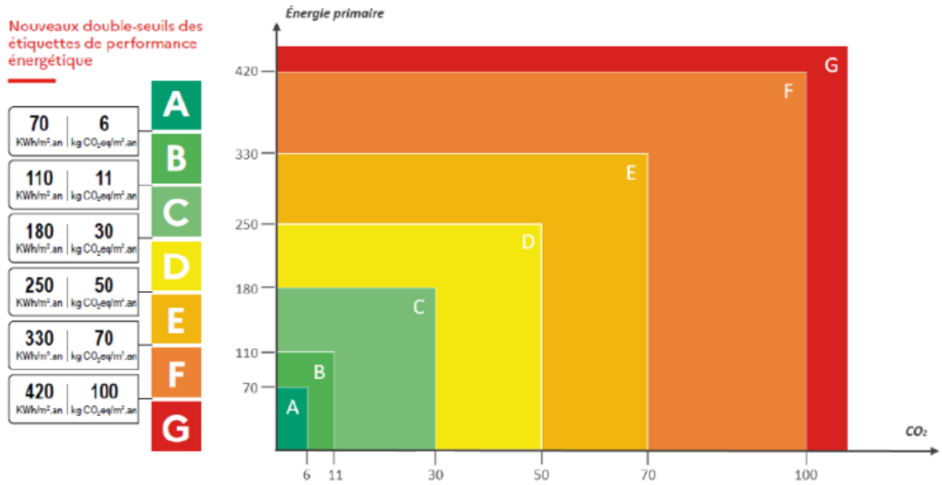


Figure 1.3 Source: Ministere de la Transition ecologique et de la Cohesion des territories, Ministere de la transition energetique

The DPE includes a label ranging from A (extremely efficient) to G (extremely inefficient), covering two aspects: energy consumption and greenhouse gas emissions. The label is based on the worse of the two assessments: that of energy consumption and greenhouse gas emissions.

Two ratings in the form of letters are given: one concerning primary energy consumption, the other concerning the carbon footprint. This is called the double threshold. The lowest score is kept to define the class to which the accommodation belongs.

<u>Explanation of energy labels</u>



***Source :** Cerema, Le nouveau DPE - Guide à l'attention des diagnostiqueurs (version 2 – octobre 2021)*

Figure 1.4 Source: Cerema le nouveau DPE

[18] Diagnostic de performance énergétique – DPE; Ministère de la Transition écologique et de la Cohésion des territoires, Ministère de la Transition énergétique

The impact of heat pump solutions on the DPE label

Daikin Europe has calculated the impact of the installation of a heat Pump using the energy balance calculator provided by Engie France[19]. For each simulation, two identical buildings were taken into consideration (year of construction, district, living area, shape, etc.). The results are summarised below[20].

Starting energy class – gas boiler	Starting energy consumption – kWhEP/m²/year	Resulting energy class – heat pump	Resulting energy consumption – kWhEP/m²/year
G	434.6	F	350.2
F	379.6	E	307.4
E	269	D	221.2
D	191.9	C	161.1
C	111.6	B	98.5
B	99.2	B	94.1

After the installation of the heat pump, the energy consumption of the building improves, resulting in a jump of one energy class in five out of six scenarios.

1.2 3 United Kingdom

Energy Performance Certificate assessment

In the UK, the a property's EPC is produced using the Standard Assessment Procedure (SAP), a methodology used by the government to assess and compare energy and environmental performance. It provides accurate and reliable assessments to support energy and environmental policy initiatives. The Simplified Building Energy Model (SBEM) is a similar methodology used for non-domestic properties.

The most recent version, SAP 10 (10.2) [21], became effective in June 2022 with updated Part L building regulations. It includes changes to fuel prices, CO_2 emissions and primary energy factors. For existing dwellings, a simplified version called Reduced Data SAP (RdSAP) [22] is used, which assumes certain conventions and requirements based on when the dwelling was constructed.

SAP and RdSAP are used for various purposes, such as demonstrating compliance with building regulations for new dwellings and generating EPCs. SAP works by assessing how much energy a dwelling will consume when delivering a defined level of comfort and service provision. This is based on standardised assumptions for occupancy and behaviour and enables a like-for-like comparison of dwelling performance.

SAP quantifies a dwelling's performance in terms of:

- energy use per unit floor area;
- a fuel cost-based energy efficiency rating (the SAP rating);
- CO_2 emissions (the Environmental Impact rating).

These indicators are based on estimates of annual energy consumption for the provision of space heating, domestic hot water, lighting and ventilation.

The SAP ratings table[23] (below) shows the relationship between the SAP rating and the intermediate SAP bands. The higher these ratings, the more efficient the dwelling will be. This in turn increases the value of the property (for more on this subject, see Section 1.3.3).

[19] Energy balance – Engie.fr
[20] Please note that the simulations have the purpose of showcasing the effect of heat pump installation and do not always reflect feasible renovation projects. To receive tailored advice, please refer to professional energy advisors.
[21] SAP 10.2: Government's standard assessment procedure for energy rating of dwellings: Version 10.2 (11-04-2023)
[22] Appendix S: Reduced Data SAP for existing dwellings
[23] Ofgem Energy Company Obligation (ECO4) Guidance: Delivery V1.1

SAP rating	Intermediate SAP band
Below 10.5	Low G
10.5 to 20.4	High G
20.5 to 29.4	Low F
29.5 to 38.4	High F
38.5 to 46.4	Low E
46.5 to 54.4	High E
54.5 to 61.4	Low D
61.5 to 68.4	High D
68.5 to 74.4	Low C
74.5 to 80.4	High C
80.5 to 85.9	Low B
86.0 to 91.4	High B
91.5 to 95.9	Low A
96.0 and above	High A

FIGURE 1.5 SAP RATINGS AND CORRESPONDING INTERMEDIATE SAP BANDS.
SOURCE: ENERGY COMPANY OBLIGATION (ECO4) GUIDANCE: DELIVERY V1.1 OFGEM

Future developments include SAP 11, which is being developed to support net zero commitments for buildings. A consortium led by the Building Research Establishment is working on this, with recommendations to enhance its accuracy, robustness and suitability for net zero goals. SAP 11 is expected to come into force in 2025, along with the Future Homes Standard update of the Building Regulations.

ECO4

The Energy Company Obligation (ECO) is a government funding scheme aimed at improving energy efficiency and reducing carbon emissions in Great Britain while tackling fuel poverty. The most recent version is ECO4.

The ECO scheme works by obliging medium and large energy suppliers to promote measures to improve the ability of low-income, fuel-poor and vulnerable households to heat their homes. This includes actions that result in reduced energy usage, such as installing insulation or upgrading a heating system. This mechanism is known as the Home Heating Cost Reduction Obligation.

There are minimum increases in the energy efficiency rating of properties after measures funded by the ECO4 scheme have been carried out. The minimum requirements are to improve the energy efficiency rating of band D and E homes to at least a band C, and band F and G homes to at least a band D.

ECO funding is affected by a number of variables such as:

- type of property;
- combination of measures used;
- starting band of the property;
- type of heating system used.

EPC Improvement using heat pumps under ECO4

Daikin UK employed consultancy firm Gemserv[24] to carry out the tests[25] on different house types and calculate the banding before and after the changes were made. The measures were heat pumps, PV panels, cavity wall insulation and loft insulation.

According to ECO4, other measures such as double glazing and smart thermostat could also be added to potentially improve the banding and therefore funding for the property. However, in this instance, double glazing and smart thermostats were not considered. Note that no emitters were changed as part of this simulations.

[24] Gemserv – part of Talan International Consulting Group
[25] Please note that the simulations have the purpose of showing the effect of heat pump installation and do not always reflect feasible renovation projects. To receive tailored advice, please refer to professional energy advisors.

Archetype:	Building Type:	Build Date:	Reference Floor Area:	Energy Efficiency Rating Before Heat Pump:	Heat Pump Added = Daikin	EPC Rating After (WITHOUT PV)	EPC Rating After (WITH PV)
Archetype 5	Semi-detached	1900-1929 (SW)	93	D-64	EDLA08EV3	C-71	B-87
Archetype 7	End-terrace	2007-2011 (CW)	98	E-50	EDLA08EV3	C-77	A-95
Archetype 8	Mid-terrace	Pre-1900 (SW)	105	D-66	EDLA08EV3	C-73	B-89
Archetype 12	Mid-terrace	1967-1975 (CW)	85	E-39	EDLA08EV3	C-71	B-88
Archetype 13	Detached	1983-1990 (CW)	127	F-31	EDLA08EV3	C-72	B-84
Archetype 14	End-terrace	1983-1990 (CW)	74	E-41	EDLA08EV3	C-71	B-90
Archetype 15	Top Floor Flat	1930-1949 (CW)	56	D-59	EDLA08EV3	C-78	A-102

FIGURE 1.6 SIMULATIONS BY GEMSERV FOR DAIKIN UK

Property archetypes (house types) used

Ten Archetypes Considered

				
Archetype 1: Detached House Pre-1900 – Solid Wall* Heat Demand: 21,110 kWh/a **Current: Oil Boiler**	**Archetype 2:** Detached House 1950-1966 – Cavity Wall **Heat Demand: 19,887 kWh/a** **Current: Oil Boiler**	**Archetype 3:** Detached House 1967-1975 – Cavity Wall **Heat Demand: 17,241 kWh/a** **Current: Oil Boiler**	**Archetype 4:** Detached House 1991-1995 – Cavity Wall Heat Demand: 18,077 kWh/a **Current: Oil Boiler**	**Archetype 5:** Semi-detached House 1900-1929 – Solid Wall* Heat Demand: 11,464 kWh/a **Current: Oil Boiler**
				
Archetype 6: Semi-detached House 1950-1966 – Cavity Wall Heat Demand: 12,106 kWh/a **Current: Oil Boiler**	**Archetype 7:** End-terrace House 2007-2011 – Cavity Wall Heat Demand: 8,353 kWh/a **Current: Electric Panel**	**Archetype 8:** Mid-terrace House Pre-1900 – Solid Wall* Heat Demand: 11,161 kWh/a **Current: Oil Boiler**	**Archetype 9:** Top Floor Flat Pre-1900 – Solid Wall Heat Demand: 9,502 kWh/a **Current: Oil Boiler**	**Archetype 10:** Mid Floor Flat 1967-1975 – Solid Wall Heat Demand: 12,407 kWh/a **Current: Electric Panel**

Table 1: displays the ten archetypes selected to test the various heating system / retrofit scenarios.

*It has been assumed that these archetypes have external solid wall insulation

FIGURE 1.7 SOURCE: OWN

SW = solid wall, CW = cavity wall

The 10 archetypes were chosen to represent a variety of typical UK properties, including detached and semi-detached houses, terraces and flats, across a range of construction dates and heat demands. Using the TABULA online tool, it has been determined that these 10 archetypes are representative of 60 % of the UK housing stock.[26]

Following initial analysis it was agreed that only archetypes 6-10 would be used, as these represented the most suitable options for Daikin models and typical eco properties. The improvement in EPC rating depends on whether PV panels are also used.

[26] UK findings of the IEE funded project Episcope

1.2.4 Italy

Energy Performance Certificate

The technical legislation for energy performance calculation is regulated by the Specifica tecnica UNI/TS 11300[27] .

For the purpose of energy efficiency calculation, the country is divided into climatic zones from A to F, with A being the warmest (i.e., small islands in the Mediterranean Sea) and F the coldest (i.e., Alps).

For each climatic zone, a heating period is defined. Every city has an annual reference climate based on historical values, with a typical design temperature (i.e. minimum annual is -5°C for Milan) and a defined medium temperature for every hour in a year. The geographical areas are divided into zones according to the *gradi giorno* value of each Commune. The gradi giorno are calculated as the difference between the average inside and outside temperature (set at 20° C). The map below summarises the climate zones in Italy.

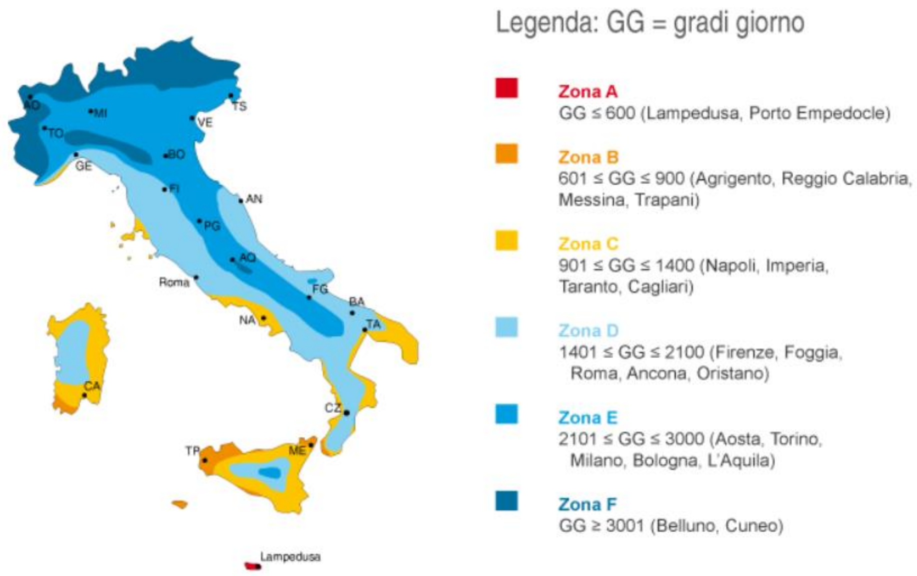


FIGURE 1.8 SOURCE: CERTIFICO.COM

According to UNI 11300, heat pumps' effect on buildings' energy efficiency must be simulated into two conditions: full load using EN 14511 data and partial load according to EN 14825 data.

The EPC label in Italy is called the APE (attestato di prestazione energetica) and according to the Legislative Decree 192/2005[28] is mandatory for buildings listed on the market from 01/07/2009 and for building rentals starting from 01/07/2010.

After several updates, there are 10 energy classes from G to A+++ (A4). Each class represents a range of energy consumption, which is expressed through the overall energy performance index, denoted by the acronym EPGL. This indicates the kWh/(m^{2}year) required to heat the room during the cold season, to cool it in summer, to produce domestic hot water, to ventilate it and to light it[29].

[27] Le norme tecniche di riferimento per la stima delle prestazioni energetiche degli edifici UNI/TS 11300
[28] Decreto legislativo 19 agosto 2005, n. 192 Attuazione della direttiva 2002/91/CE relativa al rendimento energetico nell'edilizia. (GU Serie Generale n.222 del 23-09-2005 - Suppl. Ordinario n. 158)
[29] Acea Energia - Nuova classificazione energetica edifici: cos'è e come migliorarla

FIGURE 1.9 SOURCE: ACEA.IT

The EPC label is calculated as the sum of many primary energy consumptions. The EPGL takes into account:

- winter heating ;
- summer air conditioning;
- domestic hot water production;
- mechanical ventilation;
- artificial lighting, only for non-residential properties;
- transport of people or things, only for non-residential properties.

In this calculation, renewable energy is considered a negative addendum. This applies to electricity production from PV, heat from heat pumps, part of biomass combustion, etc.

There is not an absolute separation (kWh/m^2) between classes, as it varies across climatic zones, as described above, for which a reference building is defined (setting the typical envelope, windows, thermal insulation characteristics, etc.)[30]

An EPC label is therefore assigned to each building comparing it with the set reference building.

Heat pump installation effect on the EPC

In such legislation, it is very difficult to define a typical impact of heat pump on EPC label. For this reason, Daikin Italia commissioned specific simulations from an external energy efficiency expert[31]. The calculations were performed using Edilclima[32] software.

In a first exercise, the simulation focused on the renovation market, on buildings carrying EPC labels from F or E which means they were built approximately before 1990. Daikin considered the substitution of old gas boiler (oversized and not condensation), with a right-size heat pump or a hybrid system maintaining the existing envelope[33].

For buildings in climate zone E (Milan), considering the worst classes from F to E, the heat pump installation could result in a jump of three or four classes.

For buildings in climate zone D (Rome, Naples), considering the worst classes from F to E, heat pump installation could result in a jump of four or five classes.

Using a condensation boiler with weather-dependent regulation, substitution with a heat pump could result in buildings in classes G to E jumping by at least two classes. Hybrid installation was responsible for one class jump[34].

[30] Descrizione dell'edificio di riferimento e parametri di verifica – Requisiti minimi Appendice A
[31] Davide Rosa – Studio tecnico Home page
[32] Edilclima Engineering & Software – About us
[33] Please note that the simulations have the purpose of showing the effect of heat pump installation and do not always reflect feasible renovation projects. To receive tailored advice, please refer to professional energy advisors.
[34] Please note that the simulations have the purpose of showing the effect of heat pump installation and do not always reflect feasible renovation projects. To receive tailored advice, please refer to professional energy advisors.

In Milan, climatic zone E, starting from class E with condensation boiler, a jump of two EPC classes was achieved with a centralised EPRA system, and a single EPC class jump was performed with a mix of ERLA system and boiler (centralised hybrid).

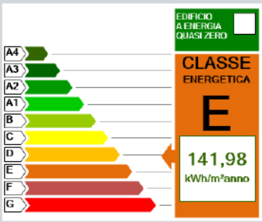
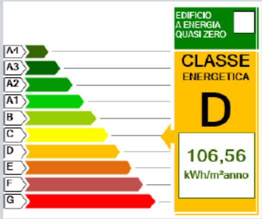
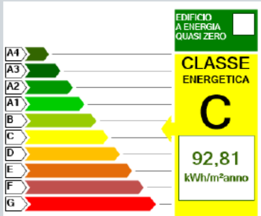
	PRE intervento	SISTEMA IBRIDO	POMPA DI CALORE
ηH,gn,pnren	96,3 %	137,9 %	163,7 %
EPH,nren	117,68 kWh/m²a	82,19 kWh/m²a	68,51 kWh/m²a
Classe energetica			

FIGURE 1.10 SOURCES: EDILCLIMA SIMULATIONS

1.2.5 Spain

EPC framework

The Royal Decree 235/2013[35] transposes the Directive 2010/31/EU into Spanish legislation and sets the basic procedure for the certification of energy efficiency of buildings in Spain. According to the RD 235/2013, new building projects must refer to the new basic procedure, with the previous rating calculation methods being valid (Lider-Calener, CE2, CEs, CERMA, HE1mem).

The energy certificate measures the energy characteristics of a premises, office or home. An energy rating is obtained according to an energy label: A, B, C, D, E, F or G, with A the most favourable rating and G the least. Next to each letter is shown the energy consumption expressed in kWh/year and emissions of $kgCO_2/m^2$ year[36].

The owners of existing buildings are obliged to obtain and show the EPC to potential buyers or tenants as well as to the general public if the building is open to the public and/or occupied by public authorities.

Calificación	Índice
A	$C1 < 0,15$
B	$0,15 \leq C1 < 0,50$
C	$0,50 \leq C1 < 1,00$
D	$1,00 \leq C1 < 1,75$
E	$1,75 \leq C1$
	$C2 < 1,00$
F	$1,75 \leq C1$
	$1,00 \leq C2 < 1,50$
G	$1,75 \leq C1$
	$1,50 \leq C2$

FIGURE 1.11 ENERGY RATING AND INDEXES FOR BUILDINGS FOR PRIVATE RESIDENTIAL USE (HOUSING)

35 Real Decreto 235/2013, de 5 de abril, por el que se aprueba el procedimiento básico para la certificación de la eficiencia energética de los edificios.

36 Calificación de la eficiencia energética de los edificios – Ministerio de Industria, Energía y Turismo

The energy efficiency certificate is an official document and as such can only be issued by professionals with the qualifications to develop thermal projects, e.g. engineers or architects as expressed in the LOE[37] and the Building Planning Law[38], which regulate the building sector in Spain.

According to the Ministry of Industry on Energy Efficiency, energy efficiency certificates must contain four documents:

- energy efficiency rating;
- recommendations;
- description of the tests;
- compliance with environmental requirements.

Heat pump installation effect on the EPC label

Daikin Spain carried out a simulation of the impact of installing a heat pump in a single family house in Cadiz, south-west Spain. Daikin used a certified software for the EPC calculation.

Using the complete data of the building (location, isolation, orientation, shadows and ventilation level) the software calculates the cooling and heating demand. The house is then assigned a preliminary label based on this.

The software accounts for the impact of the heating generator in terms of type, efficiency, the possible PV or thermal solar installation. With this data, a new label is issued for the non-renewable energy consumption per square metre as well as a labelling for CO_2 emissions per square metre.

For the purpose of the simulation, the heat pump used is Daikin's ERGA06 in a 110 m^2 single-family house. The house was originally labelled in the lower part of D (76.31 kWh/m^2/year). By substituting the boiler with a heat pump, the energy label improves to a high C". Therefore, depending on the initial situation of the building, replacing a gas boiler with a heat pump improves the energy label by one class.

BOILER

2. CALIFICACIÓN ENERGÉTICA DEL EDIFICIO EN CONSUMO DE ENERGÍA PRIMARIA NO RENOVABLE

Por energía primaria no renovable se entiende la energía consumida por el edificio procedente de fuentes no renovables que no ha sufrido ningún proceso de conversión o transformación.

INDICADOR GLOBAL		INDICADORES PARCIALES			
<21.10 A 21.10-40.1 B 40.10-67.80 C 67.80-108.60 D 108.60-196.10 E 196.10-213.80 F =>213.80 G	76,31 D	CALEFACCIÓN		ACS	
		Energía primaria no renovable calefacción (kWh/m2año)	B	*Energía primaria no renovable ACS (kWh/m2año)*	G
		13,77		34,58	
		REFRIGERACIÓN		ILUMINACIÓN	
Consumo global de energía primaria no renovable (kWh/m2año)1		*Energía primaria no renovable refrigeración (kWh/m2año)*	B	*Energía primaria no renovable iluminación (kWh/m2año)*	-
		14,59		-	

FIGURE 1.11 SOURCE: DAIKIN'S SIMULATION

[37] Ley Orgánica 2/2006, de 3 de mayo (BOE del 4 de mayo), de educación (LOE)
[38] Real Decreto 1627/1997, de 24 de octubre, por el que se establecen disposiciones mínimas de seguridad y de salud en las obras de construcción.

ALTHERMA

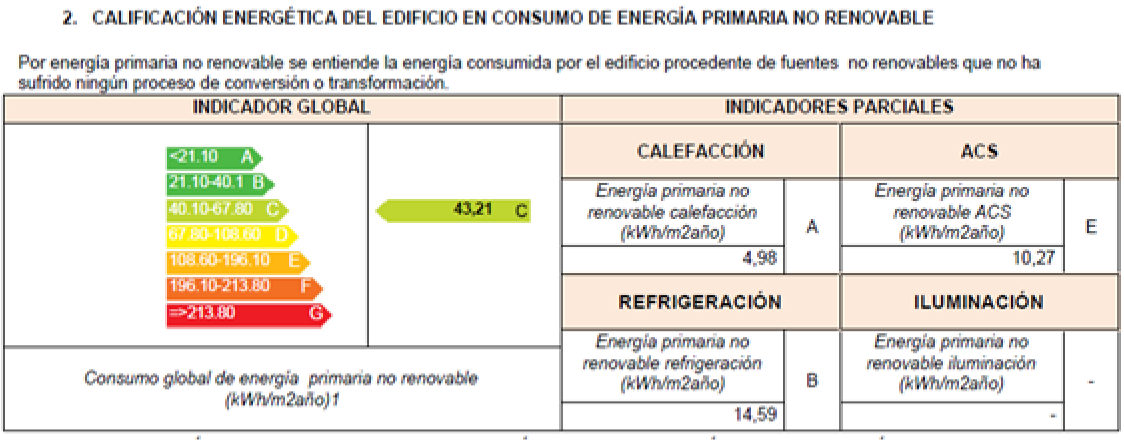


FIGURE 1.12 SOURCE: DAIKIN'S SIMULATIONS

1.2.6 Poland

EPC framework

The Act on the Energy Performance of Buildings (2014)[39] establishes the Central Register of the Energy Performance of Buildings, which includes databases of:

- persons authorised to produce EPCs;
- persons entitled to inspect heating or AC systems;
- EPCs;
- protocols for heating or AC system inspections.

Along with building codes, the listed regulations and the databases form the main framework for the implementation of the EPBD in Poland.

A maximum energy performance index value (kWh/(m^2/year)) determines the annual non-renewable energy demand for space heating, ventilation, cooling and domestic hot water, and, for collective, industrial, storage and livestock buildings, for built-in lighting. This index is calculated according to Polish legislation for calculating a building's energy characteristics[40]. The above requirements for new buildings also apply to the renovation of existing buildings.

The maximum energy performance from 1 January 2021 must be:

- for single family houses: 70 kWh/(m^2/year);
- for multi-family houses: 65 kWh/(m^2/year).

In 2024, new energy efficiency classes for buildings are planned to be introduced in Poland. Previously, sellers or landlords were obliged to provide energy performance certificates for buildings when concluding the relevant agreement, but this obligation was not subject to a penalty. Under the amendment, sellers and landlords are required to provide EPCs for the parts of the buildings to which the respective agreements relate, and introducing a fine in case of non-compliance.

See below the draft energy classes with corresponding performance:

[39] Ustawa z dnia 29 sierpnia 2014 r. o charakterystyce energetycznej budynków

[40] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

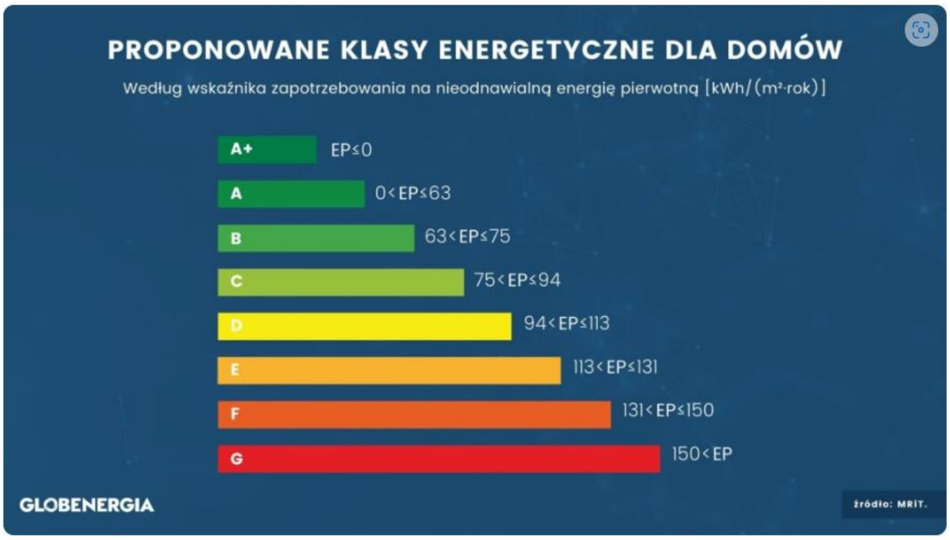


FIGURE 1.13 SOURCE GLOBENERGIA

Effect of heat pump installation on the EPC

Daikin Poland has simulated the impact on the EPC of a change in heating source on the building energy class. The simulation featured a building from 2015 measuring 116.7m^2, with EP = 117kWh/m^2/year. The starting heat source is a gas boiler.

The heat pump characteristics to use in the simulation are set by legislation[41] and are summarised below.

21	Pompy ciepła typu powietrze/woda, sprężarkowe, napędzane elektrycznie: a) 55/45˚C, b) 35/28˚C	 2,60 3,00

FIGURE 1.14 SOURCE: METHODOLOGY FOR DETERMINING THE ENERGY PERFORMANCE OF A BUILDING OR PART OF A BUILDING

To determine the annual demand for non-renewable primary energy , the annual demand for final energy should be calculated, taking into account the non-renewable primary energy factor (wi), which depends on the energy carrier or fuel used[42]. The wi coefficient in this case is set at wi = 3.0 because electrical energy is mostly generated by burning coal.

[41] legislation for AW HP: rozporządzenie ministra infrastruktury i rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

[42] A. Alsabry, K. Szymański, B. Michalak "Energy, Economic and Environmental Analysis of Alternative, High-Efficiency Sources of Heat and Energy for Multi-Family Residential Buildings in Order to Increase Energy Efficiency in Poland" Alsabry, Szymánski, Michalak (2023)

The Wi coefficient is the non-renewable primary energy input factor for the generation and supply of heat (wH factor), domestic hot water (wW coefficient), cooling (wC factor), or electricity (wel factor). [43]

No.	Method of Supplying the Building or Its Part with Energy	Type of Energy Carrier or Energy	w_i	EC CO_2 Emission Indicators [kg/kWh]
1	Local energy generation within the building	Heating oil	1.10	0.267
2		Natural gas	1.10	0.199
3		Liquefied gas	1.10	0.227
4		Coal	1.10	0.341
5		Lignite	1.10	0.402
6		Solar energy	0	0
7		Wind energy	0	0
8		Geothermal energy	0	0
9		Biomass	0.20	0
10		Biogas	0.50	0
11	District heating from cogeneration	Coal or natural gas	0.80	0.337/0.199
12		Biomass, biogas	0.15	0
13	District heating from a heating plant	Coal	1.30	0.341
14		Natural gas or heating oil	1.20	0.199/0.267
15	System power grid	Electrical power	3.00	0.708

FIGURE 1.15 COEFFICIENTS OF NON-RENEWABLE PRIMARY ENERGY INPUT WI AND EC CO2 EMISSION INDICATORS. SOURCE: METHODOLOGY FOR DETERMINING THE ENERGY PERFORMANCE OF A BUILDING OR PART OF A BUILDING

The selected building, according to draft energy classes (which is likely to be introduced in Poland in 2024) falls within the E class. Calculations below for this building[44]:

ENERGIA KOŃCOWA	Roczne zapotrzebowanie na energię końcową dostarczaną dla budynku dla systemu ogrzewczego	$Q_{k,H}$	58	[kWh/(m²*rok)]
	Roczne zapotrzebowanie na energię końcową dostarczaną dla budynku dla systemu przygotowania cwu	$Q_{k,W}$	47	[kWh/(m²*rok)]
	Roczne zapotrzebowanie na energię pomocniczą końcową dostarczaną do budynku dla systemów technicznych	$E_{el, pom}$	0	[kWh/(m²*rok)]
	ROCZNE ZAPOTRZEBOWANIE NA ENERGIĘ KOŃCOWĄ	Q_k	106	[kWh/(m²*rok)]
ENERGIA PIERWOTNA	Roczne zapotrzebowanie na nieodnawialną energię pierwotną dostarczaną systemu ogrzewczego	$Q_{P,H}$	65	[kWh/(m²*rok)]
	Roczne zapotrzebowanie na nieodnawialną energię pierwotną dla systemu przygotowania cwu	$Q_{P,W}$	52	[kWh/(m²*rok)]
	ROCZNE ZAPOTRZEBOWANIE NA NIEODNAWIALNĄ ENERGIĘ PIERWOTNĄ	Q_P	117	[kWh/(m²*rok)]

After replacing with a air-to-water heat pump (SCOP = 3.0), the Ep = 95 kWh/m²/year, so the energy class changed to D.

ENERGIA KOŃCOWA	Roczne zapotrzebowanie na energię końcową dostarczaną dla budynku dla systemu ogrzewczego	$Q_{k,H}$	18	[kWh/(m²*rok)]
	Roczne zapotrzebowanie na energię końcową dostarczaną dla budynku dla systemu przygotowania cwu	$Q_{k,W}$	13	[kWh/(m²*rok)]
	Roczne zapotrzebowanie na energię pomocniczą końcową dostarczaną do budynku dla systemów technicznych	$E_{el, pom}$	0	[kWh/(m²*rok)]
	ROCZNE ZAPOTRZEBOWANIE NA ENERGIĘ KOŃCOWĄ	Q_k	32	[kWh/(m²*rok)]
ENERGIA PIERWOTNA	Roczne zapotrzebowanie na nieodnawialną energię pierwotną dostarczaną systemu ogrzewczego	$Q_{P,H}$	55	[kWh/(m²*rok)]
	Roczne zapotrzebowanie na nieodnawialną energię pierwotną dla systemu przygotowania cwu	$Q_{P,W}$	40	[kWh/(m²*rok)]
	ROCZNE ZAPOTRZEBOWANIE NA NIEODNAWIALNĄ ENERGIĘ PIERWOTNĄ	Q_P	95	[kWh/(m²*rok)]

1.2.7 The Netherlands

Homeowners who are selling or renting out an existing home, or building a new home, are obliged to provide a registered and definitive energy label to the buyer or tenant. The label indicates the energy performance of the house and what improvements are possible.

The energy label is determined according to the calculation method NTA 8800[45], Assessment guideline (BRL) 9500 and ISSO Publication 82.1. This method applies to existing and new buildings. Labels remain valid for 10 years.

[43] Dz.U.2015.376 ROZPORZĄDZENIE MINISTRA INFRASTRUKTURY I ROZWOJU 1 z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej
[44] Please note that the simulations have the purpose of showing the effect of heat pump installation and do not always reflect feasible renovation projects. To receive tailored advice, please refer to professional energy advisors.
[45] Nederlandse technische afspraak NTA 8800:2023 (nl) Energieprestatie van gebouwen - Bepalingsmethode

Energy performance advisors determine the label based on how much fossil energy – coal, oil and natural gas – the home uses in terms of kWh/(m^2/year).

The image below[46] summarises the energy class split in the Netherlands. The least energy efficient class is the G label, which consumes 380 kWh/m^2/year of energy from fossil fuels. The best performing class groups together energy neutral dwellings (net fossil fuel consumption equals zero).

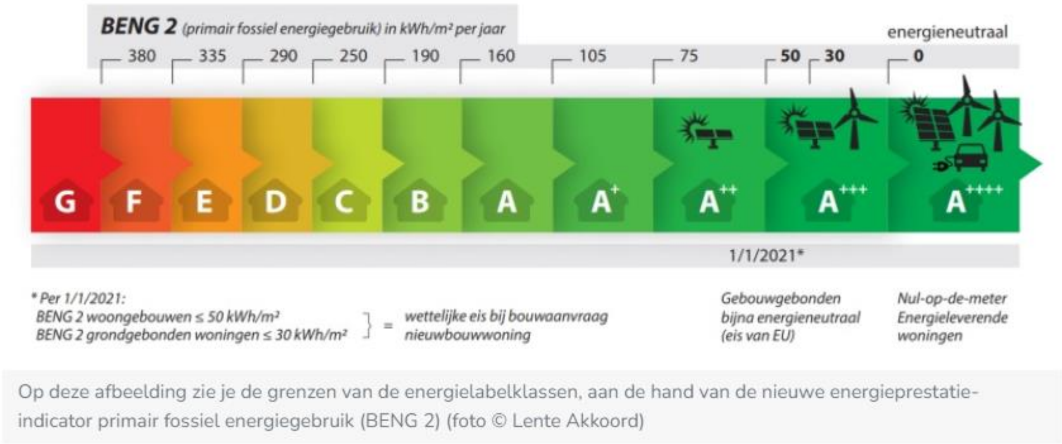


FIGURE 1.16 THIS IMAGE SHOWS THE BOUNDARIES OF THE ENERGY LABEL CLASSES, USING THE NEW ENERGY PERFORMANCE INDICATOR PRIMARY FOSSIL ENERGY USE (BENG 2) (PHOTO © SPRING AGREEMENT) SOURCE: WOONBEWUST.COM

The most common energy label for building in the Netherlands (taking out class A to A++++) is C.

Daikin Netherlands has performed six simulations of heat pump installation, to assess the effect of the energy efficiency of the dwelling in different settings. Each terraced house starts from a different energy label; the results are summarised below.

Current label	Walls Insulation	Roof Insulation	Floor Insulation	Windows	Heating system	Ventilation	Heating and Domestic hot water	**Label with HP air/water**
F (1965)	0,44 (m2.k)/W	0,4 (m2.k)/W	0,15 (m2.k)/W	5,1 W/(m².K)	Radiators	Natural	Boiler non condensing	**D**
E (1975)	1 (m2.k)/W	1,04 (m2.k)/W	0,28 (m2.k)/W	5,1 W/(m².K)	Radiators	Natural	Boiler non condensing	**C**
D (1985)	1,3 (m2.k)/W	1,3 (m2.k)/W	1,3 (m2.k)/W	3,7 W/(m².K)	Radiators	Natural inflow - mechanical outflow	Boiler non condensing	**B**
C (1995)	2,5 (m2.k)/W	2,5 (m2.k)/W	2,5 (m2.k)/W	3,1 W/(m².K)	Radiators	Natural inflow - mechanical outflow	Boiler non condensing	**A**
B (2005)	2,5 (m2.k)/W	2,5 (m2.k)/W	2,5 (m2.k)/W	3,3 W/(m².K)	Radiators	Natural inflow - mechanical outflow	Condensing boiler	**A+**
A (2015)	3,5 (m2.k)/W	3,5 (m2.k)/W	3,5 (m2.k)/W	1,65 W/(m².K)	Underfloor heating	Natural inflow - mechanical outflow	Condensing boiler	**A++**

FIGURE 1.17 EFFECT OF HEAT PUMP INSTALLATION ON ENERGY LABELS SOURCE: DAUK CALCULATIONS

[46] Woonbewust.com - Het nieuwe energielabel voor woningen. Wat verandert er in 2021?

In all cases, the installation of the heat pump improves the energy efficiency of the house, resulting in a jump of two energy classes in each simulation[47].

1.2.8 Belgium

In Belgium, each of the three regions – Flanders, Wallonia and Brussels-Capital – has its own version and scope of the EPC label regulation. This includes the subdivision of energy consumption[48,49,50] range into labels; see below.

Flemish region		
Range [kWh/(m²year)]		Label
< 0		A+
100	0	A
200	100	B
300	200	C
400	300	D
500	400	E
> 500		F

Walloon region		
Range [kWh/(m²year)]		Label
0	45	A+
45	85	A
85	170	B
170	255	C
255	340	D
340	425	E
425	510	F
> 510		G

Brussels capital region		
Range [kWh/(m²year)]		Label
< 45		A
45	95	B
95	150	C
150	210	D
210	275	E
275	345	F
> 345		G

FIGURE 1.18: EPC - LABEL SUBDIVISION PER BELGIAN REGION.

Other differences mainly apply to the relevant sector (apart from the residential sector). A more in-depth discussion is beyond the scope of this section.

To carry out an EPC simulation, the heat pump's energy performance should be calculated in one of two ways, either using the exact (s)COP values[51] or via the energy label. The simulations in Belgium used the energy labels. These indirectly contain the (s)COP value as each label represents a certain energy performance range. The software, if a label is entered, will calculate with the lowest and therefore least efficient value.

In Belgium, the simulations were carried out in Flanders by a recognised energy expert. The heat pump's energy performance for space heating and domestic hot water was entered according to the energy label. For the EPC labels considered (F to B), an existing residential building was selected, representative of the building stock with that label.

A and A+ labels were not considered because it is very difficult to reach those performance figures without installing a heat pump. For each simulation, the existing heating system was replaced with a heat pump and the same emitters were kept. When the emitters in the original building were radiators or convectors, the same type of emitter was chosen for the heat pump system.

The results of the simulations are shown in the table below[52]. In the last column, the simulated reduction in annual energy consumption is expressed in EPC label jumps. One EPC label jump corresponds to 100 kWh/(m²/year) as that is the resolution used by Flanders for the subdivision in labels. A given reduction in yearly energy consumption depends on the original situation (i.e. the original energy needs) whether an EPC label change occurs or not.

[47] Please note that the simulations have the purpose of showing the effect of heat pump installation and do not always reflect feasible renovation projects. To receive tailored advice, please refer to professional energy advisors.
[48] Energy performance certificates (Flanders) – Belgium.be
[49] Energy performance certificate for a dwelling – Service Public de Wallonie
[50] EPB certificate for residential units – Brussels-Capital Region
[51] Seasonal efficiency is a new way of measuring the true energy efficiency of heating and cooling technology, over an entire year. This new measure gives a more realistic indication of the energy efficiency and environmental impact of a system. Source: What is seasonal efficiency (SCOP and SEER)-Daikin.eu
[52] Please note that the simulations have the purpose of showing the effect of heat pump installation and do not always reflect feasible renovation projects. To receive tailored advice, please refer to professional energy advisors.

Original situation				New situation				EPC Label-jump
Heating system	***Emitter***	***Label***	***kWh / (m² jaar)***	***Heating system***	***Emitter***	***Label***	***kWh / (m² jaar)***	[-]
Oil fuel non-condensing boiler	Radiator/convector	F	629	Daikin heat pump	Radiator/convector	D	345	2.84
Gas non-condensing boiler	Radiator/convector	E	447		Radiator/convector	C	278	1.69
Oil fuel non-condensing boiler	Radiator/convector	D	377		Radiator/convector	C	226	1.51
Gas condensing boiler	Radiator/convector	C	276		Radiator/convector	B	197	0.79
Gas condensing boiler	Under floor heating and radiator/convector	B	138		Under floor heating and radiator/convector	B	104	0.34

FIGURE 1.19 SOURCE: THIRD PARTY EXPERT

1.3 Effect of improved energy efficiency on real estate property value

In some member states where energy performance schemes have a long tradition, a positive impact on the real estate market has been recorded: in 2013, a European Commission study[53] captured encouraging price sensibility to energy class rating increases in eight of the nine regions examined (see Fig. 1.1).

The improvement of one class impacted resale prices more than rent transactions.

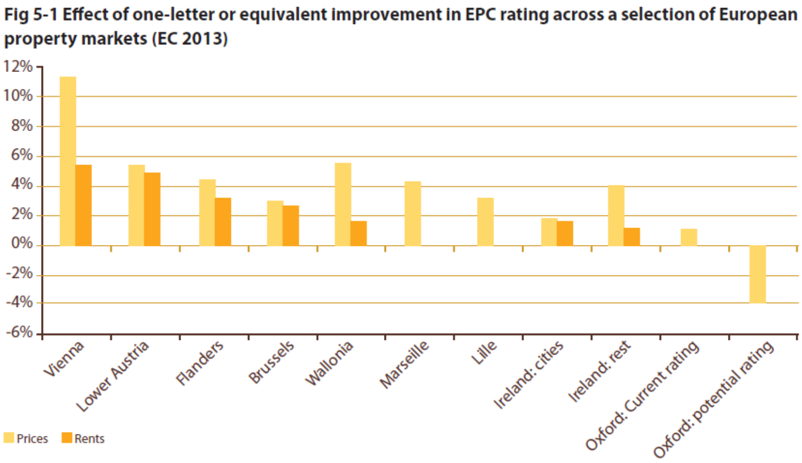


FIGURE 1.20 SOURCE: ENERGY PERFORMANCE CERTIFICATES ACROSS THE EU (2014) BPIE

These findings build confidence in the existing literature on energy efficiency premiums such as Brounen and Kok (2009) who were the first researchers to investigate the capitalisation of energy savings resulting from retrofits into housing prices in the European context. Their model was able to provide evidence of a price premium for green-labelled dwellings in residential markets in the Netherlands[54]. Later, Popescu, Bienert, Schützenhofer, & Boazu (2012) isolated market sensitivity to energy efficiency measures in Romania as well[55].

In the same year that the EC carried out its assessment, Hyland et al. (2013) concluded that A-rated properties received a sales price premium of 9 % compared to D-rated properties in the Irish market[56]. Ramos et al. (2015) observed how properties in Portugal with EPC labels equal to A, B or C were sold at a 5.9 % higher price per square metre compared to those with an EPC equal to D. EPC labels equal to E, F or G were sold for 4% less[57].

[53] BPIE "Energy performance certificates across the EU" (2014)
[54] D.Brounen, N.Kok, J. Menne "Energy Performance Certification in the Housing Market Implementation and Valuation in the European Union" (2009)
[55] D.Popescu, S. Bienert "Impact of energy efficiency measures on the economic value of buildings" (2012)
[56] M. Hyland, R.C. Lyons, S. Lyons "The value of domestic building energy efficiency — evidence from Ireland" (2013)
[57] A. Pérez-Alonso, A. Ramos, S. Silva "Valuing Energy Performance Certificates in the Portuguese Residential Sector" (2015)

In the Irish rental market, Stanley et al. (2016) showed how a one-point improvement in the 15-point scale from G to A1 yielded a list price increase of 1 % [58].

Fuerst et al. (2016) observed that higher energy ratings were correlated with higher prices and shorter selling times in the period 2009-2012 in Finland[59]. In the same year, Wahlström correlated improved energy efficiency of buildings with a premium reselling price in Sweden[60].

On the Eastern European market, Taltavull et al. (2017) found an energy premium between 2.2 % and 6.5 % was paid for energy-efficient properties in Bucharest[61].

Finally, Khazal and Sønstebø (2020) found that real estate with the same characteristics and EPC label in the Norwegian market was assigned a higher rental price by professionals compared to non-professionals. Properties with high energy efficiency were associated with a 5 % higher premium if rented out by a professional, where 1.8 % is the difference in green label valuation[62].

1.3.1 Effects on the German market

In Germany, the German Energy Act for Buildings (GEG) was passed to promote higher renovation rates and accelerate decarbonisation. The GEG aims to simplify regulations and unify national energy standards for buildings. Additionally, a federal funding scheme called Bundesförderung für effiziente Gebäude provides tax deductions for energy-efficient renovations (see more on the topic in Tier 4 “EU Incentives overview”).

The first evidence of EE labels on German real estate value is explained by Kholodilin, Mense and Michelsen (2016) in “The market value of energy efficiency in buildings and the mode of tenure”, which focuses on the Berlin apartment housing market. The results indicate that for a **€1 reduction in annual energy costs, there is an associated €15.50 increase in the per square metre house price. For rented properties, a €1 reduction in energy cost per square metre/year is associated with a premium of €6.22**. The willingness to pay for energy efficiency in owner-occupied dwellings is almost 2.5 times greater than in rented homes. A decrease in annual energy costs by €1 leads to an increase in annual rental income of approximately €0.23 per square metre.

Owner-occupants also appear to be conservative, bordering on pessimistic, about the potential revenues from reselling their homes, which more than recoup the costs associated with retrofitting.

In 2019, Cajias, Fuerst, and Bienert further investigated the German rental market in the paper “Tearing down the information barrier: the price impacts of energy efficiency ratings for buildings in the German rental market”. The findings indicate that landlords receive a small but significant premium for energy-efficient dwellings when leasing residential properties.

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[58] S. Stanley, R.C. Lyons, S. Lyons “The price effect of building energy ratings in the Dublin residential market” (2015)
[59] F. Fuerst, E. Oikarinen, O. Harjunen “Green signalling effects in the market for energy-efficient residential buildings” (2016)
[60] M. H. Wahlström “Doing good but not that well? A dilemma for energy conserving homeowners” (2016)
[61] P. Taltavull, I. Anghel, C. Ciora “Impact of energy performance on transaction prices: Evidence from the apartment market in Bucharest” (2017)
[62] A. Khazal, O.J. Sønstebø “Valuation of energy performance certificates in the rental market – Professionals vs Non professionals” (2020)

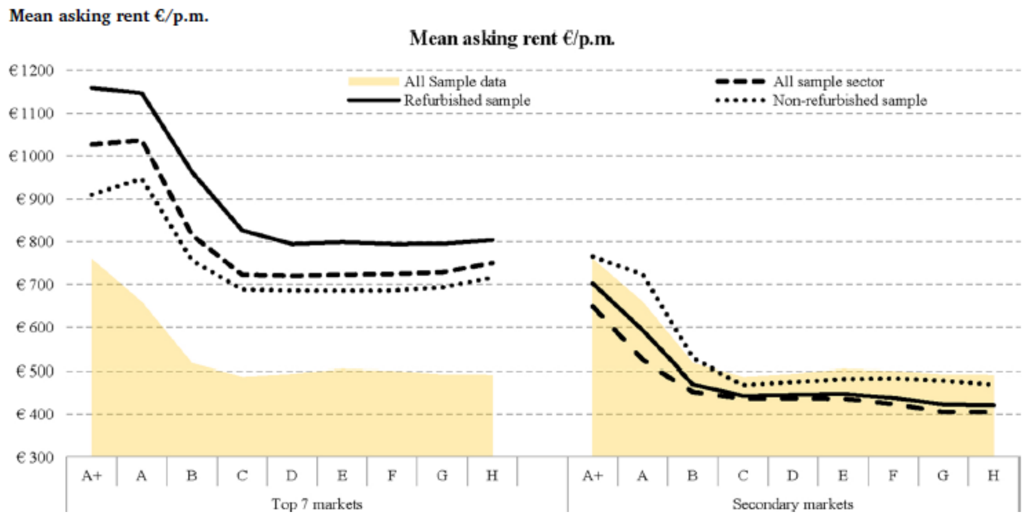


FIGURE 1.21 SOURCE: CAJIAS, FUERST, AND BIENERT "TEARING DOWN THE INFORMATION BARRIER: THE PRICE IMPACTS OF ENERGY EFFICIENCY" (2019)

Although the energy efficiency effect is reflected in rents across the German residential market, the premiums are somewhat lower in densely populated cities due to high demand and low housing supply.[63]

The presence of EPCs influences tenants' utility function[64], leading to higher demand for energy-efficient dwellings and reduced demand for rental properties that do not meet energy efficiency standards. Additionally, regression results indicate that energy-inefficient dwellings experience longer time-on-market.

When focusing on the overall German market, **asking rents within the energy categories A+, A, B and C are on average 0.9 %, 1.4 %, 0.1 % and 0.2 % higher than the reference category D**, whereas dwellings in the subsequent categories show substantial rental discounts. Energy-inefficient dwellings in the categories F, G and H exhibit rental discounts of up to 0.1 %, 0.3 % and 0.5 % respectively.

Effects on the German market of EPCs are further investigated by Taruttis and Weber (2022)[65]. In the paper, the authors highlight the importance of the installed heating system in relation to energy efficiency in dwellings. **Houses equipped with heat pumps are found to be the most energy efficient on average**. Approximately one-quarter of the analysed dwellings underwent renovations since 2000, and there is evidence to suggest that sustainable energy systems like solar panels, wood pellet heating or heat pumps have been installed in these modernisation efforts.

The effects of energy efficiency on prices vary across regions, with urban areas experiencing an average price increase of 6.3 % when energy consumption decreases by 100 kWh/m2/year. The effect is weaker in large cities (5 %). The geographical distribution shows positive Energy Efficiency Premiums (EEPs) clustered in rural districts. Differences across regions can be explained by market conditions. For instance, EEPs are lower in regions where housing supply is tight and in high-income districts leading to the hypothesis that high energy costs are not considered problematic by affluent buyers.

Costs for single measures of energy refurbishment, such as installing a new heating system, are capitalised into housing prices by about 86 %, excluding the effect of government funding.

The estimated house price increase for a €1 reduction in yearly energy costs amounts to approximately €20.

[63] Cajias, Fuerst, and Bienert "*Tearing down the information barrier: the price impacts of energy efficiency ratings for buildings in the German rental market*" (2019) TOP7Markets: Hamburg, Berlin, Dusseldorf, Cologne, Frankfurt, Stuttgart, Munich
[64] a function relating specific goods and services in an economy to individual preferences Source: Collins Dictionary, definition of "utility function"
[65] Taruttis and Weber "*Estimating the impact of energy efficiency on housing prices in Germany: Does regional disparity matter?*" (2022)

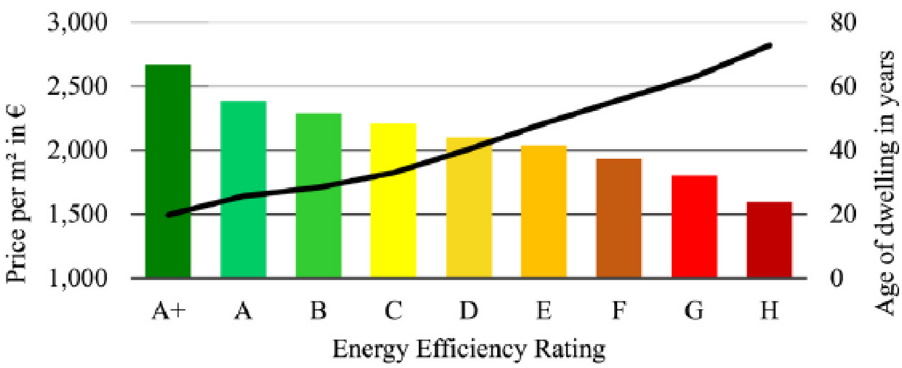


Figure 1.22 Average asking price and age by category of the energy efficiency rating. Source: Taruttis and Weber (2022)

1.3.2 Effects on the French market

In France, a working paper by Leboullenger et al. (2018) identifies a **sales premium between 1 % and 3 % for green single houses** in the local housing market of Dijon (Burgundy, France)[66].

More recently, Civel (2020)[67] analysed two real estate markets with very different levels of prices, one densely populated (the Lyon metropolis, central France) and one with low-density and vast rural spaces (Brest, in Brittany).

Absolute premiums associated with each grade of the EPC are largely similar in the two regions, despite the important differences between each market. **Capitalisation of energy label information is therefore more important in relative terms in rural areas,** but in absolute terms rural and urban green premiums are similar, reaching about €35,000 for low-consumption houses. Moreover, those premiums are consistent with corresponding renovation costs, suggesting that green value results from a Bertrand-type competition[68] between sellers, thus preventing them from selling a low-consumption property for a price higher than its renovation cost.

The association Notaires de France recently published a statistical study on the value of old homes in 2021 according to their energy label[69]. This study is based on information from their property transfer databases. The report shows stability in the distribution of existing housing transactions according to the energy label in mainland France in 2021 compared to 2020.

[66] *Leboullenger et al. "Is there a market value for energy performance in a local private housing market?"* (2018)
[67] Civel *"Capitalization of energy labels versus Techno-economic assessment of energy renovations in the French housing market."* (2020)
[68] In which sellers play a strategy of setting prices below competitors' prices Source: C. Qin and C. Stuart "Bertrand versus Cournot Revisited" (1997)
[69] Notaires de France *"La valeur verte des logements en 2021"* (2022)

Dwellings classified A and B represent 7 % of transactions in 2021, while the most energy-intensive (F-G) account for 11 %.

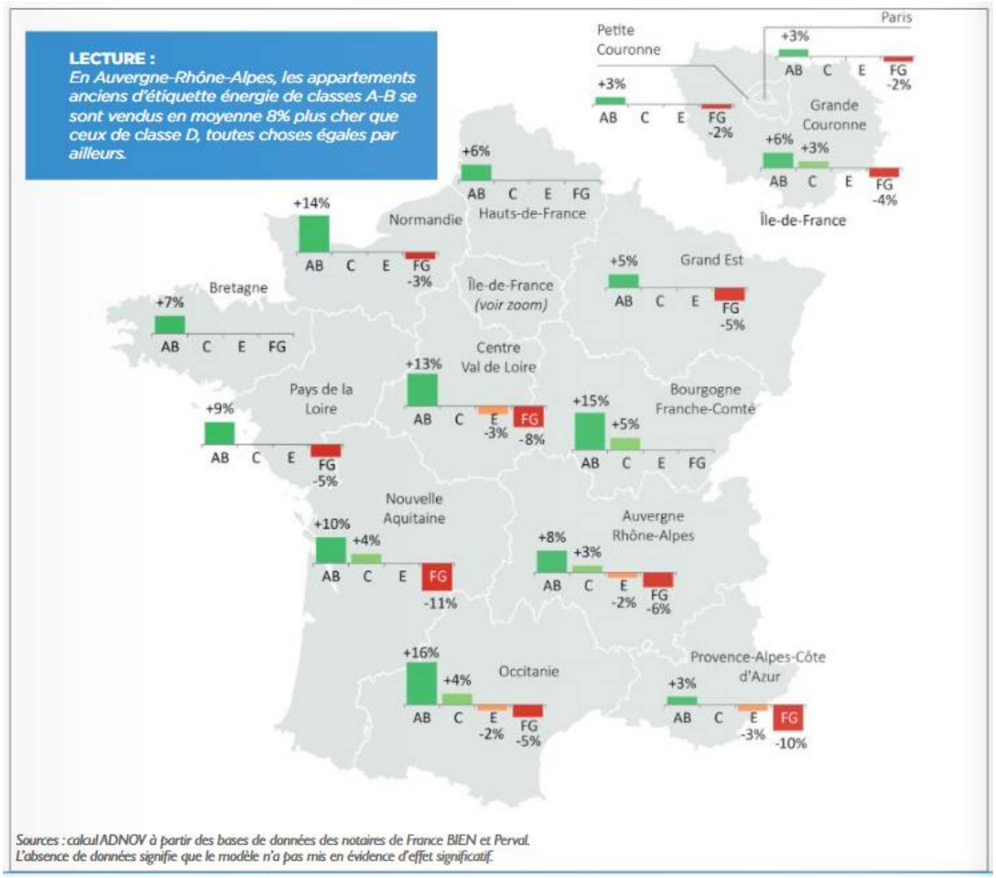


FIGURE 1.23 ENERGY LABEL IMPACT ON APARTMENT SALE PRICES. SOURCE: NOTAIRES DE FRANCE "THE GREEN VALUE OF HOUSING IN 2021" (2022)

The impact on price of switching from a D label to A or B is significant whether for apartments (an increase of 3-16 %) or houses (6-14 %).

It is, however, lower in Provence-Côte d'Azur (from +3 to +6 % depending on the type of property) and higher in Occitanie (from +11 to +16 % depending on the type of property). The negative premiums of a very energy-intensive label (F-G) are more significant in houses (from -3 to -19 %) than in apartments (from -2 to -11 %).

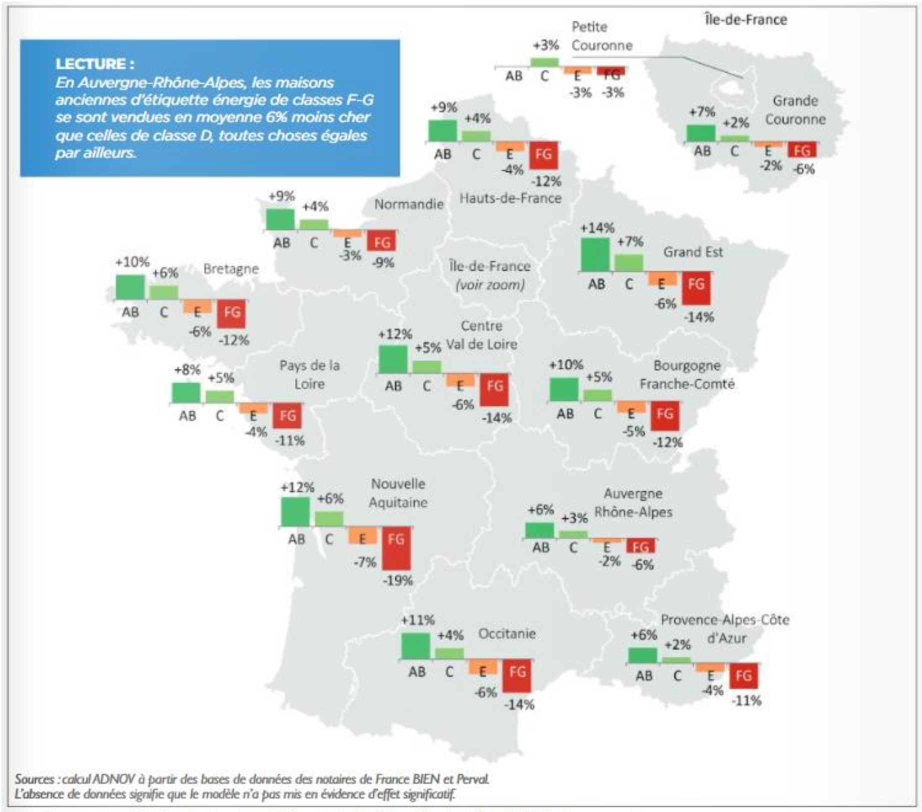


Figure 1.24 Energy label impact on house sale prices.

Source: The green value of housing in 2021 (2022)

Similar findings were reached by Creti (2021)[70] who found an effect of the EPC on house prices between classes C and D, D and E, and E and F. In absolute terms, the **potential label premium is estimated between €1,454 to €2,549 for houses, and between €697 and €2086 for apartments, implying that the EPC class premium might be larger for bigger dwellings.** Buyers of bigger properties might therefore place a higher value on energy efficiency as they anticipate facing higher heating requirements.

The study found no impact at the thresholds between the two most energy-efficient classes (A and B) or the two classes with the worst energy performance (F and G).

Current legislation[71] in France prevents energy-inefficient dwellings (> 450 kWh/m^2) from being offered on the rental market. From 2024, G-labelled dwellings will not be allowed on the rental market and in 2028, the ban will be extended to F-class dwellings.

1.3.3 Effects on the UK market

The UK implemented the European Union's Energy Performance of Buildings Directive in 2008. This led to the creation of EPCs aimed at providing information about a building's energy performance.

The first large-scale empirical project on energy savings capitalisation in the UK was published in 2015[72] and analysed dwellings sold between 1995 and 2012 in England. The paper found a positive relationship between properties' energy efficiency rating and the transaction price per square metre. The price effects of superior energy performance are higher for terraced dwellings and flats than for detached and semi-detached properties. The evidence is less robust for growth rates of house prices.

[70] Creti *"Greenium or manipulation? An analysis of the French housing market"* (2021)
[71] LOI n° 2021-1104 du 22 août 2021 portant lutte contre le dérèglement climatique et renforcement de la résilience face à ses effets (1)
[72] Fuerst, McAllister, Nanda and Wyatt *"Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England"* (2015)

A second study, published in 2016[73], looked at residential prices in Wales between purchasers who buy dwellings for their own use and those who buy for investment purposes. Fuerst et al.[74] found statistically significant **positive price premiums in EPC bands A and B (12.8 %) and C (3.5 %) compared to band D.** Conversely, statistically significant discounts were observed for dwellings in band E (-3.6 %) and F (-6.5 %).

More recently[75], research by Knight Frank found that homes in the UK that had moved from a D to a C rating added an additional 3 % to their value above local house price growth, which is on average equivalent to £9,003 premium on the resale value. Homes moving two bands forward from E to C saw an average uplift of 8.8 % (£29,289).

Scottish Power and WWF published a study in 2022, highlighting how low-carbon technologies (LCTs) can increase energy savings and increase property value[76]. According to their analysis, **installing a heat pump could increase the sales value of a home by around £5,000-£8,000 gross** (excluding the cost of installation); solar panels could increase sales value by £1,350-£5,400; and an EV charge point could increase it by £5,400-£7,400. A combination of these technologies could increase the value of a home by, on average, around £10,000. Individual homes could see sales value increases in excess of this figure.

Authors created an equity valuation model, with a large dataset containing over 5.4 million English and Welsh house sales transactions, along with a dataset containing over 1 million installations of LCTs. The potential increase in sales value is proportional to the capital cost of installing the LCT for heat pumps and solar panels (see table below), while it is disproportionately higher than the cost of installation for EV charging points, as the table illustrates.

	Average Installation Cost[6]	Average Equity Value on Sale[7]
Air Source Heat Pump	£10,980	£6,220[8]
Solar Photovoltaic	£3,800	£3,840
EV Charge point	£1,000	£5,200

Table 1.
Average LCT Installation Cost Vs. Average Equity Value Uplift

Figure 1.25 Source: WWF and Scottish Power "Better home, cooler planet"(2022)

LCTs also have the potential to significantly reduce energy bills.

The average equity value increase of air-source heat pumps reflects the average equity value uplift for all heat pumps (air- and ground-source). This is because the number of heat pumps installed in the UK is still relatively small, so limiting the analysis to air-source heat pumps would have made the sample less robust. It should be noted, however, that a large majority of the sample were air-source heat pumps.

A survey of home buyers carried out by property firm Savills[77] showed that homes with **heat pumps command a 59 % premium compared to regional averages**. Its survey showed that 71% of buyers consider EPC ratings in their decision-making, with 59 % willing to pay a premium for a home 75 % powered by renewable sources.

Properties using heat pumps command the second highest average prices (£483,935). This premium is most acute in the south east, with homes on average 84% more expensive.

1.3.4 Effects on the Spanish market

Compared to other European countries, the implementation of the EPC Directive into Spanish law is relatively recent (June 2013).

[73] Energy performance ratings and house prices in Wales: An empirical study (2016)
[74] Energy performance ratings and house prices in Wales: An empirical study (2016)
[75] Improving your EPC rating could increase your home's value by up to 20% (2022)
[76] Better home, cooler planet: how low-carbon technologies can reduce bills and increase house value (2022)
[77] Buyers paying significantly more for homes with low-carbon technology, as energy prices rise (2022)

Ayala, Galarraga and Spadaro (2015)[78] determined the ratings of a sample of 1,507 homes across Spain and applied a hedonic price technique[79] to investigate whether the Spanish market capitalises the value of energy efficiency. Energy-efficient dwellings with higher EE ratings registered a price premium of between 5.4 % and 9.8 % compared to those with the same characteristics but lower level. The findings are generally in line with the European housing market literature: the sales price premiums of improving energy rating generally fall in the estimated range (5.4-9.8 %).

According to hedonic pricing estimations, **all else being equal, homes labelled A, B or C are valued at 9.8% higher than D, E, F or G-rated ones**. Properties with an A, B, C or D rating have a 5.4 % premium compared to homes with E, F or G ratings.

Duarte and Cheng (2018)[80] investigated the evolution of EPC impacts on residential prices in Spain (the metropolitan area of Barcelona) over time. The study confirmed a positive rise in prices for increased EPC ratings .

In relation to rank G (the comparison base) energy class A increases prices by 8.6 % for both years (2014 and 2016); the remainder of the classes for the base year is not statistically significant. However, the interaction variables (i2016 x EPC class) suggest that the importance of energy rating on price has clearly increased as shown in Figure 1.26.

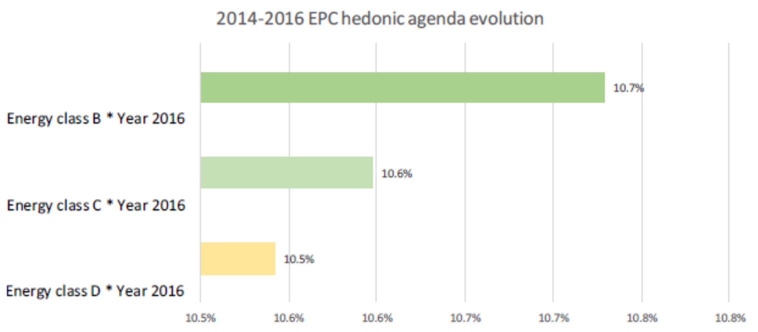


FIGURE 1.26 SOURCE: DUARTE AND CHENG "THE EVOLUTION OF ENERGY EFFICIENCY IMPACT ON HOUSING PRICES. AN ANALYSIS FOR METROPOLITAN BARCELONA" (2018)

The study concludes that, in general, **the more efficient ratings exhibit an increased impact on prices. Such increment ranges from 10.7 % to 10.5 % for B to D ranks respectively**. Rank A also shows a positive increase but fails to meet the significance criteria.

More recently, Duarte and Chen (2022)[81] found that EPC rating remain a price driver (7.5 % increase for A, B and C ratings) for the upper tier of apartments in central and affluent zones and they are positively correlated with price increments (on average 1.8 % increase for each EPC increment). The case study focused on multi-family homes in the Barcelona metropolitan region, where these types of property are dominant.

The paper highlighted that, if the dwellings' architectural quality (from functionality and quality of materials to aesthetic features) is poorly controlled, the marginal price of EPC ratings is artificially inflated. Through housing market segmentation, however, it appears that a market premium for efficient homes exists in the niche of apartments that target an affluent, well-educated population.

This demographic is not primarily concerned with energy savings but has a higher level of awareness and subsequent willingness to pay for the benefits of efficient homes on their well-being.

[78] A. de Ayala, I. Galarraga, J. V. Spadaro "The price of energy efficiency in the Spanish housing market" (2015)
[79] The method assumes that different goods are differentiated by the number of characteristics (attributes) they pose. At the market equilibrium, the price is a mixture of demand-side and supply-side attributes that can be analysed with the method. A complete description of this technique can be found in Braden and Kolstad (1991).
[80] C.M. Duarte, A. Chen "The evolution of energy efficiency impact on housing prices. An analysis for Metropolitan Barcelona" (2018)
[81] C.M. Duarte, A. Chen "Uncovering the price effect of energy performance certificate ratings when controlling for residential quality" (2022)

1.3.5 Effects on the Dutch market

The first notable study to analyse the impact of energy efficiency on house prices in the Netherlands was carried out by Brounen and Kok (2011)[82]. Their work was carried out between 2008 and 2009.

Non-labelled homes were used as a comparison group. Based on the thermal quality of the homes, they are rated from A++ to G, where an A++ label indicates the highest energy efficiency.

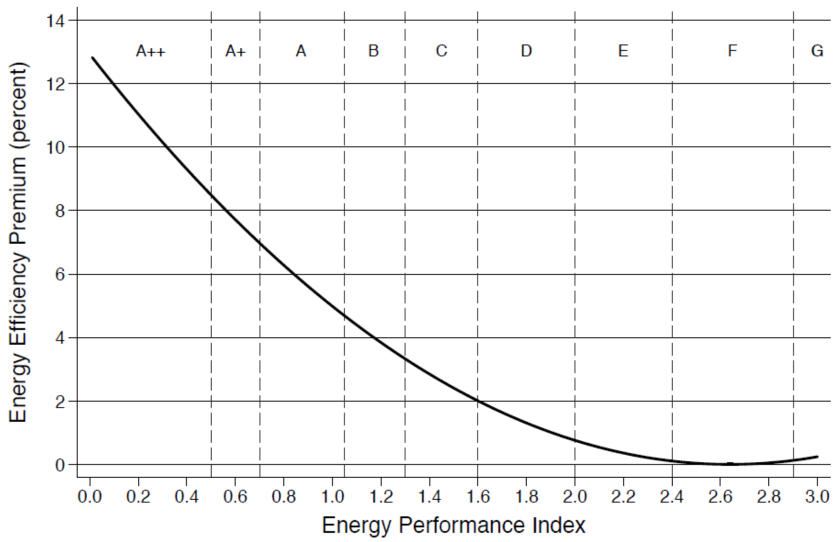
Evidence suggests that Dutch homes with an A label sell for 10.2 % more than otherwise similar homes with a D label. The premium for B-labelled homes is 5.5 % and houses with a C label sell for 2.1 % more. Dwellings rated less than D are sold at a discount.

In 2016, Chegut, Eichholtz and Holtermans[83] focused on energy savings capitalisation in the affordable housing sector. In this case, recouping the energy savings through higher rents is difficult due to an extensive programme of rent protection. The tenant benefits from the reduced energy bill while the building owner undertakes the energy efficiency investment, resulting in a split incentive.

One solution for affordable housing owners would be to sell energy-efficient affordable dwellings on the market. In principle, this solution is viable, but many countries have legal impediments in place to prevent this. Dutch affordable housing institutions, however, are allowed to sell from their stock, and the authors used this natural experiment in housing policy to analyse the value of energy efficiency in affordable housing.

The results of the EPC labelled sample show that homes with an A label command a 7.0 % premium compared to an otherwise similar dwelling with a C label, while B-labelled dwellings command a 1.9 % premium. This suggests

Figure 1
Transaction Value and Energy Performance Index



Notes: The above figure displays the non-linear relationship between the energy performance index and the incremental transaction value per square meter. The graph has been rebased to zero for ease of interpretation. The vertical dashed lines display the different cut-off values for the energy labels. This categorization has been revised in January 2015; the cut-off values used are the ones applicable at the time of transaction.

FIGURE 1.27 SOURCE: CHEGUT, EICHHOLTZ AND HOLTERMANS "ENERGY EFFICIENCY AND ECONOMIC VALUE IN AFFORDABLE HOUSING" (2016)

that the average C-labelled home in the sample would sell for approximately €10,800 more were it to be A-labelled. The increase in transaction value for a B label is just over €2,900.

Dwellings bought by households with higher incomes are valued at an additional premium of almost 1%. Within the labelled sub-sample, households with a relatively high income pay a 4.6 % premium for the most

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[82] D. Brounen and N. Kok "On the economics of energy labels in the housing market" (2011)
[83] A. Chegut, P. Eichholtz, R. Holtermans "Energy Efficiency and Economic Value in Affordable Housing" (2016)

energy-efficient homes, while that premium is only 1.6 % for middle-income families and even lower if they have higher wealth. Demographics do not influence premiums for energy-efficient dwellings.

A later study by Tilburg and Maastricht universities in 2021 already showed that a red energy label yields less than a green label house when sold[84]. In 2022 the Netherlands Enterprise Agency estimated an average €30,000 premium for a C label compared to a comparable house with G class efficiency (7.9% of the selling price)[85].

A new study by the Netherlands Enterprise Agency in 2023[86] found that the gross effect of an improved energy label on property value amounts on average to a 7.2 % increase compared to the same house with the old label.

Oud label \ Nieuw label	A	B	C	D	E	F	G
A							
B	2.8%						
C	5.0%	2.2%					
D	7.2%	4.3%	2.1%				
E	8.2%	5.3%	3.0%	1.0%			
F	10.2%	7.2%	4.9%	2.8%	1.8%		
G	13.3%	10.3%	7.9%	5.7%	4.8%	3.0%	

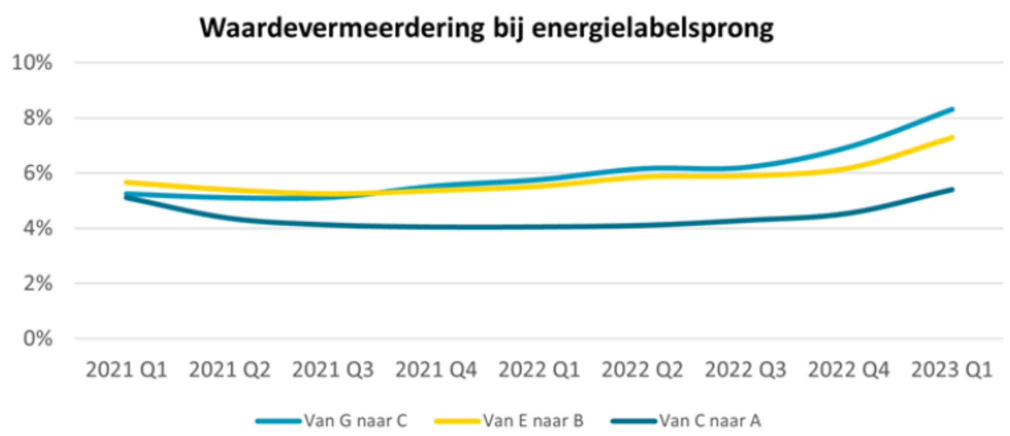
Bron: brainbay

Figure 2: % increase in house value for all houses in the Netherlands. An average of 7.9% more is paid for a house with label C than for a comparable house with label G. Source: brainbay

FIGURE 1.28 SOURCE: NETHERLANDS ENTERPRISE AGENCY (NVM) "DE WAARDE VAN HET ENERGIELABEL – INVESTEREN IN DUURZAAMHEID LOONT STEEDS MEER" 2022

The value of a home that improves from G to C saw an average increase of 8.3 % in the first quarter of 2023. In the case of a jump from C to A, the house is worth an average of 5.4 % more.

These values have increased compared to the last quarter of 2022, when a jump from G to C brought an increase of 6.9 % in property value, while a jump from C to A was valued at 4.5 %.



BRON: BRAINBAY

FIGURE 1.29 INCREMENT OF HOUSE VALUE BASED ON ENERGY LABEL IMPROVEMENT PER QUARTER. SOURCE: NVM EFFECT VAN BETER ENERGIELABEL OP WONINGWAARDE GROTER DAN OOIT (2023)

[84] Tilburg and Maastricht University "Rood energielabel doet steeds meer pijn bij woningverkoop" (2021)
[85] NVM "De waarde van het energielabel – investeren in duurzaamheid loont steeds meer" (2022)
[86] NVM "Effect van beter energielabel op woningwaarde groter dan ooit" (2023)

Landelijk

Oud label \ nieuw label	A+ en beter	A	B	C	D	E	F
A	2,2%						
B	5,1%	2,8%					
C	7,7%	5,4%	2,5%				
D	10,4%	8,0%	5,0%	2,5%			
E	*	10,4%	7,3%	4,7%	2,1%		
F	*	*	9,8%	7,1%	4,5%	2,3%	
G	*	*	*	8,3%	5,7%	3,5%	1,3%

* label jump omitted because it is less realistic in practice

FIGURE 1.30 PERCENTAGE INCREASE IN THE HOME VALUE FOR ALL THE DIFFERENT LABEL JUMPS. SOURCE: NVM EFFECT VAN BETER ENERGIELABEL OP WONINGWAARDE GROTER DAN OOIT (2023)

The increase in value decreases for homes built more after 1975, as shown in the graph below.

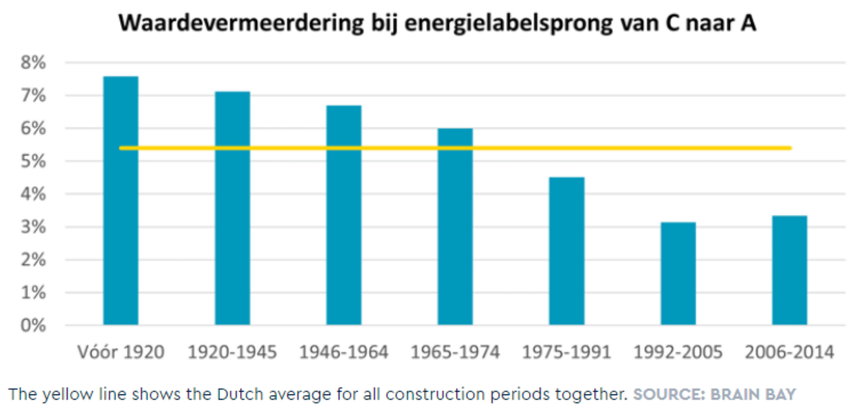


FIGURE 1.31 INCREASE IN VALUE FOR ENERGY LABEL JUMP FROM C TO A PER CONSTRUCTION YEAR. SOURCE: NVM EFFECT VAN BETER ENERGIELABEL OP WONINGWAARDE GROTER DAN OOIT (2023)

At a geographical level, property value is rising the most in the province of Groningen, where an improvement from C label to A results in a value increase of 8.7 % (first quarter of 2023). Similar increases are observed in Friesland and Limburg.

Increments in value are the smallest in Utrecht, Flevoland and North Holland.

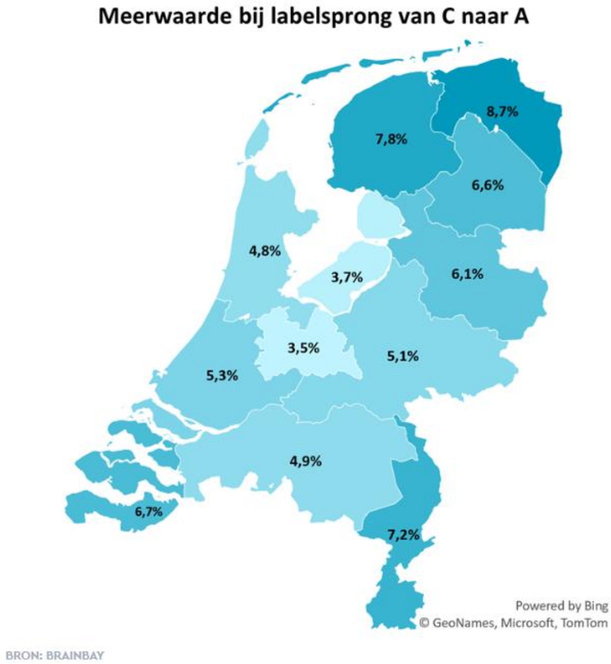


FIGURE 1.32 ADDED VALUE IN LABEL JUMP FROM C TO A PER REGION. SOURCE: NVM EFFECT VAN BETER ENERGIELABEL OP WONINGWAARDE GROTER DAN OOIT (2013)

1.3.6 Effects on the Italian market

In Italy, an EPC has been mandatory for house transactions since 2009, so there are few studies on the effect of EPC on the Italian real estate market compared to other European countries.

Fregonara, Rolando, Semeraro and Vella (2014)[87] analysed 577 residential listings in the city of Turin. The study found evidence of a **strong relationship between efficiency and listing price only for F-rated homes.** The possible cause of the weak relationship between price and high energy levels is that the energy level was not yet taken into account by real estate agencies in listing prices.

This was due to weak interest from potential buyers and final users, who at the time were not yet considering the lower maintenance costs associated with a higher energy label. Since the apartments' energy level seems not to have a direct influence on listing prices, the owners were not incentivised to invest in refurbishment actions.

Copiello (2015)[88] performed a case study in Turin focusing on one refurbished affordable apartment building, in which environmental performance had been increased during the renovation. The author was able to prove that rents in the building had gone up substantially, leading to a satisfactory financial return on the investment, thus providing a market-based incentive for improvements in environmental performance in affordable housing.

Later, Tajani, Morano Di Liddo and Doko (2019)[89] investigated the economic benefits associated with energy retrofit interventions. They examined the sustainability of energy efficiency interventions using the Superbonus 110 % mechanism[90] in provincial capitals and main urban areas and selling prices of residential, commercial and office properties. The findings show that the investment is only financially viable when the refurbishment costs are covered by the Superbonus.

The findings further indicate that **when refurbishment costs are covered by the Superbonus, the investment is financially viable for all Italian provincial capitals. However, if the investor bears the costs entirely, the**

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[87] E.Fregonara, D.Rolando, P.Semeraro, M.Vella "The impact of Energy Performance Certificate level on house listing prices. First evidence from Italian real estate" (2014)
[88] S.Copiello "Achieving affordable housing through energy efficiency strategy" (2015)
[89] F.Tajani,P. Morano,F. Di Liddo, E. Doko "A Model for the Assessment of the Economic Benefits Associated with Energy Retrofit Interventions: An Application to Existing Buildings in the Italian Territory" (2022)
[90] DECRETO-LEGGE 19 maggio 2020, n. 34 Misure urgenti in materia di salute, sostegno al lavoro e all'economia, nonche' di politiche sociali connesse all'emergenza epidemiologica da COVID-19. (20G00052)

operation is financially viable for 82 % of central areas, 63 % of semi-central areas, and 57 % of peripheral areas in the selected cities.

Minimum and Maximum Positive Break-Even Incentive Value						
Macro-Area	Central Area		Semi-Central Area		Peripheral Area	
	Minimum Value	Maximum Value	Minimum Value	Maximum Value	Minimum Value	Maximum Value
North-Western Italy	La Spezia 15%	Asti 125%	Imperia 13%	Cuneo 119%	Monza e Brianza 11%	Turin 113%
North-East Italy	Venice 4%	Gorizia 65%	Piacenza 2%	Belluno 89%	Treviso 26%	Reggio Emilia 96%
Central Italy	Fermo 1%	Ascoli Piceno 78%	Fermo 4%	Ascoli Piceno 61%	ROME 10%	Rieti 97%
Southern Italy	Salerno 7%	Catanzaro 111%	Brindisi 21%	Vibo Valentia 90%	Lecce 3%	Vibo Valentia 91%
Islands	Olbia-Tempio 14%	Sassari 77%	Nuoro 7%	Trapani 102%	Agrigento 12%	Caltanissetta 122%

FIGURE 1.0.133 SOURCE: "A MODEL FOR THE ASSESSMENT OF THE ECONOMIC BENEFITS ASSOCIATED WITH ENERGY RETROFIT INTERVENTIONS: AN APPLICATION TO EXISTING BUILDINGS IN THE ITALIAN TERRITORY" (2022)

The study also evaluates the break-even incentive threshold required for minimum convenience in the absence of the Superbonus. It identifies that 21.5 % of the areas analysed can sustain the investment without the incentive, while 1.8 % require an incentive equal to or higher than 110 %, and 76.7 % need an incentive of less than 110 %. The results show that provincial capitals in northern and central Italy are more financially attractive for energy retrofit interventions compared to those in southern Italy and the islands.

Bisello, Antoniucci and Marella (2020)[91] analysed a cross-sectional housing dataset in Bolzano, which is characterised by its compact urban form and local environmental awareness. In this context, a price premium of 6 % on moving from the worst (G) to the best (A) energy efficiency class was observed.

Finally, the Iuav University of Venice developed relevant research on three sample cities: Bergamo, Mestre and Padua for the REbuild 2023 Observatory[92]. The study concluded that spending to carry out energy retrofits is associated with a 40 % growth of the real estate asset value (with the move from G to A). Conversely, not carrying out any retrofit means a loss of the same percentage in terms of market listing.

Depending on whether a building is in the centre or in the suburbs, the change in value between E and D is around 5 % to 6 %, but rises between 14 % and 18 % when moving from G to D. Premiums increase by up to 30 % and 40 % when moving from G to A.

1.3.7 Effects on the Belgian market

The 2013 EC report Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries[93] investigates the effects of EPC on the Belgian real estate market. The analysis of 26,000 property listings has shown a clear relationship between a property's energy efficiency, as measured by its CPEB performance, and its advertised price or rent.

[91] A. Bisello, V. Antoniucci, G. Marella "Measuring the price premium of energy efficiency: A two-step analysis in the Italian housing market" (2020)
[92] REbuild 2023: l'efficienza energetica della casa ne aumenta il valore fino al 40% (2023)
[93] European Commission (DG Energy) "Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries" (2013)

Energy performance is given by the CPEB metric, kWh/m², the ratio between the characteristic annual primary energy consumption and the useable floor area. For correspondence with energy classes, please refer to the table below (for the Flemish and Walloon conversion table, see paragraph 2.8).

Energy class	Energy index: kWhPE/m²/year
A++	less than zero
A+	from 0 to 15
A	from 16 to 30
A-	from 31 to 45
B+	from 46 to 62
B	from 63 to 78
B-	from 79 to 95
C+	from 96 to 113
C	from 114 to 132
C-	from 133 to 150
D+	from 151 to 170
D	from 171 to 190
D-	from 191 to 210
E+	from 211 to 232
E	from 233 to 253
E-	from 254 to 275
F	from 276 to 345
G	346 and above

FIGURE 1.34 SOURCE: CERTIBRU THE ENERGY PERFORMANCE OF BUILDINGS

The majority of the listings are in Flanders, where analysis of the market showed that an improvement of 100 points in the CPEB metric (termed here a "major improvement" in energy efficiency) is associated with a 4.3 % higher price, on average. The rent effect was smaller but still statistically significant: an improvement of 100 points in the CPEB metric is associated with a 3.2 % higher rent.

Results for Wallonia and Brussels, based on significantly smaller sample sizes, were in line with those for Flanders. A major improvement in energy efficiency is associated with a 5.4 % higher price in Wallonia and a 2.9 % higher price in Brussels.

In the rental market, a similar improvement in energy efficiency is associated with a 1.5% higher rent in Wallonia and a 2.2 % higher rent in Brussels.

While the price effect in Wallonia is larger than that for Flanders, it is also less precisely estimated.

The Brussels-Capital region appears to be systematically different. This may reflect the higher prices in the capital: if the energy savings associated with a dwelling of 150 m² are a certain amount, this will be a smaller proportion of the price in Brussels, where such dwellings command a higher value.

Figure 6: Price and rent effects of 100-point improvement in CPEB score (and 95% confidence interval) in the Belgian property market

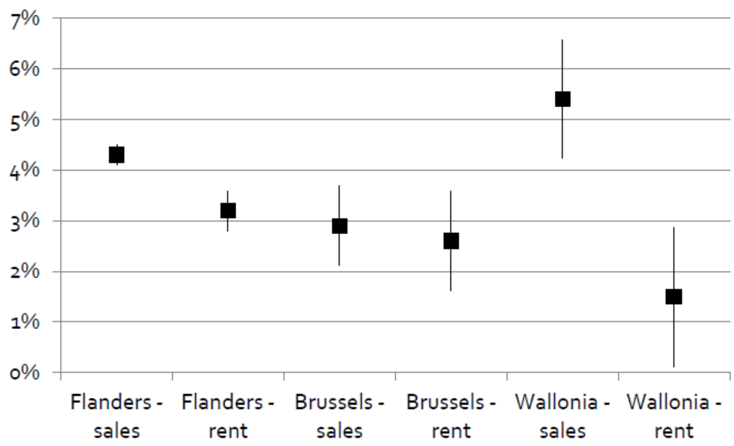

FIGURE 1.35 SOURCE: ENERGY PERFORMANCE CERTIFICATES IN BUILDINGS AND THEIR IMPACT ON TRANSACTION PRICES AND RENTS IN SELECTED EU COUNTRIES (2013)

1.4 Conclusions

The ECP labels have been fully implemented across most member states and have become decision drivers in purchases. The effect of certifications on price has been investigated heterogeneously in each country, so a precise estimate of the premium commanded by higher labels depends on the specific characteristics of the local market.

Although factors such as scarcity of supply can hamper the influence of ECP on listing prices, it is also true that more energy-efficient dwellings are consistently valued at a higher price by the market, as opposed to comparable properties with a lower energy label.

Generally speaking, prospective energy savings and improved comfort granted by energy-efficient dwellings are capitalised in selling prices, with ECP improvements being positively correlated with listing premiums.

Section 2: Savings Projections in time

Elisa Yoshitake

Product Management Officer

Heating Sales Business Unit (Daikin Europe)

"Despite the strong fluctuations of energy prices, this section aims at offering a long-term estimation future energy savings generated by a HP installation"

Simon Willemarck

Development Engineer

Heating Sales Business Unit (Daikin Europe)

2.1 Introduction

One of the recurring arguments when advocating for the installation of a heat pump is the lower anticipated energy consumption, which translates into lower bills and therefore increased savings for households. Such savings, as we have seen in the previous section, are often capitalised in the reselling price of the property. The premium paid for the increased energy efficiency is a constant in several EU member states, although it varies in quantity depending on the country and other geographical and architectural properties.

In this section, we will quantify the energy savings generated over 10 years by the installation of a heat pump in a generic house compared to a natural gas boiler.

For the purpose of this exercise, we have built on the Eurostat data as a baseline for the energy household price estimate and forecast. To estimate the effect of carbon taxation, we have used the results of the recently published study "Modelling the socioeconomic impact of zero carbon housing in Europe final"(2022) [94] by Cambridge Econometrics and the European Climate Foundation and its update (rerun of the same study) published in 2023[95].

2.2 Building the model

2.2.1 Estimating a baseline for EU energy prices

For energy price estimation, we have used historical end-consumer prices as a baseline. We have relied on the electricity prices components for household consumers[96] (annual data) and the gas prices components for household consumers[97] (annual data) from the Eurostat Data Browser to establish a baseline for future calculations.

2.2.1.1 Baseline prices

We have modelled the average European cost of electricity[98] and gas[99] taking into account the volatility that has characterised the markets in the last three years. We operated under the assumption that 2022 prices represent outliers in both series and are a consequence of the Russian invasion of Ukraine rather than an expression of market trends. For this reason, we have substituted the 2022 yearly price with the average of the yearly prices of 2018, 2019, 2020, 2021 and 2022 in both series.

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[94] Cambridge Econometrics and The European Climate Foundation "Modelling the socioeconomic impact of zero carbon housing in Europe final" (2022 – 2023)
[95] Cambridge Econometrics and The European Climate Foundation "Modelling the socioeconomic impact of zero carbon housing in Europe final" (2022 – 2023)
[96] Eurostat Electricity prices for household consumers– second half of 2022
[97] Eurostat Natural gas prices for household consumers – second half of 2022
[98] Eurostat Electricity prices for household consumers– second half of 2022
[99] Eurostat Natural gas prices for household consumers – second half of 2022

The trendline and forecast resulting from the new series are more in line with the market trends observed in the past years and less skewed by the effect of the war, while reflecting the price shift caused by 2022.

The graphs below show the historical (2006-2022) annual energy prices for electricity and gas as well as the forecast 10-year series (2022-2032) using the historical series as is (including the 2022 value, deep green line) and using the corrected series (where the 2022 datapoint is mitigated by the previous four years, light green line).

The forecast values based on the corrected historical values will serve as a baseline for energy price estimation in the model.

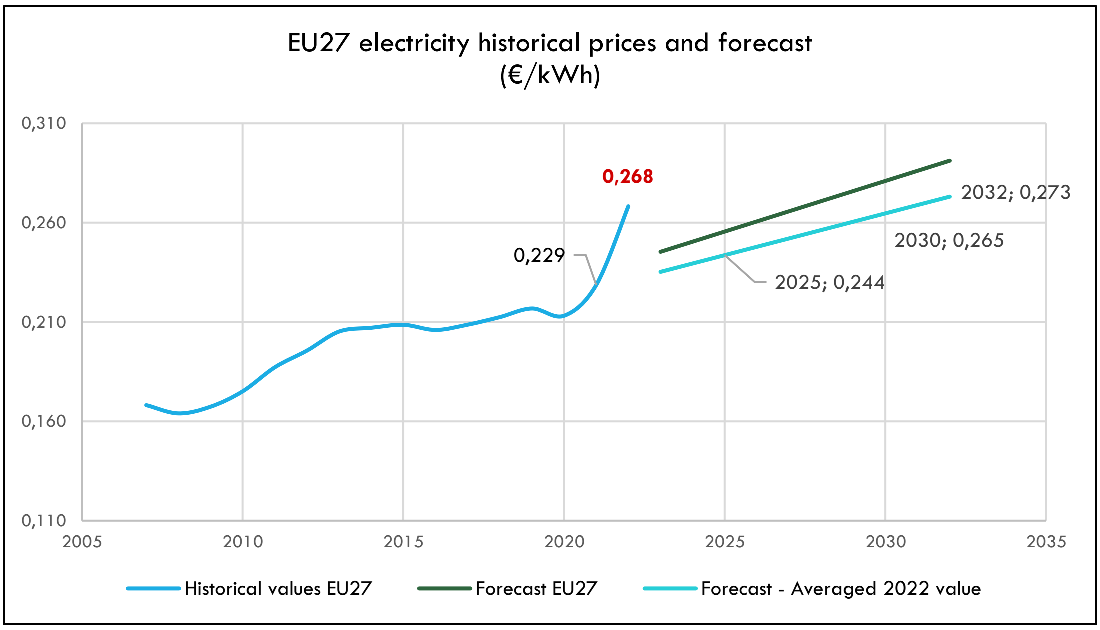

FIGURE 2.0.1 SOURCE: OWN CALCULATIONS BASED ON EUROSTAT ANNUAL DATA

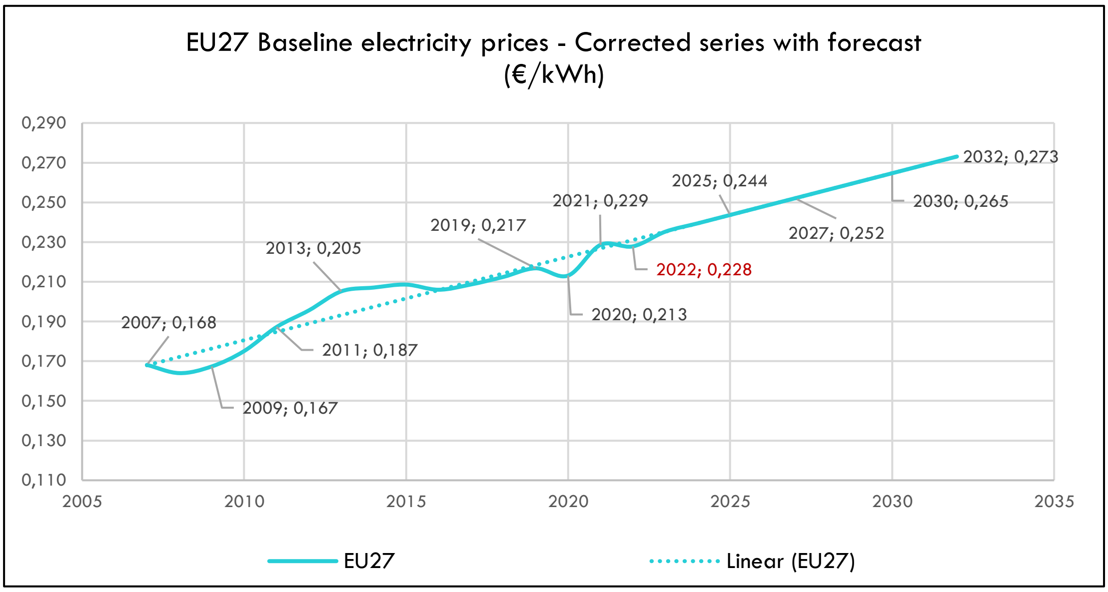

Figure 2.2 source: own calculations based on Eurostat annual data

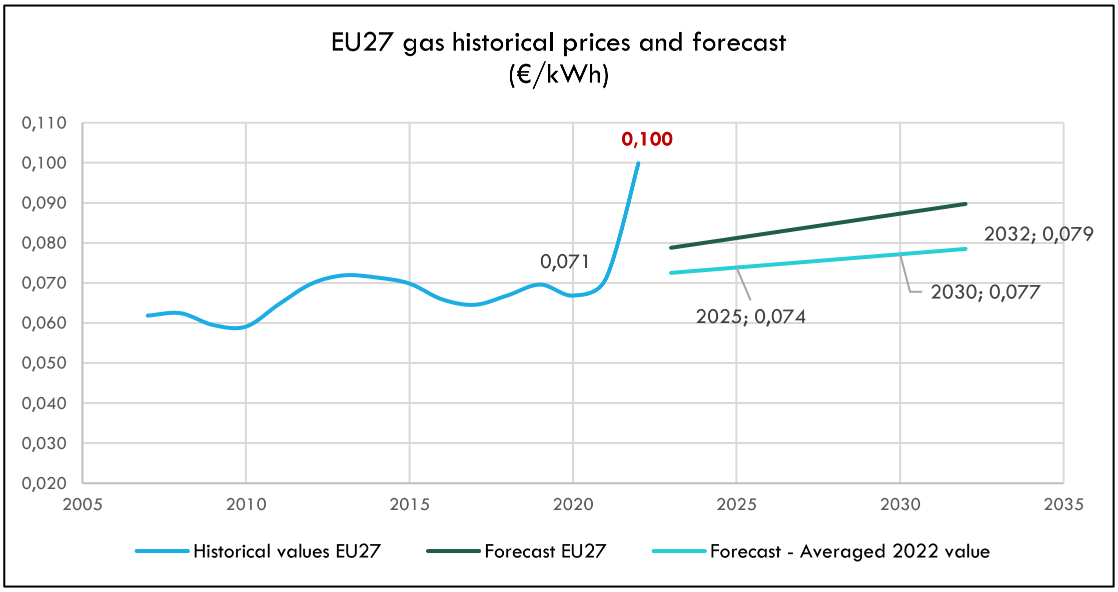

Figure 2.0.2 source: own calculations based on Eurostat annual data

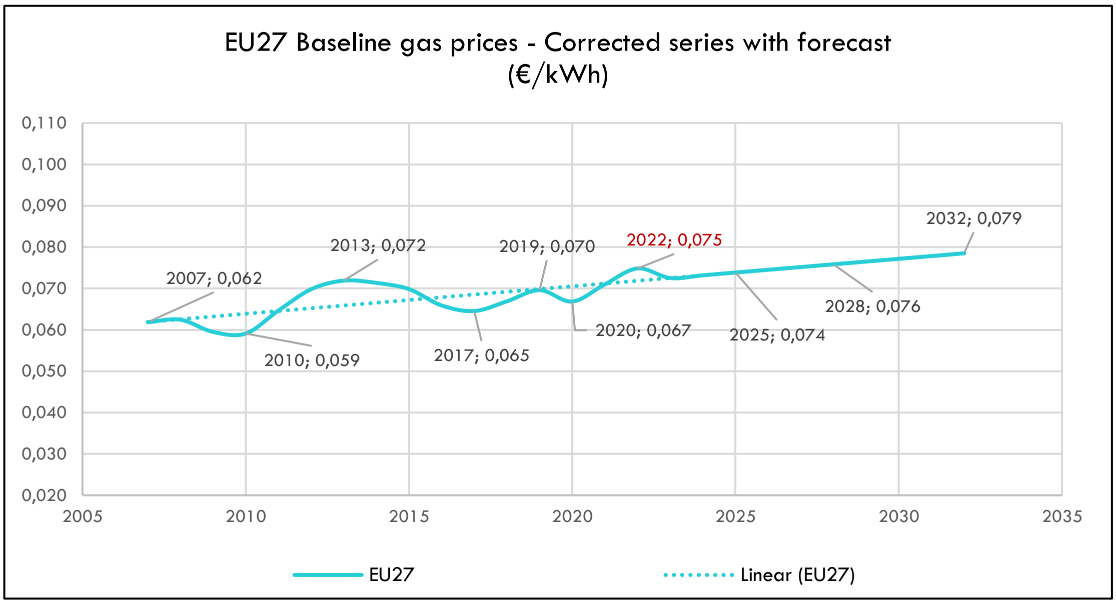

Figure 2.0.3 Source: Own calculations based on Eurostat annual data

2.2.2 Estimating the effects of ETS and carbon taxation on the forecast prices

We considered the effects of a carbon tax on top of the ETS[100] for industry to facilitate decarbonisation, and included the ETS2 for consumers. To determine the carbon penalty price for electricity, we have estimated the evolution of CO_2 intensity of electricity generation in the EU. We relied on the CO_2 intensity of electricity generation estimations made by the Global Energy Outlook (EnerOutlook)[101] software and calculated the mid-points through linear interpolation.

CO_2 intensity levels in the EU follow a decreasing trend over time (dotted line), under the assumption that the use of renewable sources will surge in the future and progressively substitute fossil fuels.

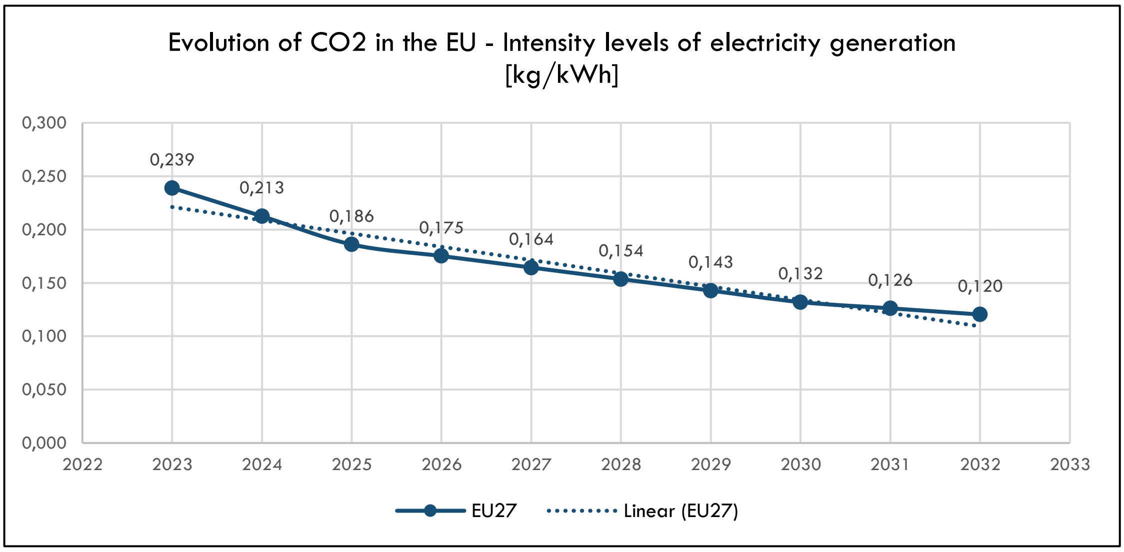

Figure 2.0.4 Source: Own calculations based on EnerOutlook data (EU)

[100] The European Emission Trading System (EU ETS) sets a cap on the total amount of greenhouse gases that participants can emit, by assigning each a quota. Quotas can be traded between participants with different levels of emissions. Link to the EC webpage about EU ETS

[101] Global Energy and Climate Outlook - CO2 intensity of electricity generation (Enerdata)

For gas, we assumed the emission factor of natural gas to be constant and set at 0.198 kg CO_2/kWh gas[102].

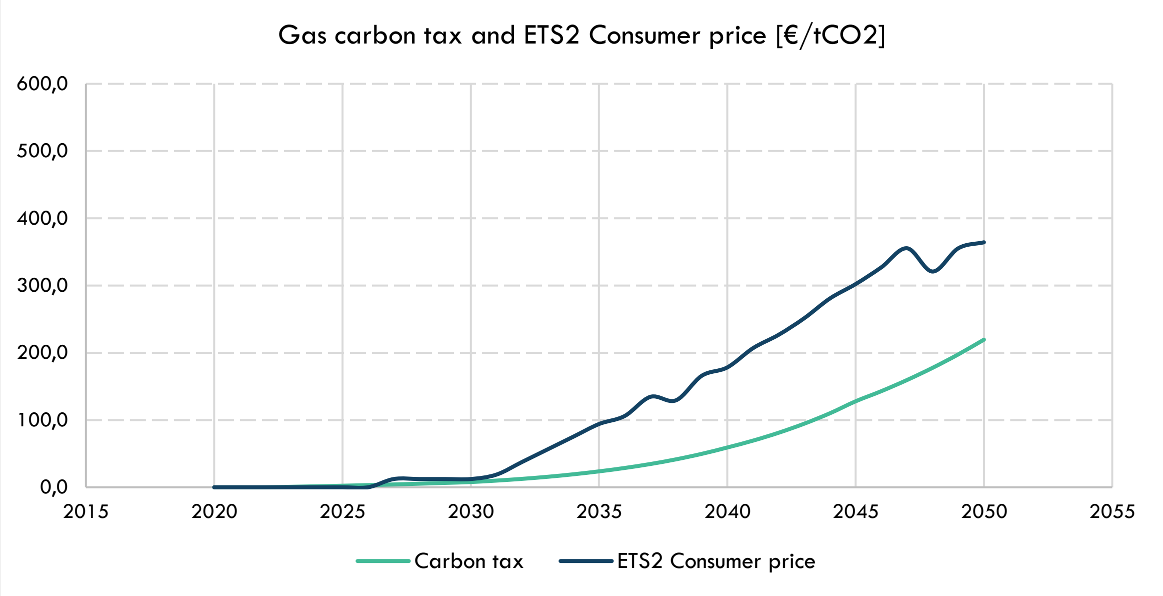

FIGURE 2.0.5 SOURCE: OWN CALCULATIONS BASED ON CAMBRIDGE ECONOMETRICS DATA

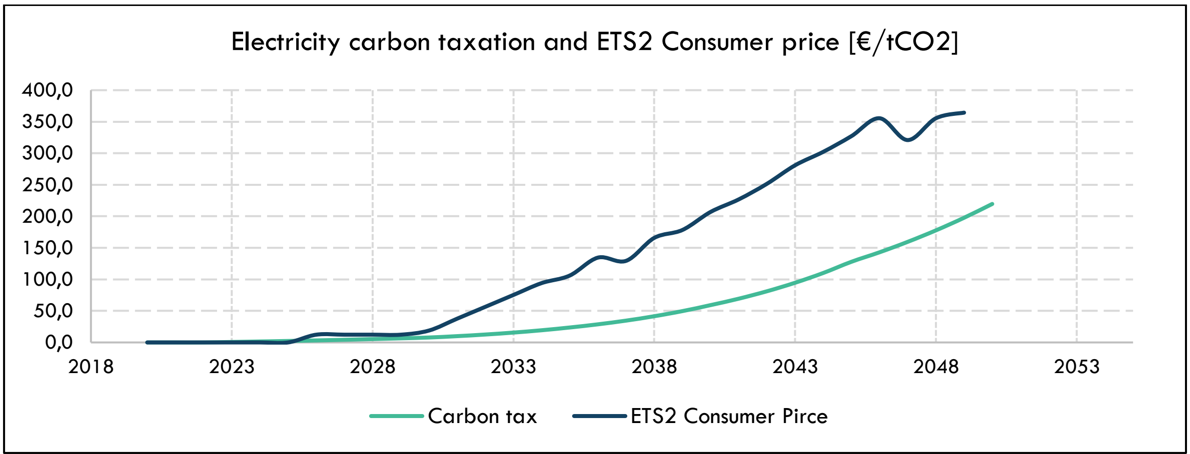

FIGURE 2.0.6 SOURCE: OWN CALCULATIONS BASED ON CAMBRIDGE AND ENEROUTLOOK DATA

With the EU Reference 2020 scenario[103], the ETS2 Consumer price has been added to the baseline prices to estimate end user prices. Carbon taxation has been added too. As explained, the carbon penalty has been computed based on the intensity levels of electricity and gas over the years and the carbon tax penalty[104] per ton of CO_2 produced.

The graphs below plot the carbon taxation and ETS Consumer prices for both natural gas and electricity.

Taking the above into consideration, we have generated the final energy price forecast (see graphs below).

[102] Cambridge Econometrics and The European Climate Foundation (2022 – 2023); European Commission "Excel files for MIX-CP scenario"
[103] EU reference scenario 2020 - Energy, transport and GHG emissions : trends to 2050
[104] Amounts provided by Cambridge Econometrics, originally computed for the paper "Modelling the socioeconomic impact of zero carbon housing in Europe final" (2022 – 2023)

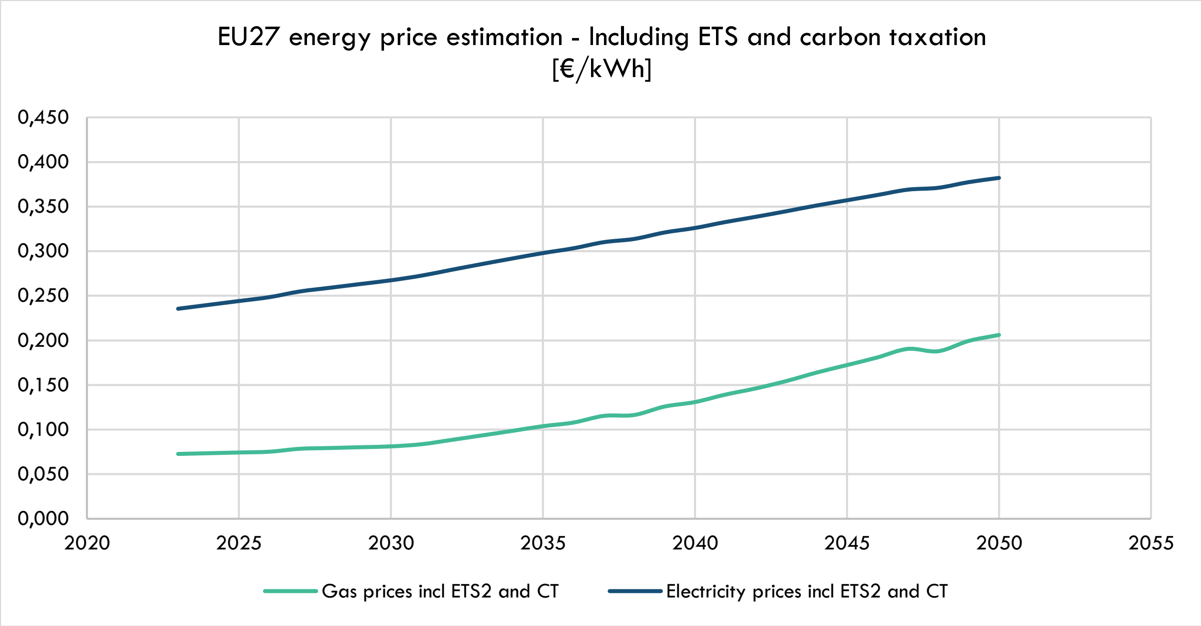

FIGURE 2.0.7 SOURCE: OWN CALCULATIONS

Since the scope of our study is restricted to a 10-year threshold, the price projections reported in this paper do not fully reflect the effect of ETS Consumer price increase and carbon taxation effect, both of which become more prominent after 2035. The graph below shows the energy prices forecast for the years 2023-2032.

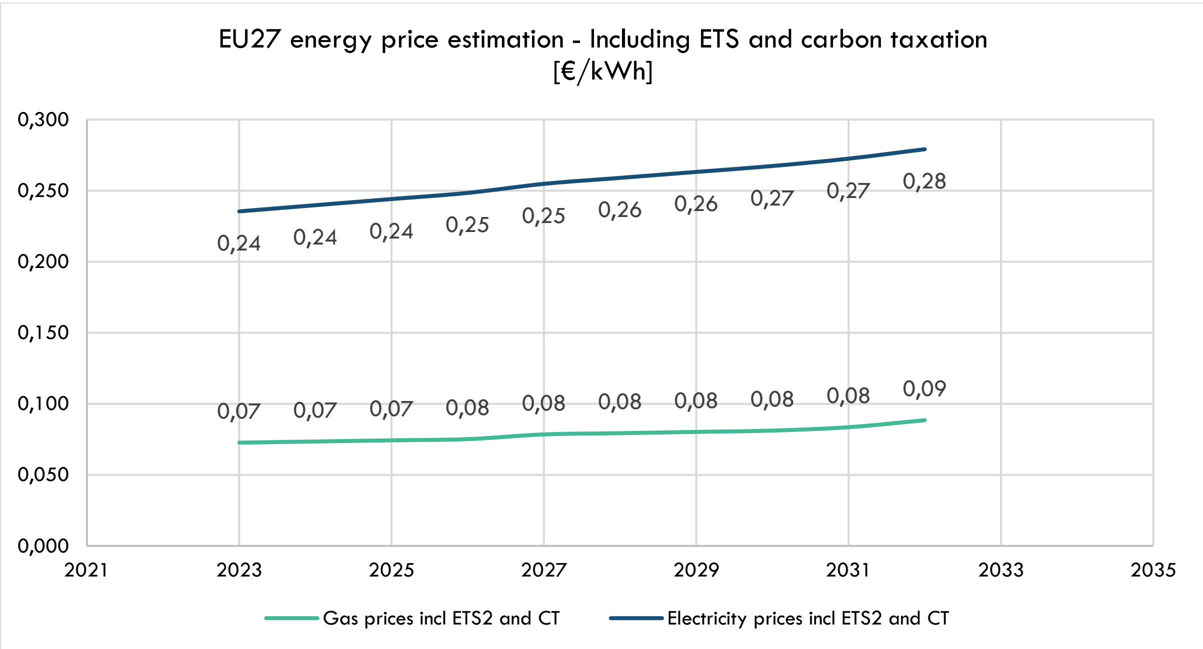

FIGURE 2.0.8 SOURCE: OWN CALCULATIONS

It is important to remember, in interpreting the data in this paper, that the forecast energy prices are driven by the underlying assumptions in the model and are subject to a great degree of uncertainty in the evolution of the energy market and global economy. It is imperative to keep in mind that these are simulations, not predictions.

2.2.3 Estimating the standard house

Once we have forecast energy prices, we set the specifications of the standard house to calculate consumption, running costs and therefore energy savings.

To estimate energy savings over a period of 10 years we compared the running costs of underfloor heating with a heat pump and the running costs of radiators powered by a gas boiler.

Energy consumption per outside temperature is defined as follows:

Td	Estimated energy input	
	10,000 kWh home (thermal output) – underfloor heating	
	HP (ERGA[105])	Gas boiler
°C	kWh (el)	kWh (gas)
+7	2,395	11111.11

For the gas boiler, we took into consideration the following characteristics:

	INPUT
Gas boiler efficiency [%]	90
Yearly space heating demand [kWh]	10,000
Yearly gas energy [kWh]	11111.11
Emission factor [kg C02/ kWh gas]	0.198

2.2.2 Estimated running costs and energy savings

Based on the estimated energy input and technology efficiency, and the energy prices over the forecast period, we have estimated the running costs of heating using a heat pump (with underfloor heating) and a gas boiler (through radiators).

The heating costs associated with the gas boiler are higher than the costs generated by the heat pump.

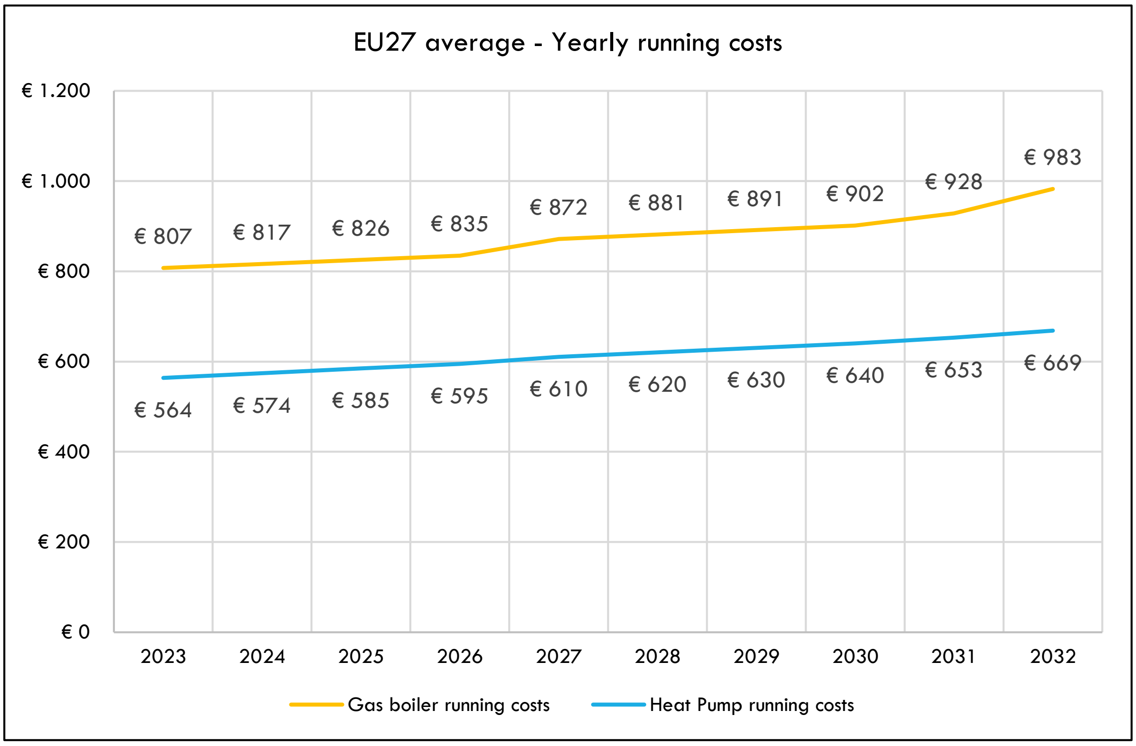

FIGURE 2.0.9 SOURCE: OWN CALCULATIONS

[105] Daikin ERGA Low-temperature Heat Pump (Refrigerant Split)

The graph below plots the yearly savings generated by the heat pump (compared to the gas boiler) and the trend line of the series (dotted line). It is clear that, under the assumptions of the model, the heat pump generates positive savings that increase over the forecast period of 10 years.

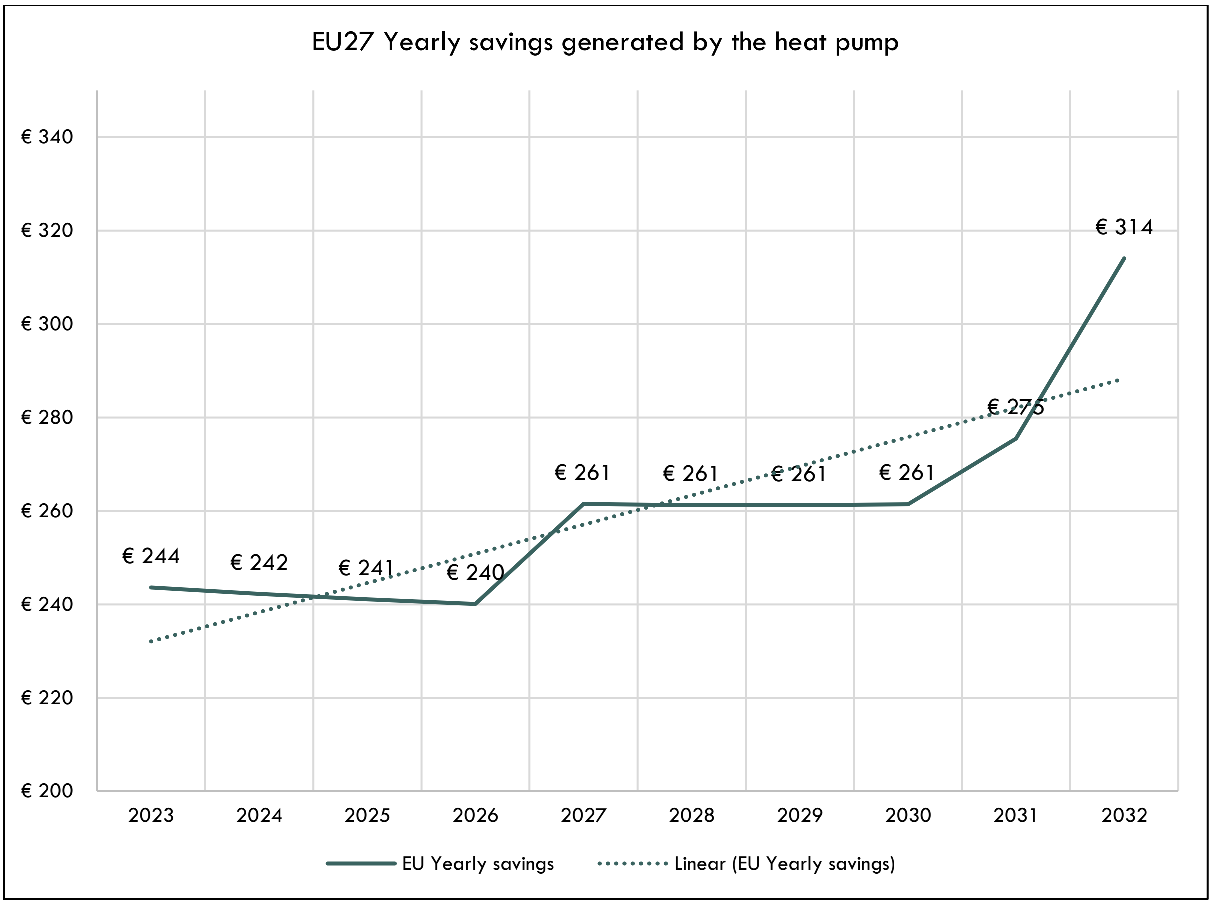

Figure 2.0.10 Source: Own calculations

The table below shows the expected energy savings (running costs of heat pump vs boiler) deriving from the use of a heat pump. The table below summarises the findings.

	EU27 average			
	10,000 kWh home			
Year	Yearly running cost heat pump	Yearly running cost gas boiler	Energy savings	Cumulative Savings
2023	563,82 €	807,44 €	243,62 €	243,62 €
2024	574,24 €	816,50 €	242,27 €	485,88 €
2025	584,58 €	825,66 €	241,08 €	726,96 €
2026	594,98 €	835,06 €	240,08 €	967,04 €
2027	610,21 €	871,69 €	261,49 €	1.228,53 €
2028	620,25 €	881,48 €	261,23 €	1.489,76 €
2029	630,28 €	891,48 €	261,20 €	1.750,95 €
2030	640,28 €	901,71 €	261,43 €	2.012,39 €
2031	652,69 €	928,14 €	275,45 €	2.287,84 €
2032	668,54 €	982,59 €	314,06 €	2.601,90 €

The estimated energy savings are always positive and constant over time. Cumulative savings over a 10-year period (2023-2032) amount to €2,602 in 2032.

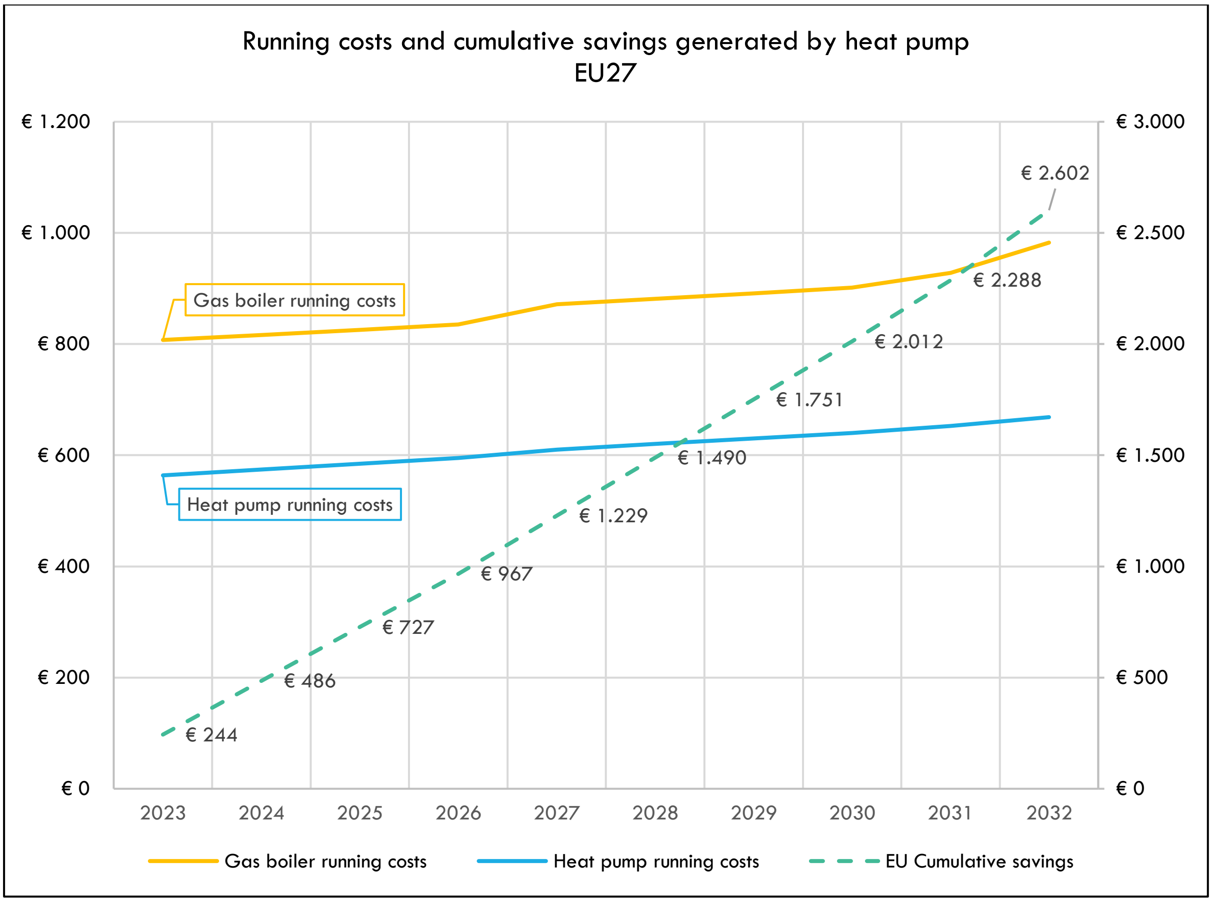

FIGURE 2.12 SOURCE: OWN CALCULATIONS

2.5 Conclusions

Under the market assumptions used in this model, installing a heat pump to substitute a natural gas boiler as a heating and domestic hot water system is expected to generate energy savings over the forecast 10-year period. Savings increase over time and amount to an estimated value of €2,602 in 2032. These findings assume a renovation rate and amplification effect coherent with the current European rate, then implementation of carbon taxation from 2023 to facilitate decarbonisation, and constant market shares of technologies with eventually a phase-out of non-condensing boilers.

It is important to remember, in interpreting the data in this paper, that the forecast energy prices are driven by the underlying assumptions in the model, and are subject to a great degree of uncertainty in the evolution of the energy market and global economy. It is therefore imperative to keep in mind that these are simulations, not predictions.

To share your comments with the authors or for additional information, email heatpumpadoptioneuhsbu@daikin.eu

Section 3: Ban on existing technologies

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Product Management Officer

Heating Sales Business Unit (Daikin Europe)

"This section paper was put together to help you choose your next heating equipment at home, as a future proof one"

Governments – specifically in Europe – are on a journey towards their net zero ambitions. The number of countries announcing pledges to achieve net zero emissions in the coming decades continues to grow. However, to reach these long-term targets they must set measurable short-term milestones.

The ambition of the International Energy Agency (IEA)[106] is for all countries to implement zero-carbon-ready building codes by 2030. A zero-carbon-ready building is highly energy efficient. It uses renewable energy directly or an energy supply that will be fully decarbonised by 2050, such as electricity or district heat. These buildings will become zero-carbon buildings by 2050, without further adaptations. This radical change in building heating systems, which is part of the objective of achieving climate neutrality, is based on the following observations: reducing heating needs by insulating buildings is essential; heating networks will have an important role to play; and renewable heat sources such as aerothermal or geothermal heat pumps, or solar thermal and recovery must be favoured. Heat pumps are three to five times more efficient[107] than gas boilers, according to the International Energy Agency.

The European Commission's ambition[108], indicated in its REPowerEU plan of May 2022, is a complete ban on the sale of standalone fossil fuel boilers in 2029 via a revision of the Ecodesign regulation. This is in line with the recommendations of the IEA, which proposed a worldwide ban on new fossil boilers from 2025 in its report Net Zero by 2050[109], published in May 2021.

To share your comments with the authors or for additional information, email heatpumpadoptioneuhsbu@daikin.eu

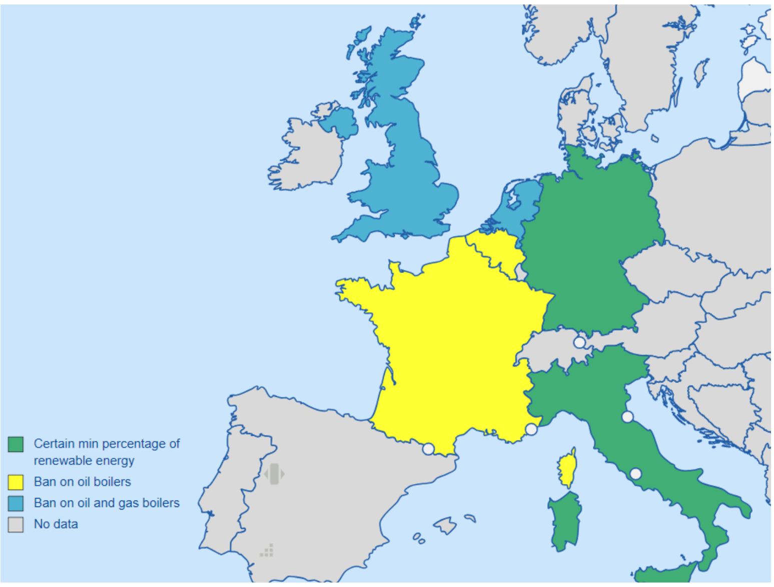

FIGURE 3.0.1 FOSSIL BAN SITUATION IN THE EUROPEAN COUNTRIES UNDER SCOPE. SOURCE: OWN

[106] IEA "Net Zero by 2050: A Roadmap for the Global Energy Sector"(2021)
[107] International Energy Agency "The Future of Heat Pumps" (2022)
[108] Communication from the Commission to the European Parliament, the Council, the European Economic and social Committee and the Committee of the Regions Eu 'save energy' 2018
[109] IEA "Net Zero by 2050: A Roadmap for the Global Energy Sector"(2021)

3.2 Germany

Germany is the fourth-largest economy in the world and home to leading producers of heat pumps[110]. According to government figures, about 80 % of heating in Germany's buildings is currently generated by fossil fuels. Nearly half of the country's households have gas heating, while about 25 % use oil-powered systems[111].

On the 8th of September 2023, the German Bundestag approved the revision of the German Buildings Energy Act (Gebäudeenergiegesetz, GEG), introducing a minimum share of 65% renewable energies for heating in buildings.

For the 65% provision to apply municipalities must publish a heating plan, showcasing the available options for renewable energy supply, before 2026 or 2028, depending on the number of inhabitants (see table below):

TABLE 1 SOURCE: DAIKIN ANALYSIS

Legend	Size of municipality	Final deadline	Population	% of the total population
1	above 100,000 inhabitants	**June 30, 2026**	26.576.802	32%
2	between 10,000 and 100,000 inhabitants	**June 30, 2028**	35.470.062	43%
3	below 10,000	**June 30, 2028**	21.190.260	25%

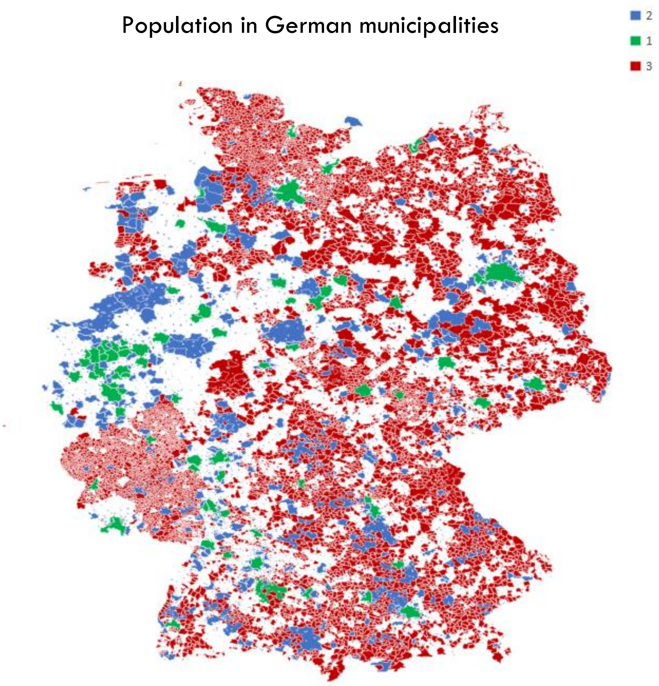

FIGURE 3.2 SOURCE: DAIKIN ANALYSIS

The gas/oil boiler ban has been postponed to 2028 (it was initially foreseen for 2024), as the installation of fully fossil fuel boilers will still be allowed until the heating plans are not in place. Boilers may be operated with fossil fuels until the end of 31 December 2044 at the latest.

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110 Bundesregierung.de "Climate-friendly heating: new Building Energy Act to be implemented"(2023)
111 Wohnsituation privater Haushalte - Fachserie 15 Sonderheft 1 - 2018 (destatis.de)

For new buildings in New Development Areas, the 65% renewable energy heating constraint is valid from 2024.

After the deadlines in 2026 or 2028, new gas heating systems may only be installed, if they can be converted to process 100% hydrogen. In addition, the building must be located in a network area that is to be converted to hydrogen in accordance with a heating plan and released by the Federal Network Agency

New oil heating systems may only be installed if they run on bio-oil, or they are combined with a heat pump as a hybrid system.

After the deadlines in 2026 or 2028, gas boilers can in principle continue to be installed if they are operated with 65 % green gases (biomethane, or green or blue hydrogen).

Replacement market:

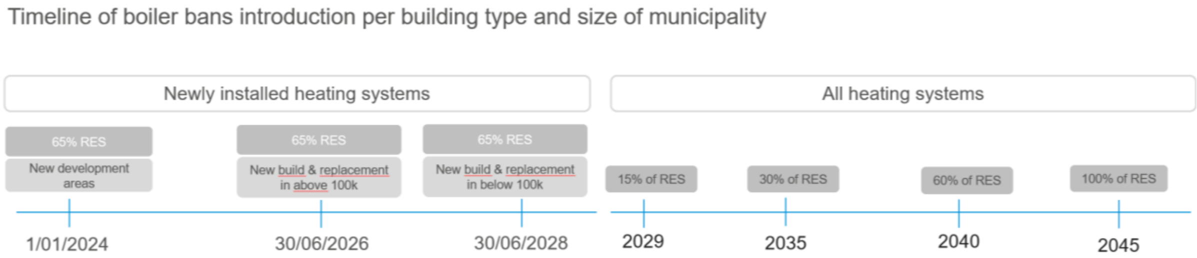

FIGURE 3.4 SOURCE: DAIKIN ANALYSIS

Until 2028 (municipalities > 100k habitants)/2026 (municipalities < 100k habitants), gas boilers can be replaced with 100% oil/natural gas boilers. After 2028 (/2026), the new heating system must be powered by 65% renewable sourced energy (RES).

From 2029 onwards, heating systems must use an increasing percentage of RES (see image above).

New built market:

From the 1st January 2024, heating systems installed must be powered by 65% RES. The obligation applies to all new buildings for which the building application is submitted from January 2024 in a new development area[112].

For new buildings outside of new development areas, the same rules as in the replacement market apply.

A transition period is foreseen in selected cases:

- A one-time installation of a fossil fuel-operated heating system, including potentially used ones, is allowed if a heating system complying with the 65% renewable energy requirement is planned to be installed within 5 years after the heating system's failure.
- If a connection to a district heating network is not yet feasible, the property owner must commit to connecting to the district heating network within 10 years after the heating system's failure (no later than December 31, 2034). In the meantime, they can use a heating system that does not meet the 65% renewable energy requirement.
- If a conversion to hydrogen is planned before December 31, 2034, the building owner may install a gas heating system capable of burning both gas and hydrogen. Starting from 2030, they are bound to source 50% green gases (biomass/hydrogen), and from 2035 it increase to 65%.
- For the conversion of individual room heating systems and room heating appliances, a decision period of 5 years after the failure of the first individual room heating system in a building is granted to allow for the planning of centralization of the heating system. If the centralization of the heating system is chosen, property owners are given an additional 8 years to implement this centralization.

Before Federal laws were introduced, four German states (Baden-Württemberg, Hessen, Niedersachsen and Schleswig-Holstein) implemented heat planning initiatives, mandating the most populated municipalities in the Land to publish heat plans (see table below). Lower Saxony extended the obligation to the whole Region.

112 A new development area is an area of a city or municipality where the development plan allows the construction of residential buildings .

FINAL DEADLINES (State & Federal law) Tab.1		
Land	**Municipalities**	**Population**
Baden-Württemberg	**1.101**	**11.124.642**
no obligation	841	3.400.206
31/12/2023	103	5.615.165
30/06/2028	157	2.109.271
Hessen	**422**	**6.295.017**
no obligation	253	1.368.731
30/06/2026	5	1.529.506
30/11/2026	54	1.874.593
30/06/2028	110	1.522.187
Niedersachsen (Lower Saxony)	**941**	**8.027.031**
no obligation	-	-
30/06/2026	8	1.564.697
31/12/2026	933	6.462.334
Schleswig-Holstein	**1.106**	**2.922.005**
no obligation	1.015	1.008.686
31/12/2024	34	1.324.056
31/12/2027	42	384.306
30/06/2028	15	204.957
Grand Total	3.570	28.368.695

FIGURE 3.5 SOURCE: DAIKIN ANALYSIS

Thanks to local initiatives, in 2026, 60% of the German population will be under the new heating law compared to 40% planned by the federal law.

3.3 Belgium

3.3.1 Flanders

To realise its energy and climate objectives, Flanders is committed to improving the energy efficiency of its building stock, increasing the share of renewable sources in the energy supply, and improving energy infrastructure[113]. A 2022 decree established a ban on oil boilers in new buildings and replacing existing oil boilers with new ones[114]. New connections to the gas network for large new building projects have been prohibited since 2021. From 2025, no new connections to the gas distribution network will be permitted. (Replacing a fuel oil boiler means replacing the entire installation, and not replacing individual parts of an existing heating installation, such as the burner.)

3.3.2 Brussels

In Brussels, there are bans on coal and oil heating installations, from September 2021 and June 2025 respectively[115]. From 2025, new buildings will not be permitted to use fossil fuel heating. From 2030, this will also apply to buildings undergoing major renovations.

3.3.3 Wallonia

There is currently no such ban foreseen in Wallonia.

113 Voorstel van decreet tot wijziging van artikel 4.1.16/2 van het Energiedecreet van 8 mei 2009
114 Belgische Federatie der Brandstoffenhandelaars vzw and Others and Lamine v. Flemish Government - Climate Change Litigation (climatecasechart.com)
115 Brussels brings together air, climate and energy in an integrated vision: COBRACE and the PACE regional plan | Citizen - Brussels Environment (environnement.brussels)

3.4 France

In France, heat production accounts for half of energy consumption and is still largely based on fossil fuels[116]. France is highly dependent on fossil gas, which, in addition to being bad for the planet, is expensive. Due to a lack of major deposits, France, even if it is learning to do without Russian gas, imports 98 % of its gas needs[117]. The objective is to replace 1 million individual oil-fired boilers by the end of 2023 and 3 million in 2028[118]. Installation of new oil-fired boilers has been banned[119] since July 2022. There is an ongoing consultation[120] on the ban of gas boilers that will be finalised by the end of July 2023. If it comes into effect, from January 2024 it will only be possible to install full electric heat pumps or hybrid heat pumps in new buildings. The consultation expects an end to the use of fuel oil boilers by 2030[121].

The initial ban on oil boilers was a result of Decree No. 2022-8 of 5 January 2022, relating to the minimum environmental performance from the installation of heating or domestic hot water systems in a building. The decree sets a CO_2 threshold of 300 g CO_2/kWh for the installation of new heating systems, which prohibits the installation of new oil-fired boilers since 1 July 2022.

Despite a first consultation suggesting lowering the threshold to 150 g CO_2/kWh, and therefore prohibiting the installation of new boilers using natural gas and LPG, the French Government has decided not to permanently ban the gas boilers for the time being[122].

3.5 United Kingdom

The UK government plans to implement a new initiative known as the Future Homes and Building Standard (FHS), which aims to guarantee that newly constructed residences have energy-efficient heating systems and are prepared for future sustainability. As part of a roadmap leading to the FHS, various measures will be implemented to minimise energy consumption and decrease greenhouse gas emissions in new buildings.

In September 2023, the Government pushed back the end date for new and replacement fossil fuel heating installations in existing properties in England to 2035 including an exemption for off-gas grid properties with no suitable low-carbon heating solution.

Despite this setback, however, the new legislation maintains that new homes will not be built with fossil fuel heating, such as a natural gas boiler. Considering the low penetration of district heating (heat networks currently meet approximately 2% of heat demand in the UK[123]), it is expected that heat pumps' uptake will increase in new homes under the FHS.

The introduction of the FHS will ensure that from 2025, an average home will produce at least 75 % lower CO_2 emissions than one built to current energy efficiency requirements. The legislation will considerably improve the energy efficiency standards for new homes in the long run. In fact, homes built under the Future Homes Standard will be zero-carbon ready:

- From 2025, new homes built to the Future Homes Standard will have carbon dioxide emissions at least 75% lower than those built to current Building Regulations standards.
- Introducing the Future Homes Standard will ensure that the homes are more environmentally friendly and affordable for consumers to heat, with low carbon heating and very high fabric standards.
- All homes will be 'zero carbon ready', becoming zero carbon homes over time as the electricity grid decarbonises, without the need for further costly retrofitting work.[124]

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[116] International Energy Agency (IEA) "France 2021 Energy Policy Review" (2021)
[117] Commission de Régulation de l'Énergie – Natural gas network
[118] Ministére de la transition écologique et solidaire "Stratégie francaise pour l'énergie et le climat - Programmation pluriannuelle de l'énergie 2019-2023; 2024-2028" (2019)
[119] Premiére Ministre; Secrétariat general á la planification écologique "La planification écologique dans les bâtiments – 12 jiun 2023 – Réunion de travail sur la renovation énergétique
[120] Gouvernement Francaise – Décarbonation des Bâtiments Ce qui va changer en 2024
[121] Gouvernement Francais - Dossier de concertation "Accélérer la decarbonation du secteur du bâtiment" (2023)
[122] 8 p.m.: interview with President Emmanuel Macron on TF1 and France 2 (24th sept 2023)
[123] Department for Business, Energy and Industrial Strategy "Opportunity areas for district heating networks in the UK - National Comprehensive Assessment of the potential for efficient heating and cooling"(2023) pg 6
[124] Ministry of Housing, Communities and Local government: "The Future Homes Standard: 2019 Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings"

The proposed notional building specification for FHS states low carbon heating as a heating appliance (see image below), which can be easily complied with using a heat pump.

Table 2 - Fabric and services comparison with the 2021 Part L and draft Future Homes Standard specification

	Proposed 'zero carbon homes' standard[1]	Current 2013 Part L standard	2021 Part L Standard	Indicative FHS specification
Floor U-value (W/m^2.K)	0.13	0.13	0.13	0.11
External wall U-value (W/m^2.K)	0.18	0.18	0.18	0.15
Roof U-value (W/m^2.K)	0.13	0.13	0.11	0.11
Window U-value (W/m^2.K)	1.4	1.4	1.2	0.8
Door U-value (W/m^2.K)	1.0	1.0 - opaque 1.2 – semi-glazed	1.0	1.0
Air permeability at 50 Pa	5.0 m^3/(h.m^2)	5.0 m^3/(h.m^2)	5.0 m^3/(h.m^2)	5.0 m^3/(h.m^2)
Heating appliance	Gas boiler	Gas boiler	Gas boiler	Low-carbon heating (e.g. Heat pump)
Heat Emitter type	Regular radiators	Regular radiators	Low temperature heating	Low temperature heating
Ventilation System type	Natural (with extract fans)	Natural (with extract fans)	Natural (with extract fans)	Natural (with extract fans)
PV	30% ground floor area	No	40% ground floor area	None
Wastewater heat recovery	No	No	Yes	No
y value (W/m^2.K)	0.05	0.05	0.05	0.05

Notes:
1. This table reflects the zero carbon homes specification that was proposed under a previous Government.

Figure 03.6 Source: Ministry of Housing, Communities and Local government: "The Future Homes Standard: 2019 Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings" pg 18

Table 3 - On-site carbon targets for a typical semi-detached home[1]

	Current 2013 Part L standards	Proposed 'zero carbon homes' standard[2]	2021 Part L	Indicative FHS specification
Carbon (kgCO$_2$/m^2/yr)	16.0	13.5	11.0	3.6

Notes:
1. All figures use the same 10.1 version of SAP software and carbon factors as the Part L 2021 uplift for accurate comparison.
2. This table reflects the zero carbon homes specification that was proposed under a previous Government. This standard was set at 11.0 using carbon factors and SAP software at the time.

Figure 3.7 Source: Ministry of Housing, Communities and Local government: "The Future Homes Standard: 2019 Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings" pg 18

The introduction of a primary energy matrix as one of the pass criteria to meet the building regulation part L makes the case for heat pumps stronger for the new build market under FHS. The reason is that heat pumps provide around three times the amount of heat compared to the electricity used thus significantly reducing the primary energy demand, e.g., the fuel that goes into the power station to generate the electricity used in a home. This represents an incentive for contractors to use heat pumps as heating technology to meet the primary energy pass criteria under FHS.

As mentioned earlier, the Government has set the deadline for the fossil fuel heating ban in England in 2035, although an exemption is foreseen for off-gas grid properties where there is no suitable low-carbon heating solution.

In Scotland, the government has proposed a ban on gas boilers in all new buildings from April 2024. If passed into law, it will apply to both residential and business properties.

3.6 Netherlands

The Dutch government has presented a package of climate measures which includes the ban of new installations of fossil fuel-based heating systems starting from 2026 and mandated the use of (hybrid) heat pumps or connections to heat networks, known as district heating. The government maintains hybrid heat pumps can achieve an average of 60 % savings on natural gas consumption, as they run on electricity for most of the year[125]. Fully electric heat pumps will be specified for well-insulated homes, using no natural gas.

According to new proposals, when households replace their central heating systems, they will have to switch to a more sustainable alternative. Hybrid heat pumps will become the standard choice; however, fully electric heat pumps or a connection to a heat network will also be possible.

This change in the "Decree on construction works in the living environment" (Building Decree) is expected to enter into effect on 1 January 2026.

There are a few exceptions[126]: There will be an exception for situations where the standard cannot be properly applied, for example, because of noise requirements or necessary adjustments to the home, where the heating system leads to disproportionate costs, or if a collective district solution (such as a heat network) will be realised within 10 years. Due to complex permit processes, protected buildings are exempted in advance for the time being. The same applies to apartments because of points of attention in terms of noise and spatial integration.

Please note: The effective date of this measure is not yet final. Entry into force is subject to its passing through the upper and lower houses of the Parliament.

3.7 Italy

On 13 June 2022, the obligations listed in Annex 3 of Legislative Decree 199/2021[127] were triggered and the share of 60 % renewable energies became mandatory in new buildings. The first renewable legislative decree was approved in 2011 with a 20 % obligation and then updated three times to the last decree. The obligations apply to new buildings, existing buildings when net useful volume is increased more than 15% and those undergoing major renovation. Buildings undergoing a major renovation are primarily existing buildings that have a useful area of more than 1,000 square metres and are subject to complete renovation; or are subject to demolition and reconstruction.

The minimum renewable quota is 60 % for domestic hot water production, and 60 % for heating, domestic hot water and cooling combined.

Since, according to technical legislation, the energy produced by renewables is a negative addendum in the sum of the total amount of primary energy consumption of the building, the obligation (60 %) cannot be fully satisfied exclusively through a renewable electricity production system, it means not only through PV for example. Therefore, the energy produced by PV is deducted from the energy consumption of the household and does not contribute to the percentage of renewable consumption.

It also means that the client is obligated to install also a thermal renewable energy system, I. e heat pump, thermal solar system, biomass, etc.

For public buildings, the total amount rises from 60 % to 65 %.

Exception here are the buildings connected to a district heating system, offices, and commercial buildings in general.

Even if some associations and politicians talked about gas boiler ban or at least incentive ban, nowadays there is not still a law or law proposal about gas boiler.

[125] Government of the Netherlands - News "Netherlands to phase out public funding for new fossil fuel exports"(2021)
[126] Heat pumps mandatory to replace boiler | Business.gov.nl
[127] DECRETO LEGISLATIVO 8 novembre 2021, n. 199 Attuazione della direttiva (UE) 2018/2001 del Parlamento europeo e del Consiglio, dell'11 dicembre 2018, sulla promozione dell'uso dell'energia da fonti rinnovabili. (21G00214)

3.8 Conclusions

Across Europe, the movement towards phasing out fossil fuel heating is gaining momentum. Several countries are taking proactive steps by either implementing their initial bans on fossil fuel usage for heating or accelerating the enforcement dates of previously established bans. This exciting shift highlights the increasing relevance of heat pumps as the leading, future-proof heating solution for residential purposes.

To share your comments with the authors or for additional information, email heatpumpadoptioneuhsbu@daikin.eu

Section 4: Incentive schemes

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Product Management Officer

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“European governments' incentives are paving the way to a more sustainable future through heat pumps. This dedicated section is designed to empower you to leverage local incentives and acquire a heat pump under favourable terms.”

4.1 Intro

Heat pumps may require a larger initial investment than traditional heating systems. However, householders may be eligible for one or more premiums, which can make investing in a heat pump an attractive alternative.

Gas has been the primary source of heating for homes and businesses in Europe for more than a century. However, in a concerted effort to combat climate change, many governments have decided to phase out gas and oil boilers and are encouraging the adoption of low carbon solutions such as heat pumps.

Heat pumps create free environmental heat from the air, soil or water that can be used for heating properties, using an electrical process that does not emit any pollutants on site. This is one reason why states are awarding an attractive subsidy for the heat pump.

Convincing homeowners to switch to heat pumps has so far proved to be a significant challenge. However, with rising gas prices becoming a concern across Europe and subsidies now available in most countries, there is a growing enthusiasm and recognition that heat pumps are a viable option.

While air-to-air heat pumps can be cost-effective compared to gas boilers in certain markets, subsidies play a crucial role in enhancing the competitiveness of air-to-water and ground-source units. We can further accelerate the transition towards sustainable heating solutions by incentivising the adoption of these technologies.

4.2 Germany

With the Federal Funding for Efficient Buildings (BEG)[128], householders can receive support for the renovation of buildings that save energy in the long term and thus protect the climate. The BEG is available to renovators.

On September 8, 2023, the German Bundestag passed the amendment to the key points for the new funding for heating replacement. On this basis, the federal funding guidelines for efficient buildings (BEG) are now being revised and will come into force at the beginning of 2024.

Renovators receive a subsidy of 30 % via the BAFA subsidy for heat pumps. This can be increased by 5 % if they use water, soil or wastewater as a heat source or for HP with natural refrigerant. As the temperatures in the groundwater and in the ground are higher all year round, the heating system has to do less, leading to better efficiency, low power consumption and, ultimately, lower heating costs.

An income-related bonus of 30% is envisioned for owner-occupiers with taxable household income lower than € 40,000/year. BEG also grants a speed bonus for owner-occupiers of 20 until 2028 for the early replacement of old fossil heating systems (gas boilers older than 20 years, all other boilers independent from age). From 2029 the amount of the “speed bonus” is decreased to 17%. Every 2 years from 2029, the amount decreases by 3%.

The bonuses can be accumulated up to a maximum funding rate of 70-75%. The maximum eligible costs for heating system exchange is currently set at €30.000 (at a funding rate of 70%, which equals €21.000 subsidy for SFHs.

An alternative to the BEG is the tax bonus for renovation. Starting from 2024, this is worth 30 % of the costs incurred for measures in a house that is at least 10 years old and used by the owner. Spread over three years, renovation costs of up to €40,000 can be deducted from the owner’s income tax.

[128] Förderprogramm im Überblick - Bundesamt für Wirtschaft und Ausfuhrkontrolle (2023)

4.2.1 Minimum technical requirements for the subsidy of a heat pump

To apply for a subsidy, minimum technical requirements must be met, including separate electricity and heat meters. The following other requirements apply:

- Individual testing according to EN 14511/EN 14825 or certification based on the established European series regulations (EHPA, Keymark, EUROVENT ECP, MCS, NF, etc.) by an ISO 17025 accredited testing institute. Most Daikin Altherma heat pumps are Keymark certified.
- Seasonal space heating efficiency (ηs or ETAs) for water heating systems as follows:

Min seasonal space heating energy efficiency		Eta % @35°C	Eta % @55°C
From 1 January 2024	Air-source heat pump	145	125
	Geothermal and water-source	180	140

- Achieve an annual performance factor of at least 3.
- SG-Ready heat pump heaters for grid-supportive operation: Eligible heat pumps must have interfaces that allow them to be automated. They must be activated and operated in a grid-friendly manner (e.g. on the basis of the standards SG Ready or VHP Ready).
- Reduction of the limit values for noise emissions of the outdoor unit of air-to-water heat pumps by 5 dB lower than the legal limit.

Consult the BAFA list of suitable heat pumps here: Infoblatt zu den förderfähigen Maßnahmen und Leistungen (gültig ab 20.06.2023).

4.2.2 Other eligible costs for subsidies

Homeowners who apply for a subsidy for their heat pump not only receive financial support for heating. The costs of numerous environmental measures can also be subsidised. This includes work on the technical room as well as optimisation measures on the existing heating system. For example, hydraulic balancing, insulation of pipelines or installing new radiators and floor surfaces. BAFA provides an overview in the information sheet[129] on the eligible measures and services.

If homeowners do not comply with the minimum technical requirements for the complete subsidy, the tax bonus for services is an alternative. This allows them to claim 20 % of the wage costs incurred for craftsmen for tax purposes every year. A maximum of €6,000 can be credited, with a maximum funding amount of €1,200. This must be used for refurbishment, renovation or maintenance work in an owner-occupied property. The application is made retrospectively via income tax return. Invoices with reported wage costs and transfer receipts must be submitted.

4.2.3 New buildings

If homeowners choose a heat pump heating system for a new build, they are eligible for financial support from the Kreditanstalt für Wiederaufbau (KfW) through BEG funding. This provides access to low-interest loans with a repayment subsidy of 5 %. This reduces the total loan amount that needs to be repaid on building a structure that adheres to the Efficiency House Standard 40 and has a sustainability certificate. More information can be found on the KfW website.

4.3 Belgium

4.3.1 Federal

The Federal Council of Ministers has approved a Royal Decree[130] that reduces VAT to 6 % for the installation of solar panels, heat pumps and solar water heaters. The reductions[131] apply from 1 April 2022 to 31 December

129 Bundesförderung für effiziente Gebäude - Infoblatt zu den förderfähigen Maßnahmen und Leistungen
130 Afbraak en wederopbouw - Nieuwe maatregel (programma wet bs 30.12.2020) - Federale Overheidsdienst Financiën
131 A federal crisis plan to combat soaring energy prices – Belgium Official information and services

2023 for homes less than 10 years old, including newly built homes and homes rebuilt after demolition. This VAT reduction does not apply to the purchase of newly constructed homes, including those with heat pump systems, that are still in the planning or construction phase. After 31 December 2023, the reduction will still apply for heat pump installation (until end of 2024) and to homes over 10 years old. For heat pumps, this measure has been extended to 31 December 2024 inclusive[132]. This extension does not apply to solar panels or solar water heaters.

4.3.2 Flanders

The My Renovation Premium[133] applies to houses, flats and all other buildings in the Flemish region. This subsidy covers the installation of all types of heat pumps: geothermal, air-to-air, air-to-water and hybrid air-to-water. The building should be connected to the electricity distribution network before 2014. The building can be connected to the electricity distribution network after 2014 if the environmental permit for urban planning acts more than 5 years before the date of the final invoice meeting the EPB requirements. In this case, the EPB declaration, a report describing how a construction project is carried out in terms of energy performance and indoor climate, must be submitted in a timely manner. A building that is demolished and completely rebuilt is not eligible, but the Federal VAT reduction can be applied in such cases.

In July 2023, the Flemish Government decided to discontinue the premium for a gas condensing boiler for final invoices from 1 November 2023. The decision is also in line with the Flemish Energy and Climate Plan (VEKP) 2021-2030, which the Flemish government approved earlier in May.

Conditions

- The heat pump is responsible for space heating, possibly with the production of domestic hot water.
- The applicant has not received a premium for a heat pump in the past 10 years.
- The installation or validation of the installation of the heat pump must be carried out by an official installer:
  - The list of certified installers can be consulted here: ResCert Gecertificeerde installateurs – Warmtepompen.
- The total invoice amount of the eligible heat pump category is at least €1,000.
- The heat pump is placed as a replacement and not in a new build residence.
- The heat pump is to be the sole source of heat in the building.

Minimum technical requirements for the subsidy of a heat pump

- The heat output temperature of the system is up to 55°C.
- An air-to-water heat pump should have a European product label of A+ or higher for heating.
- An air-to-air heat pump should have a European product label of A+ or higher for heating.
- A hybrid air-to-water heat pump should have a package label with a minimum seasonal energy efficiency (Ns) of 110 % for the combination.
- A geothermal heat pump should have a European product label of A++ or higher.

Note: Energy efficiency in heat pumps in homes and apartments granted under Commission Delegated Regulation (EU) No 811/2013 of 18 February 2013 supplementing Directive 2010/30/EU of the European Parliament and of the Council as regards energy labelling of space heaters, combination heaters, packages of space heaters, temperature controllers and solar installations and packages of combination heaters, temperature controllers and solar installations; or Commission Delegated Regulation (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of air conditioners.

Amount of the grant

The amount of the premium depends on depends on the type of heat pumps, final invoice date and household income category[134]. Categorisation for income can be found at Mijn VerbouwPremie website - Vlaamseoverheid.

Lower income category

[Table 1]

[132] Réduction temporaire de la tva : panneaux solaires, chauffe-eaux solaires et pompes à chaleur – Service Public Féderal webstite
[133] My Renovation Premium for heat pump – Vlaanderen.
[134] Who can apply for My Renovation Premium? | Vlaanderen.be

Type of heat pump	Final invoice date	Basic premium	Premium for heat pumps replacing electric heating
Geothermal	-	€6,400	€9,600
Air-to-air	-	€480	€720
Air-to-water	Until 31-12-2023	€4,800	€7,200
Air-to-water	From 01-01-2024	€3,600	€5,400
Hybrid air-to-water	Until 31-12-2023	€3,200	€4,800*
Hybrid air-to-water	From 01-01-2024	€2,400	€3,600*

*These amounts only apply to a hybrid air-to-water heat pump that replaces electric heating and not to hybrid air-to-water heat pumps that are installed in an area without a natural gas connection.

Notes:

- The premium is a maximum of 50 % of the invoice amount (excluding VAT).
- The increased premium for the replacement of electric heating or installation in an area without natural gas applies to premium applications submitted up to 31 December 2025.
- For Air to Water Heat Pumps , PV panels are mandatory.

Middle income category and higher

[Table 2]

Type of heat pump	Final invoice date	Basic premium	Premium for heat pumps replacing electric heating
Geothermal	-	€4,000	€8,000
Air-to-air	-	€300	€600
Air-to-water	Until 31-12-2023	€3,000	€6,000
Air-to-water	From 01-01-2024	€2,250	€4,500
Hybrid air-to-water	Until 31-12-2023	€2,000	€4,000*
Hybrid air-to-water	From 01-01-2024	€1,500	€3,000*

*These amounts only apply to a hybrid air-to-water heat pump that replaces electric heating and not to hybrid air-to-water heat pumps that are installed in an area without a natural gas connection.

Notes:

- The premium is a maximum of 40 % of the invoice amount (excluding VAT).
- The increased premium for the replacement of electric heating or installation in an area without natural gas applies to premium applications submitted up to 31 December 2025.
- For Air to Water Heat Pumps , PV panels are mandatory.

Applications for the premium can be submitted via the https://loket.mijnverbouwpremie.be/ (identification through eID necessary)[135].

Example[136]:

For a household where the residence is older than 15 years; it is used as the main residence by the owner; and the household consists of a couple with two dependants, where the joint annual income is €60,000, a premium of **€3,600** is available from the My Renovation Premium for an air-to-water heat pump, and **€2,400** for a hybrid heat pump.

[135] Mijn verbouwpremie - Vlaanderen
[136] Simulator premie-aanvragen 2023 – Vlaams Energie & Klimaatagentschap

4.2.3 Brussels

The government has amended the Decree of the Government of the Brussels-Capital Region of 9 February 2012 on the granting of financial support in the field of energy, published on 31 March 2023. The premium is accessible to both private individuals and businesses, regardless of their status. It applies to building renovations within the Brussels-Capital region, as long as the buildings were constructed at least 10 years prior to submitting the premium application. The premium covers activities such as the installation or replacement of a heat pump designed for heating purposes or for both heating and domestic hot water. The installation of a hybrid heat pump, which combines a heat pump and a gas-condensing boiler in a single appliance, is also eligible for the premium.

Conditions

- For the same address, any application below the minimum amount of €250 in RENOLUTION premiums will be refused.
- The residential heat pumps should have an energy efficiency of A+.
- The amount of the premium may cover up to 90 % of the invoiced amount of the eligible work. The maximum amount for single-family homes is €50,000.

Amount of the grant

The premium amount for the heat pump heating varies based on the type of building. In the case of residential buildings, the amount is determined by income, which is categorised into three groups: category I (standard category), category II (average incomes) and category III (low incomes). Furthermore, the premium is calculated per individual residential unit, which includes both single-family houses and apartments within apartment buildings. The categorisation for and the additional supporting documents necessary depending on the income category are available for consultation on the Brussels official website – Les Catégories de Revenus 2023.

Income category	Air-to-water heat pump	Water-source or ground-source heat pump
Category I	€4,500	€5,800
Category II	€4,750	€6,150
Category III	€5,000	€6,500

Minimum technical requirements for the subsidy of a heat pump

Heat pumps with a rated output of less than 70 kW are required to have a minimum energy efficiency class of A+ to be eligible for the incentive.

Other bonuses

The Multi-Works Bonus is awarded if homeowners combine the application for this heat pump heating premium with at least two other premiums via the same form. The amount of the premiums will then be increased by 10 % for category I and II applicants and by 20 % for category III applicants. Premiums that are eligible for this bonus are: thermal façade insulation, installation and replacement of doors and windows, repair and adjustment of windows, repair of doors, thermal floor insulation and heating with heat pump.

The Oil and Coal Exit Bonus is granted in the event that an old oil boiler or a stove fuelled by oil or coal is eliminated. This bonus is only available to households for heating installations in homes. The amount of the premium is then increased by €300/oil boiler or €600/oil or coal stove for applicants in category I, by €350/oil boiler or €700/oil or coal stove for applicants in category II, and €500/oil boiler or €1000/oil or coal stove for applicants in category III.

4.2.4 Wallonia

To benefit from the premiums in Wallonia[137], the final invoice for work must be dated between 1 February 2022 and 30 June 2023 and must be submitted within four months of the invoice until the end of the programme (31 December 2025).

[137] Prime temporaire - Appareil de chauffage et d'eau chaude sanitaire (jusqu'au 30 juin 2023) – Wallonie énergie SPW

Depending on the installation work to be done and the income category of the household, the maximum amount that can be collected is as follows. See the income categorisation table on the official Wallonia website Prime temporaire - Appareil de chauffage et d'eau chaude sanitaire (jusqu'au 30 juin 2023):

Work conducted	Basic amount	Max amount
Heat pump for domestic hot water	€500	€3,000
Heat pump for heating or combined	€1,000	€6,000

The installation of a heat pump is also eligible for incentives under the Primes Habitation 2023 (from July 1, 2023)[138] for renovation works (external audit necessary):

Work conducted	Basic amount	Max amount
Heat pump for domestic hot water	€700	€4,200
Heat pump for heating or combined	€1,500	€ 9,000

Finally, the installation of a heat pump is also eligible for incentives under the Primes Toiture et petits travaux sans audit[139] for light renovation works (no audit needed).

Work conducted	Basic amount	Max amount
Heat pump for domestic hot water	€500	€700

4.3 The United Kingdom

4.3.1 UK and Wales

To reach the net zero carbon emissions target set by the UK government, the carbon emission from heating houses needs to be reduced by 95 % over the next 30 years[140]. To accelerate the transition, the UK has a grant scheme for the replacement of fossil fuel heaters. This will allow homeowners to have a more energy-efficient heating system, save money on fuel bills and reduce carbon emissions.

The Boiler Upgrade Scheme provides a grant to cover part of the cost of replacing fossil fuel heating systems with a heat pump or biomass boiler. Fossil fuel heating systems include oil, gas and electric. This scheme is open to people living in England and Wales.

4.3.1.1 Eligibility

The eligibility depends on the conditions of the property and the situation of the owner. The applicant must:

- own the property the application is for, be it a business, second home or property rented to tenants;
- have installed, or plan to install, the new heating system on or after 1 April 2022;
- be replacing fossil fuel heating systems such as oil, gas or electric;
- have a valid EPC with no outstanding recommendations for loft or cavity wall insulation. The EPC for a property in England, Wales or Northern Ireland can be found via Find an energy certificate – Gov.Uk website.

This premium applies only to renovation projects. New build properties that the developer is still building are not eligible. However, if an owner moves into a finished new build with a fossil fuel boiler, they may be able to get a grant for a heat pump under the scheme. Applicants are still eligible for the grant if they have previously had funding to make a property more energy efficient, such as by insulating it.

4.3.1.2 Amount of the grant

The first step is to contact an MCS certified installer for a quote. Installers can be found via the MCS – Find a contractor website. The installer will assess the eligibility of the planned renovation. Once a quite is agreed, the installer will apply on the homeowner's behalf and the value of the grant will be deducted from the amount paid for the installation.

[138] Wallonie énergie SPW "Primes Habitation 2023 (à partir du 1er juillet 2023)"
[139] Wallonie énegie SPW "Primes Toiture et petits travaux sans audit"
[140] Energy Saving Trust 2023

Note: The authorities will contact you to confirm that the installer is acting on your behalf. They might also contact you by phone or visit your property in order to check the installation. MCS might contact you to carry out their own checks

4.3.1.3 How to apply

The first step is to contact an MCS certified installer for a quote. Installers can be found via the MCS – Find a contractor website. The installer will assess the eligibility of the planned renovation. Once a quite is agreed, the installer will apply on the homeowner's behalf and the value of the grant will be deducted from the amount paid for the installation.

Note: The authorities will contact you to confirm that the installer is acting on your behalf. They might also contact you by phone or visit your property in order to check the installation. MCS might contact you to carry out their own checks.

4.3.2 Scotland

The Home Energy Scotland Grant and Loan provides funding for energy efficiency improvements and heat pumps in Scotland. It aims to support homeowners to make improvements and transition to renewable energy systems.

4.3.2.1 Amount of the grant

Grant funding for energy efficiency improvements can cover up to 75 % of the combined cost of improvements, with a maximum grant amount of £7,500, or £9,000 for homes qualifying for the rural uplift. Grant funding for heat pumps is up to £7,500, or £9,000 for eligible rural homes. The remaining funding can be taken as an interest-free loan.

The grant is subject to availability and allocated on a first-come, first-served basis until funds run out or the end of the financial year, whichever comes first.

4.3.2.2 Eligibility

To be eligible, applicants must be homeowners living in the property they own.

The grant covers interventions for:

- energy efficiency improvements: i.e. insulation (walls, doors, roof etc), electric heating, glazing;
- secondary improvements: e.g. cylinder thermostats, hot water jackets. These interventions need to be combined with energy-efficiency improvements or renewable systems;
- installation of renewable systems: e.g. heat pumps, solar PV panels, energy storage systems (heat or electric batteries).

More information can be found at Home Energy Scotland Grant and Loan: in detail.

4.3.2.3 How to apply

Interested applicants should complete the Home Energy Check on the Home Energy Scotland website before contacting Home Energy Scotland. The contact form can be found on the Home Energy Scotland website.

4.3.3 Additional possible support

The Energy Company Obligation (ECO)[141] is a requirement for energy suppliers to help low-income households reduce the costs of heating their home by fitting energy-saving measures. Different energy suppliers have different amounts of support and offer different types of improvements. The Find your local council -Gov.UK website has more information.

In England, the Social Housing Decarbonation Fund (SHDF)[142] supports the government's commitment to invest in the energy performance of homes. The programme seeks to raise the energy performance of as many as possible of the 1.4 million social homes below EPC band C to that to that level, as part of the journey for the social housing stock towards Net Zero 2050. Interested owners can apply through the SHDF Wave 2.1 website.

The Home Upgrade Grant (HUG)[143] provides energy efficiency upgrades and low carbon heating via local authority funding to low income households in England that are off the gas grid and have an EPC between D and

141 Energy Company Obligation (ECO) – Ofgem.gov.uk
142 Notice: Apply for the Social Housing Decarbonisation Fund: Wave 2.1 (closed to applications)
143 Home Upgrade Grant: successful local authorities – Gov.uk

G. The participating local authority areas are listed on the Find your local council webtool. The Home Upgrade Grant (HUG 2) will be delivered from April 2023 until March 2025.

4.4 France

MaPrimeRénov[144] is a premium available to all owners and all housing condominiums built at least 15 years ago. It concerns dwellings occupied as a main residence, by the owner or by a tenant, and is used to help finance renovation work to improve energy performance. It aims to encourage individuals to improve the energy efficiency of their homes, reduce greenhouse gas emissions and contribute to the country's climate goals.

The programme provides financial assistance in the form of grants to homeowners who undertake eligible energy renovation works. These works can include insulation installation, heating system upgrades, ventilation improvements and the installation of renewable energy systems like solar panels. The amount of aid depends on factors such as the nature of the work, the homeowner's income and the energy saving potential.

The programme was introduced in 2020 and has been expanded. It is open to a range of homeowners, including individuals, landlords and condominium associations, with different criteria and funding amounts depending on the applicant's situation. A recent change to the conditions is that, since 1 January 2023, it is no longer possible to benefit from MaPrimeRénov for the installation of a gas boiler, even with very high energy performance. The work also benefits from a reduced VAT rate[145] of 5.5 %.

As part of the 2024 finance bill, the French Government added 1.6 billion euros to the energy renovation budget, bringing the total budget devoted to housing energy efficiency to 5 billion euros[146].

These additional resources will make it possible to increase aid for the installation of air/water and geothermal heat pumps, from €1,000 to €2,000 for households with modest and middle incomes. The objective is to accelerate the replacement of boilers running on fossil fuels with carbon-free equipment.

To guide households in their renovation journey, the Government has changing the support system in place for end users:

- Households undertaking a large-scale renovation will be systematically supported by an independent trusted third party approved by the State, "My Renovation Supporter".
- This will provide valuable support in the technical, administrative and financial procedures enabling aid to be obtained and the work to be carried out. For very low-income households, this support service will be covered in full, with no additional charges.
- Households undertaking a large-scale renovation will only submit one application for assistance to the National Housing Agency (ANAH). This will provide additional aid under energy saving certificates (EEC) from January 2024.
- The MaPrimeRenov' aid will be offered only to households living in a house that is already well insulated. For this reason, an energy performance diagnosis (EPD) must be carried out at the start of the process, to direct households living in energy sieves towards the major renovation process, if necessary.

The network of 550 France Renov' advice spaces, co-financed by the State and local authorities, is expected to be strengthened to ensure the presence of a counter in each intercommunity by 2025.

4.4.1 Eligibility

- The eligibility and amount of assistance are determined based on the homeowner's income. The programme offers higher grants to households with lower incomes.
- The bonus is awarded without income conditions. However, income is taken into account to determine the amount of the premium to which a person is entitled and the work and/or service for which they are eligible.
- It is the reference taxable income that is taken into account. This is indicated on the tax notice for the year preceding the application for the bonus.

[144] Prime énergie "MaPrimeRénov'" - Vous êtes propriétaire occupant - Service PublicRepublique Francaise
[145] TVA à taux réduits : pour quels travaux ? | economie.gouv.fr
[146] French Government "MaPrimeRénov' 2024 : accélérons la rénovation énergétique"press kit

- The resource ceilings to be respected differ depending on whether an applicant lives in Île-de-France or another region. These ceilings are categorised into four profile colours (Blue, Yellow, Purple, Pink) according to levels of income. The greater a person's resources, the lower the amount of the premium.

Table - Resource ceilings outside Île-de-France

Number of people in the household (tax household)	MaPrimeRenov' Bleu (households with very modest resources)	MaPrimeRenov' Jaune (households with modest resources)	MaPrimeRenov' Violet (households with intermediate resources)	MaPrimeRenov' Rose (higher income households)
1	Up to €16,229	Up to €20,805	Up to €29,148	Over €29,148
2	Up to €23,734	Up to €30,427	Up to €42,848	Over €42,848
3	Up to €28,545	Up to €36,591	Up to €51,592	Over €51,592
4	Up to €33,346	Up to €42,748	Up to €60,336	Over €60,336
5	Up to €38,168	Up to €48,930	Up to €69,081	Over €69,081
Per additional person	+ €4,813	+ €6,165	+ €8,744	+ €8,744

FIGURE 4.1 SOURCE: ANIL

Table - Resource ceilings in Île-de-France

Number of people in the household (tax household)	MaPrimeRenov' Bleu (households with very modest resources)	MaPrimeRenov' Jaune (households with modest resources)	MaPrimeRenov' Violet (households with intermediate resources)	MaPrimeRenov' Rose (higher income households)
1	Up to €22,461	Up to €27,343	Up to €38,184	Over €38,184
2	Up to €32,967	Up to €40,130	Up to €56,130	Over €56,130
3	Up to €39,591	Up to €48,197	Up to €67,585	Over €67,585
4	Up to €46,226	Up to €56,277	Up to €79,041	Over €79,041
5	Up to 52886 €	Up to €64,380	Up to €90,496	Over €90,496
Per additional person	+ €6,650	+ €8,097	+ €11,455	+ €11,455

FIGURE 4.2 SOURCE: ANIL

Year of construction:

- The property must be at least 15 years old. This is reduced to a minimum of two years in the event of a request for a grant for the acquisition and installation of heating or domestic hot water supply equipment, replacing a boiler running on fuel oil.

Energy performance criteria:

- The home undergoing renovation must meet certain energy performance requirements after the works are completed.

4.4.2 Amount of the grant

The premiums available under MaPrimeRénov vary depending on the nature of the project and the homeowner's income. For air-to-water heat pumps, the amounts below are granted depending on income group.

	Income group			
	MaPrimeRenov' Bleu	MaPrimeRenov' Jaune	MaPrimeRenov' Violet	MaPrimeRenov' Rose
Premium amount	€4,000	€3,000	€2,000	N/A

For example, a childless couple with an annual income of € 41,000 can finance 37% of the installation cost of an air-to-water heat pump with MaPrimeRénov and the Energy Saving Certificates scheme (CEE)[147]. The rest of the cost can be covered by an eco-PTZ[148] (0% interest rate loan backed by the State) (see image below)

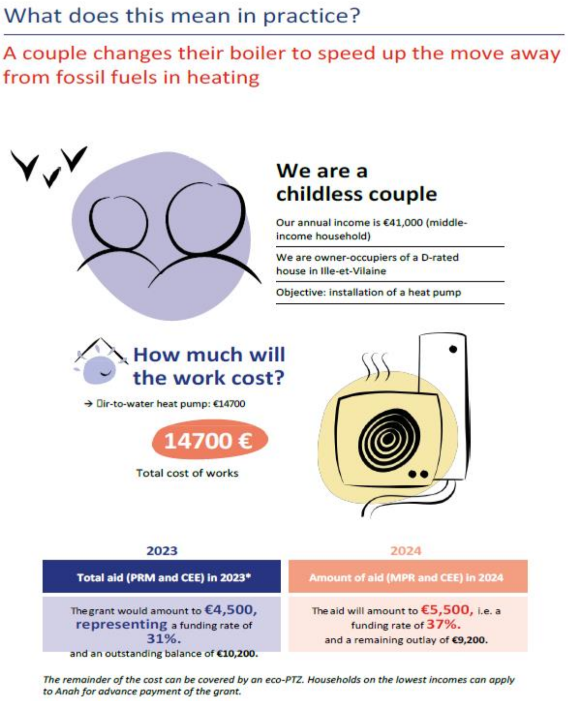

FIGURE 4.3 SOURCE: PRESS KIT "MAPRIMERÉNOV' 2024:ACCÉLÉRONS LA RÉNOVATION

To get precise information about the premiums available for specific projects and your eligibility, it is recommended to visit the official MaPrimeRénov website or consult with local partner organizations authorized to administer the program.

Note: Work and/or services must be carried out by a recognized professional responsible for the environment (RGE). Can consult the list here**:** Outil de recherche – Agence national de l'habitat (Anah) – Service Public

Premium amounts can vary based on the type and efficiency of the heat pump, as well as other factors such as regional variations and any additional conditions set by the programme. For precise information and accurate premium calculations based on specific projects and circumstances, refer to the official MaPrimeRénov website or consult with authorised local partner organisations administering the programme.

4.5 Poland

The Polish incentive for improving air quality and reducing greenhouse gas emissions by replacing heat sources and improving the energy efficiency of single-family residential buildings is called the Clean Air Program[149]. The

[147] Energy suppliers may offer financial support to individuals within the framework of the so-called energy savings certificates (EEC) to partially or fully finance their energy-saving work in their homes. Depending on the energy suppliers selected, the aid can come in the form of premium, purchase vouchers, reductions, etc. French Republic webpage "Certificats d'économie d'énergie (CEE) "Standard""

[148] French Republic "Éco-prêt à taux zéro (éco-PTZ)" webpage

[149] Program Czyste Powietrze – Ministerstwo Klimatu i Srodowiska

programme is targeted at owners of single-family houses. The financing is for thermal modernisation of buildings and replacement of old and inefficient heating equipment with a modern heat source.

4.5.1 Eligibility

The table below shows the maximum amount of grant per income category for a project involving the dismantling of an ineffective solid fuel heat source and the purchase and installation of an air-to-water heat pump or a ground-source heat pump for heating or heating and hot water.

The renovation may also include:

- disassembly, purchase and installation of a new central heating or hot water installation;
- purchase and installation of a PV micro-installation;
- purchase and installation of mechanical ventilation with heat recovery;
- purchase and installation of insulation of building partitions, windows, exterior doors, garage doors/gates (including disassembly).

4.5.2 Amount of the grant

The amount of the subsidy depends on the income category:

Level of co-financing	Basic level		Increased level		Highest level	
	With PV	Without PV	With PV	Without PV	With PV	Without PV
Amount of grant with comprehensive thermo-modernisation	PLN 66,000	PLN 60,000	PLN 99,000	PLN 90,000	PLN 135,000	PLN 120,000
Amount of grant without comprehensive thermo-modernisation	PLN 41,000	PLN 35,000	PLN 59,000	PLN 51,000	PLN 79,000	PLN 70,000

The categorisation of level of financing is as given below:

<u>Basic level:</u> Beneficiaries are owners/co-owners of single-family residential buildings or residential premises separated into single-family buildings with a separate land and mortgage register, with an annual income not exceeding PLN 135,000. In the case of obtaining income from various sources, the income is cumulative, but the sum may not exceed PLN 135,000.

<u>Increased level:</u> Beneficiaries are individuals who jointly meet the following conditions:

- They are the owners/co-owners of a single-family residential building or a residential unit separated into a single-family building with a separate land and mortgage register.
- The average monthly income per member of their household does not exceed:
  - PLN 1,894 in a multi-person household,
  - PLN 2,651 in a single-person household.

<u>Highest level:</u> Beneficiaries are individuals who jointly meet the following conditions:

- They are the owners/co-owners of a single-family residential building or a residential unit separated into a single-family building with a separate land and mortgage register.
- The average monthly income per member of their household does not exceed:
  - PLN 1,090 in a multi-person household,
  - PLN 1,526 in a one-person household,

Or, they have an established right to receive a permanent allowance, a periodic allowance, a family allowance or a special care allowance, confirmed in a certificate issued at the beneficiary's request by the commune head, mayor or president of the city, containing an indication of the type of allowance and the period for which it was granted (the allowance must be in each of the six calendar months preceding the month of submitting the application for a certificate and at least until the date of submitting the application for co-financing).

4.5.3 Additional support

Subsidies under the Clean Air Program can be combined with the thermo-modernisation tax relief[150]. In such a case, the benefits obtained by the beneficiary under both financial mechanisms are mutually complementary.

The subsidy and relief are independent instruments supporting thermo-modernisation projects. The catalogue of eligible costs in the Clean Air Program has been defined separately from the catalogue of costs deducted as part of the thermo-modernisation relief, on determining the list of types of building materials, equipment and services related to the implementation of thermo-modernisation projects

If obtaining benefits jointly from subsidies under the Clean Air Program and the thermo-modernisation relief:

- expenses financed or co-financed from subsidies or reimbursed to the taxpayer in any form from public funds are not deductible, but only the part that has not been co-financed;
- if, after earlier deductions of expenses under the thermo-modernisation relief, the beneficiary received a refund of the deducted expenses in the form of a subsidy, they are obliged, in accordance with tax regulations, to add the amounts previously deducted from the income for the tax year in which they received this refund.

4.6 The Netherlands

The Dutch government's Investeringssubsidie Duurzame Energie (Investment Subsidy for Sustainable Energy, ISDE)[151] is a financial incentive to promote the adoption of renewable energy technologies in owner-occupied homes.

The subsidy allows owners to:

- insulate their home;
- buy a solar water heater or a heat pump;
- buy an electric cooking appliance, for example, an induction hob;
- connect their house to a heating network.

For 2024, the ISDE budget was increased to €600 million, due to the large number of applications received during the previous year[152]. Nearly 180,000 applications for heat pumps have been submitted until September 2023, for a total of €333 million. In 2022, the total number of applications for the entire year was 100,000 (2022 budget: €325 million).

4.6.1 Eligibility

The heat pump to be bought should meet the below conditions:

- The heat pump is a new product and not second-hand or used.
- The heat pump has a maximum thermal capacity of 400 kW.
- The heat pump must have at least an A++ energy label to receive funding.
- Heat pumps from energy label A+++ receive an additional subsidy bonus of € 225.
- The heat pump is installed in a house built before 1 January 2019.
- The heat pump is installed before the subsidy is applied for.
- The installation was done by a building installation company.
- The owner has an invoice and proof of payment for the purchase and installation of the heat pump.
- The owner applies for the subsidy within 24 months after the installation of the heat pump.

The list of heat pumps that meet the criteria can be found at ISDE: Warmtepomp woningeigenaren.

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150 Program Czyste Powietrze - Ulga termomodernizacyjna – Ministerstwo Klimatu i Srodowiska
151 RVO - Subsidie voor duurzame energie en energiebesparing koopwoning aanvragen-isde
152 National Government webpage "€210 million extra for insulation and heat pumps"

4.6.2 Amount of the grant

The calculation for the subsidy amount depends on many parameters and a calculation tool is provided through the Netherlands Enterprise Agency website: Investeringssubsidie duurzame energie en energiebesparing voor woningeigenaren (ISDE) - ISDE calculation tool for homeowners.

As an example, a heat pump with a capacity between 5 kW and 7.5 kW is eligible for a subsidy between €2,550 and €3,060[153].

4.6.3 How to apply

See: Netherlands Enterprise Agency (RVO) - ISDE: Stappenplan aanvragen woningeigenaren

4.7 Spain

The Recovery, Transformation and Resilience Plan (PRTR)[154] is the tool through which the government of Spain has structured its strategy to channel the funds allocated by Europe to repair the damage caused by the COVID-19 crisis and, through improvements and investments, build a more sustainable future.

The PRTR is translated into several incentive programmes, the bases of which are established by the national government. Each of the 17 autonomous communities adapts each programme and publishes its own calls in which they are free to modify the budget reserve, beneficiaries, object of the incentive, etc.

It is necessary to highlight some important facts about how these incentive programs work in Spain:

- The national government approves the budgets of all programmes being funded with European funds and establishes the general guidelines for their operation.
- The national government transfers all funds to the 17 regional governments and the two autonomous cities, Ceuta and Melilla. Each of these regional governments is responsible for executing the grants and establishing the mechanisms for companies and citizens to apply for them.
- These programmes are not specifically for air conditioning, heat pumps or other climate control solutions. They are general programmes for rehabilitation and new construction that subsidise many actions, including some of the climate solutions that Daikin offers.

The main programmes:

- Incentive programmes for the implementation of thermal renewable energy installations in different sectors of the economy (RD 1124).
- Energy rehabilitation programme for existing buildings in demographically challenged municipalities (PREE 5000).
- Incentive programme linked to self-consumption and storage, with renewable energy sources, as well as to the implementation of renewable thermal systems in the residential sector (RD 477). Implementation of thermal renewable energy installations in the industrial, agricultural, service and/or other sectors of the economy, including the residential sector. Implementation of thermal renewable energy installations in non-residential buildings, public sector establishments and infrastructures.

Spain's National Recovery and Resilience Plan (NRRP) is the second largest (in absolute figures) financed by the Next Generation EU (NGEU) recovery instrument and its main spending tool, the Recovery and Resilience Facility (RRF)[155].

In October 2023, the plan was amended, by adding a REPowerEU chapter the plan's budget reached €163 billion.

[153] RVO "ISDE: Warmtepomp woningeigenaren"
[154] Spanish Government webpage "Plan de Recuperación, Transformación y Resiliencia"
[155] European Parliament website "Spain's National Recovery and Resilience Plan: Latest state of play"

4.7.1 Eligibility

The potential beneficiaries of these incentive programmes are natural persons, legal entities, homeowners' associations, local entities and public sector institutions, renewable energy communities and citizen energy communities. Eligibility varies according to the specific programme.

4.7.2 Eligible actions

i) The incentive programme for implementing thermal renewable energy installations in different economic sectors.

- Implementation of thermal renewable energy installations in the industrial, agricultural, services and/or other sectors of the economy, including the residential sector.
- Implementation of thermal renewable energy installations in non-residential buildings, establishments and infrastructures of the public sector.
- The thermal renewable technologies included are: solar thermal, biomass, geothermal, hydrothermal or aerothermal.

ii) Energy rehabilitation programme for existing buildings in demographically challenged municipalities (PREE 5000).

- Improvement of the energy efficiency of the thermal envelope.
- Improvement of the energy efficiency and use of renewable energies in the thermal heating, air conditioning and cooling, ventilation and sanitary hot water installations.
- Improvement of the energy efficiency of lighting installations.

iii) Incentive programme linked to self-consumption and storage, with renewable energy sources, as well as to the implementation of renewable thermal systems in the residential sector (RD 477).

- Implementation of self-consumption facilities, with renewable energy sources, in the service sector, with or without storage.
- Implementation of self-consumption facilities, with renewable energy sources, in other productive sectors of the economy, with or without storage.
- Incorporation of storage in self-consumption facilities, with renewable energy sources, already existing in the service sector and other productive sectors.
- Implementation of self-consumption facilities, with renewable energy sources, in the residential sector, public administrations and the third sector, with or without storage.
- Incorporation of storage in self-consumption installations, with renewable energy sources, already existing in the residential sector, public administrations and the third sector.
- Implementation of thermal renewable energy installations in the residential sector.

4.7.3 Amount of the grant

Each autonomous community establishes the percentage limits for each incentive programme. Some national programmes establish a limit; for example, programme i) has a limit of €3,000 per incentive per house).

i) The incentive programme for implementing thermal renewable energy installations in different economic sectors

- The programme has a total budget of €150 million.
- With this programme, the public support can reach 35 % of the cost of installing the thermal renewable energy installation for an individual private person.

ii) Energy rehabilitation programme for existing buildings in demographically challenged municipalities (PREE 5000).

- The programme has a total budget of €50 million.
- It includes public support for different rehabilitation actions, including replacement of thermal installations, which the government can subsidise up to 40 %.

iii) Incentive programme linked to self-consumption and storage, with renewable energy sources, as well as to the implementation of renewable thermal systems in the residential sector (RD 477).

- The programme has a total budget of €200 million for air conditioning and hot water with renewable energy.
- Aerothermal systems can receive €500/kW (€3,000/house).

4.7.4 How to apply?

Each autonomous community establishes the process, deadlines and requirements to apply for the incentive. Please contact your local authorities to be guided.

4.8 Italy

The Ecobonus is an Italian government programme aimed at promoting energy efficiency and sustainable renovations in buildings. The first Ecobonus was introduced in Italy by Law Decree 83[156] of 22 June 2012 and was renewed each year in state budget law (approved every year in December).

Under the Ecobonus scheme, individuals are eligible for tax credits for certain energy-saving and eco-friendly renovations made to their homes or buildings. The tax credits can be used to offset income tax and are available to both individuals and businesses.

The Ecobonus covers a range of energy-saving measures including: renovation of thermal systems with a new condensation boiler, biomass boiler, heat pump or hybrid system; installation of thermal solar plant or heat pumps for hot water production; improvements in building envelope such as better insulation of dispersing surface, new performant windows or insulation of roof; building automation system for energy savings, etc.

The incentive percentage varies from 50 to 65% of the total amount, depending on the type of installation. It is paid to the owner through a tax deduction over 10 years, so each financial year a rate value can be deducted.

4.8.1 Eligibility

- The property must be in Italy.
- The taxpayer must be the owner or co-owner of the property or have a long-term lease agreement.
- The property must be classified as residential, though there may be provisions for mixed-use buildings.
- The renovations must meet specific energy efficiency and sustainability criteria as defined by the scheme.

4.8.2 Amount of the grant

The tax credit percentage varies according to the type of renovation and energy efficiency improvement. The percentages are available on the website of ENEA – Dipartimento unitá per l'efficienza energetica – Ecobonus.

Example: Replacement of an existing boiler with a heat pump that costs €15,300, including materials and installation. The incentive amount from the scheme is 65 % of €15,300, or €10,000. The benefit is €1,000 in tax deduction every year for 10 years.

4.8.3 How to apply

You can submit your request via the official ENEA website – Superbonus 110% and send the required documents within three months (90 days) of the actual end of the renovation work.

4.8.4 Further bonuses

Conto Termico

Conto Termico[157] is an incentive mechanism valid for private citizens and public buildings. The technical requirements are similar to those of the Ecobonus, while the value is slightly lower. The incentive is in the form of cash, and not a tax credit system. Conto Termico and Ecobonus cannot be combined.

Superbonus

Superbonus, financed by the European Green Deal Fund, was introduced through Law Decree 34/2020 and further updates. The incentive percentage was extended to 110 % and the credit rates reduced to five years, but further conditions had to be met:

- Renovation of thermal system or 25 % of building envelope.
- Increase of at least two EPC classes.
- Technical certification of cost congruence with restrictive criteria and checks.

For single-family houses, Superbonus lasted from early 2021 to December 2022, and was extended to December 2023 for requests already admitted and work already started in 2022.

[156] Testo del decreto-legge 22 giugno 2012, n. 83 (in supplemento ordinario n. 129/L alla Gazzetta Ufficiale - serie generale - n. 147 del 26 giugno 2012), coordinato con la legge di conversione 7 agosto 2012, n. 134 (in questo stesso supplemento ordinario alla pag. 1), recante: «Misure urgenti per la crescita del Paese.»
[157] DECRETO 16 febbraio 2016 Aggiornamento della disciplina per l'incentivazione di interventi di piccole dimensioni per l'incremento dell'efficienza energetica e per la produzione di energia termica da fonti rinnovabili. (16A01548) (GU Serie Generale n.51 del 02-03-2016)

For multi-family houses, Superbonus ran from early 2021 to December 2022 with 110 % quote, and has been continued to December 2023 with 90 % quote. Superbonus is primarily an incentive for multi-family houses.

The credit market was stopped by decree from February 2023, due to the expense for the Italian government.

5.9 Conclusions

In Europe, there are numerous incentive schemes, particularly in the renovation sector, that continue to offer substantial benefits in many countries. While we anticipate that the European government's support for expanding the adoption of heat pumps will persist for some time, it's worth noting that several countries have plans to gradually reduce the incentive amounts over time. To make the most of these incentives, it is advisable to act promptly in embracing heat pumps and capitalize on the current advantageous conditions.

To share your comments with the authors or for additional information, email heatpumpadoptioneuhsbu@daikin.eu

Section 5: Optimized utilisation of solar PV technology

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5.1 Introduction

By replacing a gas boiler with a heat pump, savings will be made on the gas bill but the power consumption of the heat pump will increase the electricity bill. Depending on factors such as the country and the system, the reduction in gas will usually more than offset the increase in electricity. Moreover, in combination with PV panels, the heat pump will run for free part of the time, clearly tipping the scale in favour of the heat pump.

5.2 Reducing feed-in tariffs

What is a **feed-in tariff?** Feed-in tariffs are a policy tool designed to promote investment in PV panels by offering small-scale producers of energy such as households an above-market price for what is delivered to the grid.

PV installations reduce energy costs in two ways:

1. By consuming electricity from own PV panels instead of from the grid, the electricity bill can be reduced (self-consumption).
2. By selling excess production back to the grid (feed-in).

Feed-in tariffs are designed to promote renewable energy sources such as PV in the early stages of their development when they are not yet economically viable. As prices of PV panels are dropping and efficiency is increasing, these incentives are no longer so needed and therefore reducing in many countries across Europe. As feed-in tariffs become less interesting, the focus of households with PV shifts towards optimising self-consumption.

5.2.1 Germany

In Germany, between 2000 and 2020, the household power price (red area) gradually went up, while the PV tariff for installations up to 10 kW (dark blue line) came down quickly[158], as shown in the graph below.

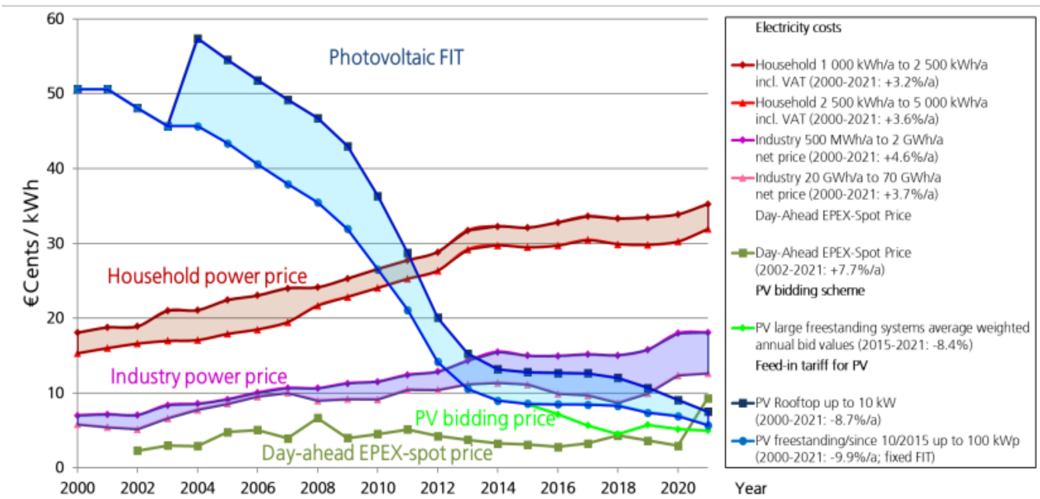


FIGURE 5.1 SOURCE: PHOTOVOLTAICS REPORT – FRAUENHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS, ISE WITH SUPPORT OF PSE PROJECTS GMBH – 21/2/2023

[158] Photovoltaics report – Frauenhofer Institute for Solar Energy Systems, ISE with support of PSE Projects GmbH – 21/2/2023 -

5.2.2 Netherlands

Via the "salderingsregeling", households and small companies can deduct their yearly production from their yearly consumption, meaning that it doesn't matter when the household produces or consumes, only the net difference counts towards the energy bill. This arrangement allowed customers to use the grid as a battery. As PV systems become more efficient and economic, the government will gradually reduce the percentage of produced energy that can be deducted from the consumed energy from 100 % in 2023 to 0 % in 2031.[159]

Year	% that can be deducted
2023	100
2024	100
2025	64
2026	64
2027	55
2028	46
2029	37
2030	28
2031 and beyond	0

5.2.3 Belgium

Similar to the Netherlands, until a few years ago in Flemish households, energy meters literally counted backwards when electricity was supplied to the grid. Since 2021 these analogue meters are being replaced by digital meters that keep track of when households produce and consume energy. When households produce more energy than they consume they will get a feed-in tariff; this is lower than the electricity price, so households are encouraged to increase their own self-consumption.[160]

5.2.4 Conclusion

In a lot of European countries, in addition to the examples above, we see reducing feed-in tariffs. The amount of money a household gets back per kW is a fraction of what they pay for electricity taken from the grid. Therefore optimalisation of self-consumption becomes more interesting compared to returning energy to the grid. Heating the house and hot water by electricity with a heat pump instead of by gas is a great way to do that.

5.3 Heat pumps and PV: seasonality throughout the year

Heat pumps take energy from the outside air or from the ground and transfer it to hot water to heat a home or shower. To run the heat pump, electricity is needed. Depending on the efficiency of the heat pump and the emitter, it needs about 1 kW of electricity to produce 3 to 4 kW of energy to heat a home and the domestic hot water.

PV panels generate electricity by absorbing solar energy. They generate the electricity the heat pumps need, but the seasonality factor needs to be considered. As can be seen in below graph, the electricity generated by PV (the

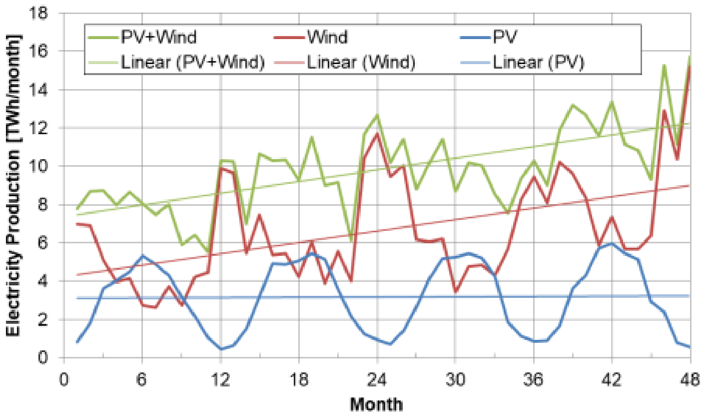


FIGURE 5.2 SOURCE: H. WIRTH, FRAUNHOFER ISE "RECENT FACTS ABOUT PHOTOVOLTAICS IN GERMANY" (2023)

[159] Rijksoverheid - Plan kabinet: afbouw salderingsregeling zonnepanelen
[160] Engie Belgium - Zonnepanelen - Je terugdraaiende teller in Vlaanderen: behouden tot 2025 of niet?

blue line) peaks every year around June and drops to a minimum in December and January. The seasonal fluctuation can be minimised somewhat by choosing south-facing modules with higher angles of inclination; however, electricity production in July will always be higher than in December. This example is from Germany but the seasonality will occur in most countries. [161]

Meanwhile, the heat demand on the heat pump has an opposite seasonality. During winter, a lot of energy is needed to keep the home comfortable and none during the summer. However, heat pumps do not just take care of space heating; they also heat hot water. The demand for hot water is very stable throughout the year and is therefore a good way to optimise self-consumption.

If the heat pump is also used for cooling during the summer, there is another opportunity to use excess PV energy.

5.4 Heat pumps and PV: profile during the day

As stated, feeding electricity back into the grid when there is a surplus becomes less and less interesting. Shifting the load curve to periods when PV generation is high is a good way to optimise self-consumption and reduce electricity bills.

Typical load curve during a summer day:

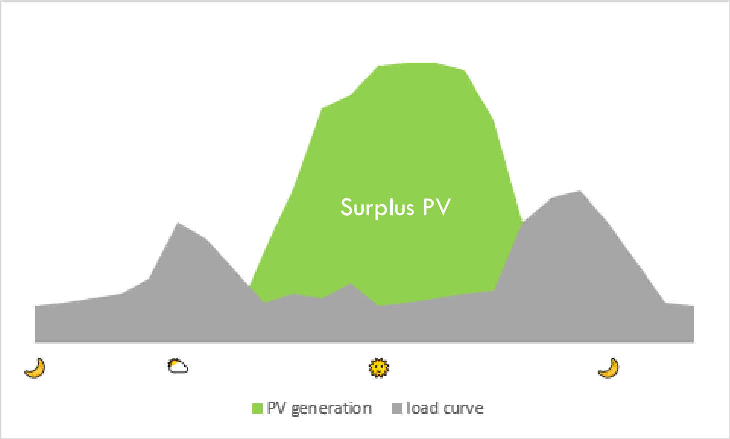


FIGURE 5.3 SOURCE: OWN CALCULATIONS

Load curve during a summer day with some load shifting:

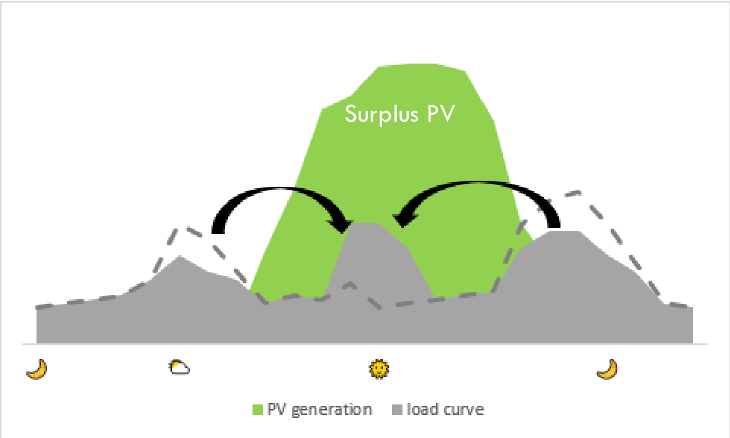


FIGURE 5.4 SOURCE: OWN CALCULATIONS

[161] H. Wirth, Fraunhofer ISE *"Recent Facts about Photovoltaics in Germany"* (2023)

Not all loads can be shifted, but hot water heating by the heat pump which is typically scheduled during the night when electricity rates are low can easily be rescheduled during the day when free electricity can be generated.

As a heat pump typically has a lower capacity than a boiler, it doesn't instantly heat water whenever there is a demand as a boiler does. Instead , over the course of 30 minutes or 1 hour it heats a hot water tank, which is then ready for use throughout the day. The size of that tank and the target temperature are typically designed to cover the household's hot water needs for a 24-hour period. As such, it doesn't matter so much if this tank is heated at night or in the day. A PV installation generates a lot of energy around noon and nothing during the night. By rescheduling the tank heat-up to noon, during a large part of the year the tank can be heated with free PV energy.

To a certain extent, some pre-heating or pre-cooling of homes, especially with underfloor heating or cooling, can also be done.

Another way to avoid feeding electricity into the grid is to store it locally. Excess energy can be stored in the form of hot water in the tank of the heat pump or an additional buffer tank.

Energy stored in water can be calculated as follows:
$E = c_p \times dt \times m$
where:
E = energy
c_p = specific heat of water = 4.18 Kj/kg°C
dt = temperature difference

So in this example
E= 4.18 x 10 x 230 = 9,614 kJ
= 2.67 kWh

By increasing the tank temperature of a typical 230 litre tank from 50 to 60°C, 2.67 kWh energy can be stored in the tank. A lot more energy can be stored by adding an additional buffer tank.

5.5 Heat Pumps and PV: optimalisation

Simply by replacing a boiler with a heat pump, a household enjoys free heating on the days and hours it is available. The heat pump will benefit from PV in the same way as a washing machine or dishwasher: if it is running while free electricity is being generated it will take advantage of it, if not, it will take energy from the grid. By scheduling the heating of the domestic hot water tank to hours where an energy excess is likely to occur, the amount of self-generated electricity being used can be increased.

However, there is a smarter way to optimally use PV-generated electricity with modern heat pumps. All recent Daikin Altherma heat pumps can receive information on the excess amount of electricity available and optimise their behaviour accordingly. When there is no request for cooling or heating of the home and the tank temperature reaches its set point, the heat pump would normally be turned off. If it receives a signal that excess PV capacity is available, it can heat the tank to the maximum set point and/or buffer energy in the space heating circuit.

5.5.1 Behaviour for domestic hot water heating

The size of the tank and the tank target temperature are selected to cover the household's hot water demands. For example a 230 litre tank is normally heated every day at 13.00 to 50°C to cover the evening bath and morning shower of a small household.

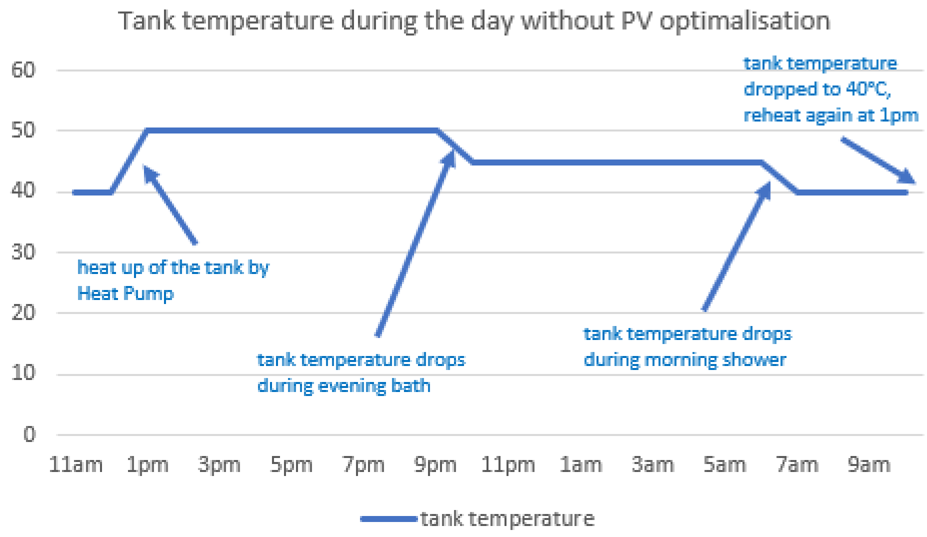


FIGURE 5.5 SOURCE: OWN CALCULATIONS

If at 15.00 there is excess PV capacity, the Daikin Altherma heat pump will know exactly how much is available and use only that amount to heat up the tank to 60°C. Additional capacity becomes available in the domestic hot water tank and prevents or reduces a heat-up the next day at 13.00 when free PV energy may not be available. When a cloud passes over the sun or the household's energy consumption suddenly increases, perhaps by charging an electric vehicle, the Daikin Altherma will immediately stop the buffering. If at a later time excess energy becomes available again, it will pick up where it left off until the maximum tank temperature is reached.

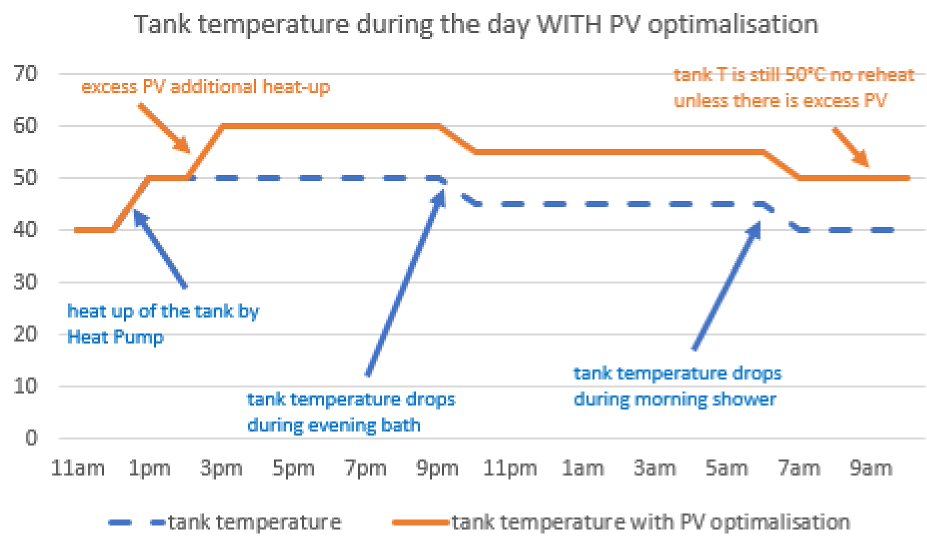


FIGURE 5.6 SOURCE: OWN CALCULATIONS

5.5.2 Behaviour for space heating and/or cooling

It is also possible to buffer extra energy from the PV panels in the space heating/cooling circuit. Users can set a heating comfort set point and a cooling comfort set point in the Daikin Altherma interface to select the maximum heating temperature and minimum cooling temperature.

If a normal heating set point is 20°C, the comfort set point can be set to 22°C. This means the house will be slightly warmer at no cost during a cold but sunny afternoon and additional heating will only be needed in the evening.

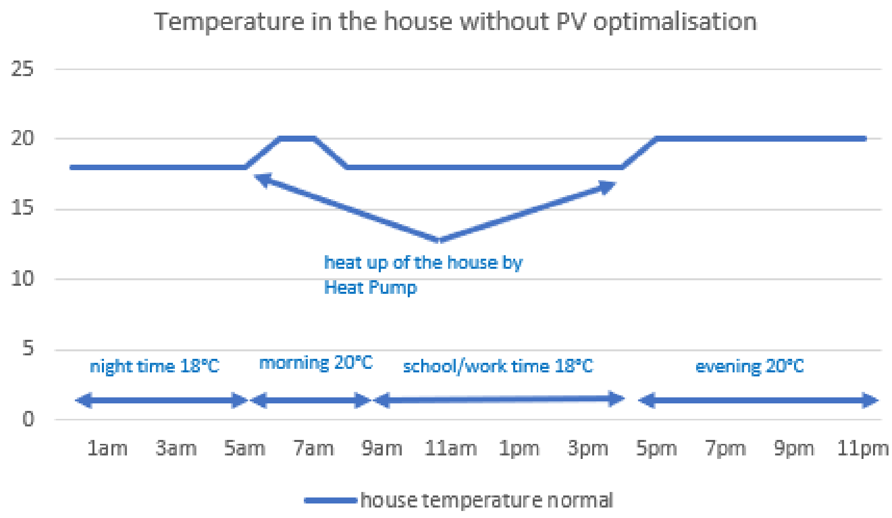


FIGURE 5.7 SOURCE: OWN CALCULATIONS

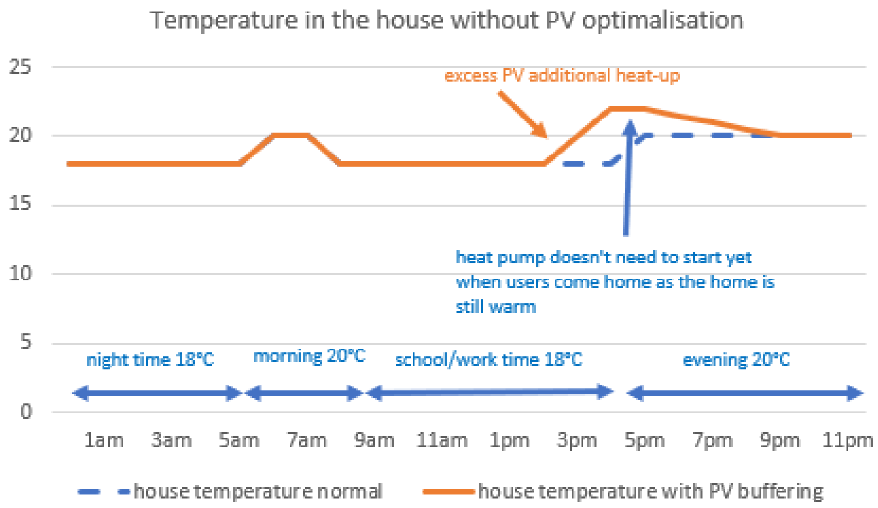


FIGURE 5.8 SOURCE: OWN CALCULATIONS

5.5.3 How to connect

Depending on the country and the recency of the Daikin Altherma there are different ways for the heat pump to know when to buffer excess PV capacity.

On older Daikin Altherma heat pumps, a pulse counter energy meter can be connected to the smart grid contacts on the product or on the optional BRP069A61. On newer models, the Daikin Home Hub EKRHH option can connect to a clamp-based single- or three-phase electricity meter, and in some countries even directly to the smart meter with a USB cable. In other countries, even cloud-based solutions are possible with the Daikin Altherma UP series.

All solutions provide an input to the Daikin Altherma when excess PV energy is available and buffering should start. As they are are based on measuring the energy, they can be used with any brand of PV panel and inverter.

5.6 Heat pumps and PV: case study

In this case study in June 2022, a Daikin Altherma heat pump UP series with PV optimalisation was installed in a Belgian household as a replacement for the existing gas boiler, to study the impact of storing excess PV in thermal energy instead of returning it to the grid.

5.6.1 Specifics of the case study

- Daikin Altherma 3 H HT W (EPRA18DV3 + ETBH16E6V) with a 250 litre tank (EKHWS250D3V3)
- Connected to the cloud and the Daikin Altherma UP series
- PV 5kWp yearly production (2021) of 4.92 MWh
- Reheat DHW mode with a set point of 45°C which was increased to 55°C when excess PV was available
- Installed in Oudenaarde, Belgium

5.6.2 Self-consumption ratio definition

The formula for self-consumption is:

$$Self\ consumption = \frac{(Total\ production - Export)}{Total\ production}$$

For example:

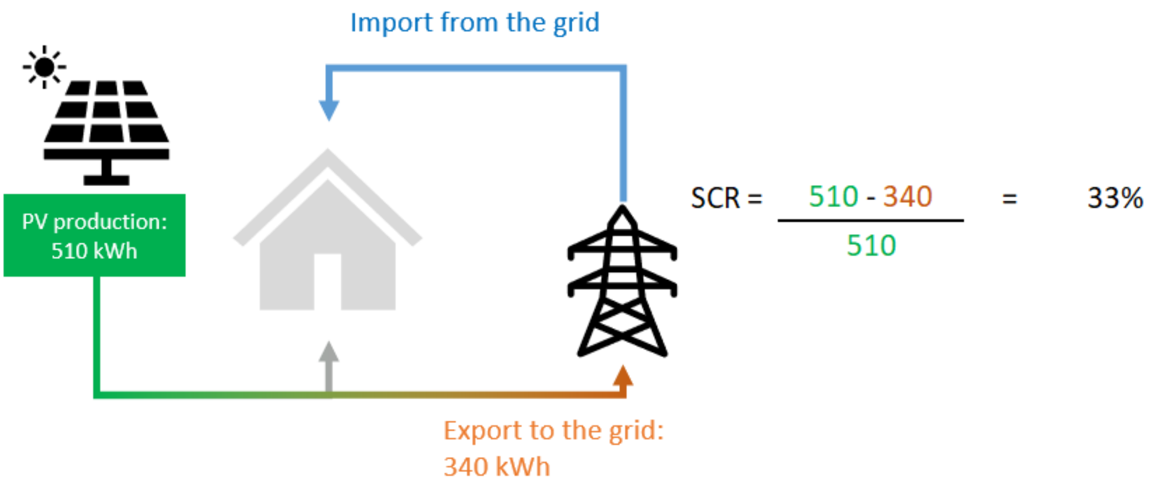


FIGURE 5.9 SOURCE: OWN CALCULATIONS

5.6.3 Graphical representation of case study results

We will focus this case study on the period between 2 June 2022 and 2 July 2022. During this time, the heat pump tank was set with a normal set point of 45°C, guaranteeing hot water for the household whether there is PV energy or not. When there was sufficient excess PV capacity, the tank set point was automatically increased to 55°C in order to store thermal energy in the tank.

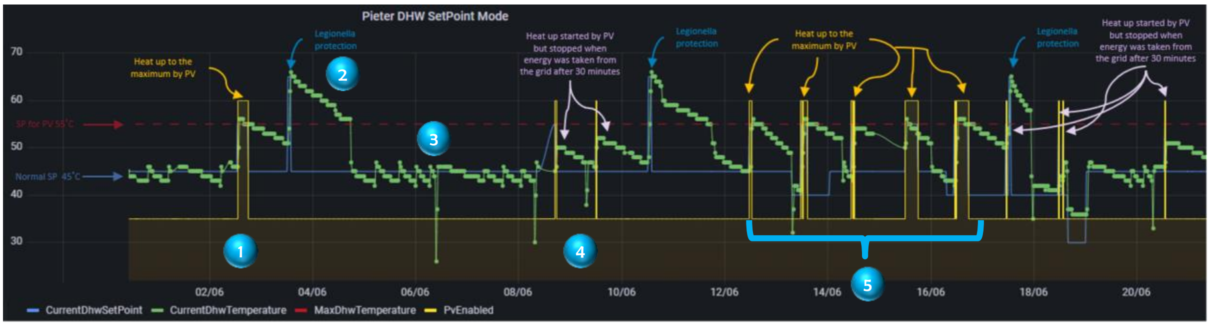


FIGURE 5.10 SOURCE: OWN CALCULATIONS

The graph above shows the behaviour of the unit. The blue line represents the tank set point, usually at 40°C, once a week increased to 65°C thanks to the legionella protection. When there is excess PV capacity available (visible by the peaks in the yellow graph), the set point is increased to 55°C. The green line is the actual tank temperature. By following the graph the behaviour of the unit can be understood.

○ Until 2 June, the heat pump maintains the tank temperature around the 45°C set point. O 2 June, the test site is activated and immediately for the first time there is excess PV capacity. The tank temperature is below 55°C, the PV algorithm is enabled (peak in the yellow line) and the tank temperature increases to 55°C.

○ The day after the weekly legionella protection, the tank temperature increases to 65°C for safety reasons.

○ In the next few days there is no opportunity to enable the PV.

○ On 9 June, the PV algorithm is activated twice. The tank temperature increases but the excess PV is not sufficient (due to clouds appearing or increased household consumption) to reach the 55°C maximum set point.

○ Between 12 and 17 June there were five occasions where there was sufficient PV energy to increase the set point of the tank by 10°C and thus store 2.9 kWh of thermal energy for later use.

5.6.4 Numerical representation of case study results

The table below shows the PV production by day and by hour. Unsurprisingly, the highest PV production is achieved between 12.00 and 14.00 on most days.

By adding the export to the grid, we can calculate the self-consumption ratio.

The self-consumption ratio during June with the Daikin Altherma UP series with PV optimalisation installed was: (650 – 392) / 650 = **39.7 %**.

To understand the effect of the heat pump, the self-consumption rate without heat pump was calculated. The PV production remains the same, but the export to the grid would be higher as without a heat pump, domestic hot water would be provided by gas boiler and thus electricity usage would be lower.

Taking as an example 16 June, on this day – thanks to the optimisation algorithm – the Daikin Altherma heated its tank during the time of the day with a lot of PV. Therefore, the majority of the power consumption came from the own PV production. If the Daikin Altherma had not consumed this power, it would have been exported back to the grid. On this day, the self-consumption ratio was 27 %; without the Daikin Altherma it would have been only 16 %. Because almost 90 % of the Daikin Altherma power consumption came from excess PV, the impact on the self-consumption ratio was very large.

This is not always the case. For example, on 9 June, the domestic hot water tank had to be reheated in the morning when no excess PV capacity was available. At 12.00 there was enough excess PV capacity to heat the tank further, but because of the first heating in the morning, only 26 % of the Daikin Altherma energy came from excess PV and as such the impact on the self-consumption ratio is smaller than in the previous example.

Of course, there were a few days where there was almost no PV capacity and no impact on the self-consumption ratio. The total power consumption of the heat pump during June was 72.45 kWh. Because of the weather, the heat pump was only used for domestic hot water with no requirement for space heating. Of this 72.45 kWh, 45.23 kWh was provided by the PV installation.

Results for June 2022:

	with HP	without HP	difference
PV production	650 kWh	650 kWh	0 kWh
Excess energy	392 kWh	437 kWh	45 kWh
SCR	40%	33%	7%

5.6.5 Summary results of the case study

1. Base line: if there were no heat pump (heating and domestic hot water done by boiler) all the excess PV would flow back to the grid and the self-consumption ratio would be 33 %
2. With the Daikin Altherma heat pump and PV optimisation algorithm, the self-consumption ratio was 40 %

5.6.6 Energy savings

In this example, with energy prices from June 2023, the monthly saving on the heat pump running cost from using PV energy is €13. Returning the excess energy to the grid instead of the heat pump would only save €3 on the electricity bill.

(Source: Daikin own case study)

5.6.7 Yearly projection

The test site results were monitored from 2 June 2022 to 2 July 2022, and by projection a yearly saving can be calculated. Using the European website[162] for Photovoltaic Geographical Information, a monthly spread of PV production can be calculated for this location (Oudenaarde, Belgium).

			extrapolated			measured			extrapolated			
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
JRC ratio	0.32	0.447	0.752	0.992	1.01	1	0.995	0.912	0.818	0.6	0.377	0.287
PV prod (kWh)	208	291	449	645	656	650	647	593	532	390	245	187

Therefore as the PV production in June was 650 kWh, we can calculate that in January it will be only 32 % of the June value, or 208 kWh. This allows us to calculate the expected PV production for the entire year.

To calculate the yearly savings, it is estimated that the demand for domestic hot water, the energy consumption to produce hot water and the household energy consumption without the heat pump remain stable throughout the year. This is a simplification, as in reality, the heat pump will consume a bit more during the colder months as efficiency is lower. However, as during the coldest months there is not much PV excess capacity to benefit from, this simplification will not have a significant impact on the yearly calculation.

As explained, the heat pump benefits in two ways from the presence of PV. Like any other electrical appliance, if it consumes energy while PV capacity is available, it will run for free. When a lot of excess PV capacity is available, additional energy can be stored in the tank by increasing the test site. This second part in this test site was only activated when at least 1.8 kWh of excess PV energy was available. For smaller capacity heat pumps, this boundary can be lower. The PV optimalisation may not be activated every time there is an excess of 1.8 kWh available, for example, if the tank is still at a high temperature due to the legionella protection or due to a previous heat-up operation.

			extrapolated			measured			extrapolated			
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PV prod (kWh)	208	291	449	645	656	650	647	593	532	390	245	187
Household consumption without HP	213	213	213	213	213	213	213	213	213	213	213	213
HP consumption for DHW total	73	73	73	73	73	73	73	73	73	73	73	73
days with >1800 watt excess	0	0	16	24	24	24	24	22	17	9	0	0
HP consumption for DHW from PV	0	8	24	45	45	45	45	33	28	17	7	0

The June data shows us that out of the 73 kWh electricity usage by the Daikin Altherma, 45 kWh came from PV production. Since the PV production and the number of days where the activation condition is reached are projected to be almost the same in April, May and July, we estimate the same energy savings in those months.

In January and December, when the monthly PV production is below the household consumption without heat pump, we don't project any energy savings. This is on the conservative side, as even in December and January there is some excess PV capacity at certain hours of the day.

During the other months, we projected the energy saving based on the June result, taking into account the projected excess capacity at 13.00 (so that a scheduled domestic hot water heat-up at that time can take advantage of whatever excess capacity is available) and the maximum number of days where additional storage in the domestic hot water tank could be possible.

[162] European Commission - EU Science Hub - Photovoltaic geographical information system: performance of grid-connected PV

For domestic hot water production over the full year, the heat pump is estimated to consume 870 kWh, of which 298 kWh will come from free PV energy, resulting in energy savings of €87. If this energy had been fed back into the grid, the gain would be only €23.

This case study clearly shows that households with PV can increase their self-consumption ratio and thus realise energy savings by heating their domestic hot water with a heat pump instead of with a gas boiler.

In the shoulder season, further energy savings can be realised as the excess PV energy can be partially used for the space heating operation of the heat pump. This was not considered here as our case study took place in June.

5.7 Heat pumps and PV: international research

Independent internal research confirms the symbiosis of heat pumps and PV. According to a report by Solar Power Europe[163], in 2022, homes with solar PV enjoyed substantial savings on their energy bills, especially in combination with electricity-based heating technologies. The report models annual energy expenses of a typical household in different countries in a new build home with the extreme energy prices of 2022[164].

The below graphs show the modelled energy savings of the three technologies: solar, heat pump and solar + heat pump in Germany, Spain and Italy.

FIGURE 6 ANNUAL SAVINGS IN EURO OF HOUSEHOLDS WITH DIFFERENT POWER & HEATING TECHNOLOGIES IN GERMANY, SPAIN, AND ITALY IN 2022

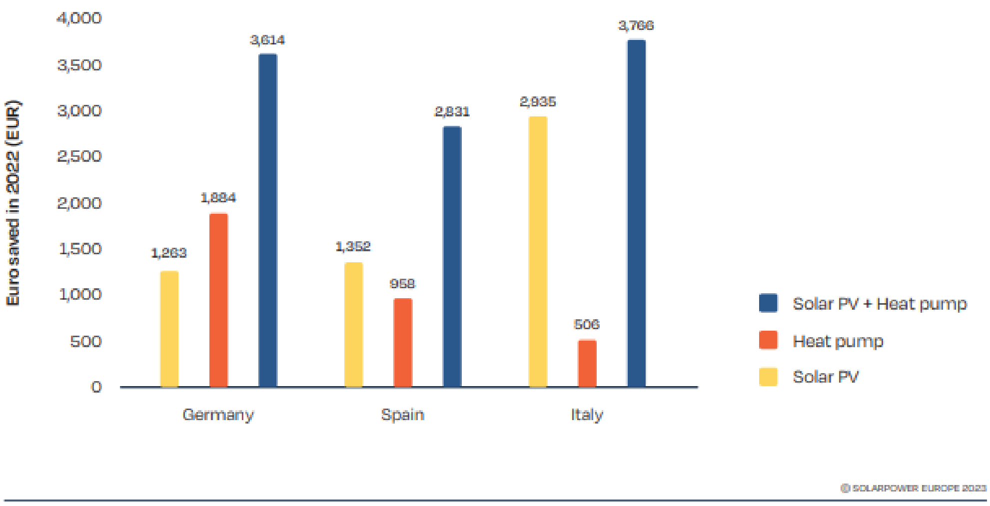


FIGURE 5.11 SOURCE: OWN CALCULATIONS

[163] Solar Power Europe "*Solar Powers Heat 2023*" (2023)

[164] Conditions

- thermal demand for space and water heating (12,000-20,000 kWh/year) corresponds to an average of existing houses using an average gas boiler with 85 % efficiency
- annual electricity demand of average family homes (4,000-4,500 kWh/year)
- average household gas and electricity prices in 2022 from the Household Energy Price Index (Vaasa ETT, 2023).

FIGURE 5 ANNUAL ENERGY BILL SAVINGS IN % FOR HOUSEHOLDS WITH DIFFERENT POWER & HEATING TECHNOLOGIES IN GERMANY, SPAIN, ITALY IN 2022

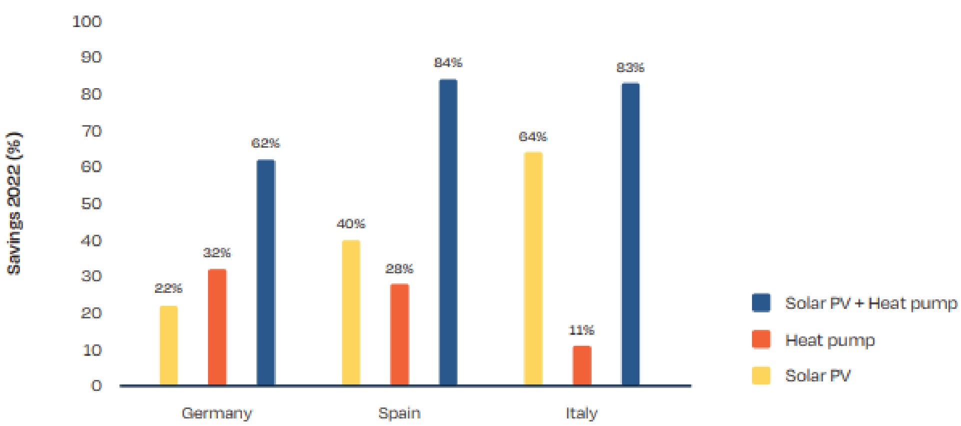
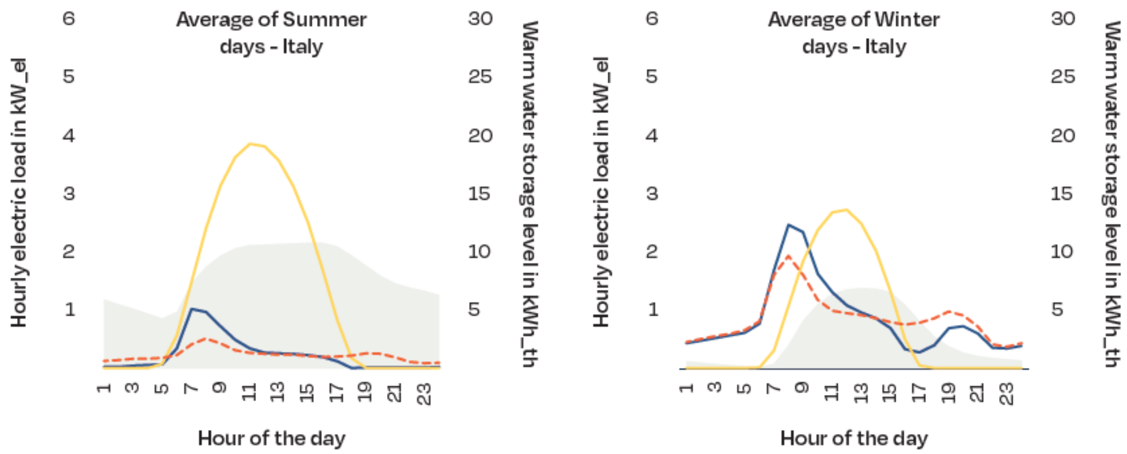


FIGURE 5.12 SOURCE: OWN CALCULATION

A PV size of 7 kW was modelled in Italy and Spain and 8 kW in Germany. Savings from reduced purchase of grid electricity and selling excess production were taken into account. Thanks to high solar production in Spain and Italy, the savings there are higher than in Germany. Trading a gas boiler for a heat pump with a water buffer tank created the highest savings in Germany due to the higher heat loads, and the lowest savings in Italy due to the highest electricity prices.

The model shows that the combination of solar PV and heat pump yields higher annual energy savings for all households compared to the sum of the separate technologies. It's important to note here that the study assumed a buffer storage size of 400 litres in Italy and Spain and 800 litres in Germany. This allows a large part of the heat load to be covered by the solar PV by storing warm water for later usage. Of course, buffer tanks of that size are not possible in all applications.

In this model, thanks to the buffer tank, self-consumption and energy savings can be maximised.



On an average summer day in Spain and Italy, the heat demand for water is fully met by the heat pump, and the water storage remains high in the evening.

Warm water storage level (kW_th)
PV production
HP load_el
Heat demand_el

FIGURE 5.13 SOURCE: OWN CALCULATIONS

This graph shows the hourly electric load profiles of solar PV and the heat pump and the effect of load shifting with the buffer tank. In summer, solar production is sufficient to run the heat pump during the day. In the evening and at night, the hot water in the buffer tank can be used for space heating and domestic hot water. However, due to the low demand for heating, only a small portion of the buffer tank capacity is used during the night. During winter, more load shifting can be observed.

Under average weather conditions and with the buffer tank to match heat pump and solar load profiles better, this study found that nearly two-thirds (62 %) of the electricity needed to heat an average Spanish family household could be covered by solar PV. For Germany this was more than one-third (38 %).

5.8 Conclusion

This paper shows that in various European countries, the return from PV by exporting excess PV capacity back to the grid is reducing year by year as government incentives reduce. To maximise the benefit of a PV installatio,n self-consumption should be increased and as much as possible the load should be shifted to periods of peak capacity. Replacing a gas boiler with a heat pump trades gas consumption for electricity consumption. This consumption is partially free thanks to PV production. In particular, domestic hot water production by the heat pump can be scheduled in such a way that the load coincides with periods of excess PV capacity. Additionally, thermal energy can be stored in the existing domestic hot water or optional buffer tank by optimising the heat pump behaviour based on actual and/or predicted excess PV capacity. The combination of heat pump and PV will generate additional energy savings.

To share your comments with the authors or for additional information, email heatpumpadoptioneuhsbu@daikin.eu

Section 6: Carbon footprint of heat pumps

Tom Lapere

Senior Certification Officer

Heating Sales Business Unit (Daikin Europe)

"The EU's commitment to climate neutrality by 2050, anchored in the EU Green Deal, highlights the pivotal role of heat pumps in our formal pursuit of sustainability."

Tatiana Fedorova

Environmental Product Declaration Officer

Heating Sales Business Unit (Daikin Europe)

"In this section, you will learn how heat pumps help to reduce GHG emissions locally and globally. The technology is here, so why don't we 'pump up' our efforts to reach carbon neutrality and make change right now?"

6.1 Ongoing decarbonisation of heating

As the devastating impacts of climate change caused by greenhouse gas emissions from human activities can already be witnessed around the world[165], countries are accelerating their efforts to combat climate change. The EU is taking a leading role in this transition and aims to become climate-neutral by 2050[166] to comply with the goal of limiting the temperature increase to 1.5°C as defined in Paris Agreement.

A decarbonised EU by 2050 is the primary and overarching goal of the EU Green Deal, an ambitious and comprehensive plan to tackle climate change. The EU aims to reduce greenhouse gas emissions by 55 % across all sectors of the economy, including energy and buildings. Currently, buildings are the largest energy consumers, accounting for 40 % of the region's total energy consumption and contributing to 36 % of its greenhouse gas emissions[167]. In the residential sector, around 80 % of the final energy consumption is used for space and water heating[168]. This energy still comes from the combustion of fossil fuels like coal, natural gas and oil, which are highly carbon-intensive and contribute drastically to global temperature rise. Since buildings and their heating are significant sources of emissions, decarbonisation of heating is essential to achieve the EU's goals.

6.2 The role of heat pumps in decarbonisation

6.2.1 Heat pump advantages for decarbonisation

Heat pumps play a crucial role in the decarbonisation of the EU. As the EU aims to transition to a low-carbon and sustainable energy system, reducing greenhouse gas emissions is a top priority. Heat pumps contribute significantly to this goal by providing a more energy-efficient and environmentally friendly alternative for heating than conventional fossil fuel-based systems.

According to European Heat Pump Market and Statistics Report 2023[169], "the heat pump stock in 2022 (heat pumps sold in the past twenty years) contributed 52.52 Mt of greenhouse gas emission savings". Globally, using heat pumps in place of conventional boilers and furnaces has the potential to reduce annual global CO_2 emissions by 3 gigatons if adopted worldwide[170].

Below are some key aspects of how heat pumps aid in the EU's decarbonisation efforts:

1. **Energy efficiency**: Heat pumps are known for their high energy efficiency. Instead of generating heat directly, as traditional heating systems do, they move heat from one place to another. This process requires less energy

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[165] AR6 Synthesis Report: Climate Change 2023 — IPCC. (2023). IPCC.
[166] European Union. (2020, March 6). *Long-term low greenhouse gas emission development strategy of the European Union and its Member States.*
[167] *Press corner*. (2021, December 15). European Commission - European Commission
[168] Eurostat. (2022, June). *Energy consumption in households*
[169] *European heat pump market and statistics report 2023*. (2023). European Heat Pump Association
[170] *Building decarbonization: How electric heat pumps could help reduce emissions today and going forward*. (2022, July 25). McKinsey & Company.

than creating heat from scratch, allows heat pumps to achieve high coefficients of performance (meaning they produce more heat energy output per unit of electricity input) and contributes to reduced energy losses. As a result, heat pumps can significantly reduce energy consumption and related emissions, contributing to the EU's energy efficiency goals. You can see specific example of heat pump efficiency in Section 6.4.

2. **Renewable energy utilisation**: Heat pumps are an efficient way to use renewable energy sources for heating and cooling. They can extract heat from the air, surface water and underground aquifers, waste heat and the ground and then amplify and transfer it into buildings for space heating or cooling. Since they primarily rely on electricity for their operation, coupling them with renewable energy sources like solar, wind, or hydroelectric power enables a substantial reduction in carbon emissions. For solar energy, Daikin has released high-efficiency thermal solar panels (Daikin Altherma ST) that are compatible with a wide range of Daikin heat pumps to help homeowners benefit from renewable energy use.
3. **Reduced fossil fuel dependence**: As the EU decreases its dependency on fossil fuels for heating, its overall carbon footprint decreases. This not only helps in meeting emission reduction targets but also enhances energy security and reduces exposure to fluctuations in fossil fuel prices.
4. **Electrification of heating**: Electrification of heat has a potential of 17 % reduction in total energy-related emissions[171]. By promoting the use of heat pumps powered by electricity, the EU can gradually shift away from fossil fuel-based heating systems and reduce its reliance on finite and carbon-intensive energy sources.
5. **Retrofitting opportunities**: The EU has a large stock of existing buildings, many of which still use inefficient and carbon-intensive heating systems. Heat pumps provide a viable retrofitting solution, enabling these buildings to transition to cleaner energy sources without requiring extensive infrastructure changes.
6. **Cooling solutions:** Climate change is also leading to an increased demand for cooling in buildings. Heat pumps can be used for efficient air conditioning, providing a sustainable alternative to conventional cooling systems that often rely on refrigerants with high global warming potential.

Overall, the widespread adoption of heat pumps in the EU can contribute significantly to achieving its decarbonisation and climate goals by reducing greenhouse gas emissions, promoting energy efficiency and accelerating the transition to renewable energy sources.

6.2.2. Heat pumps support in EU regulation

Heat pumps are key to enabling the clean energy transition and achieving the EU's carbon neutrality goal by 2050[172]. According to a 2022 report from the International Energy Agency, heat pumps are expected to reduce Europe's gas demand for building heating by at least 21 billion cubic metres in 2030[173].

The EU is working on the EU Heat Pump Action Plan, which aims to install at least 10 million additional heat pumps by 2027[174]. This plan will be supported by various existing EU policy initiatives like Renovation Wave Strategy, Renewable Energy Directive (RED) and Energy Efficiency Directive (EED), Energy Taxation Directive, Regulation on fluorinated greenhouse gases and many others.

The action plan will include an assessment of available funding options for the installation of heat pumps in individual buildings and for heating networks supplied by large heat pumps. This assessment will be integrated into local and regional heating and cooling strategies.

6.3 LCA of heat pumps

To understand the carbon footprint benefits of heat pumps in comparison with gas-powered heating technologies, it is important to perform a life cycle assessment (LCA) of heat pumps.

An LCA is "a process of evaluating the effects that a product has on the environment over the entire period of its life thereby increasing resource-use efficiency and decreasing liabilities. It can be used to study the environmental impact of either a product or the function the product is designed to perform"[175]. LCA is a standardised method to assess a product's full life cycle: from the extraction of resources, through production, use and recycling, up to the disposal of remaining waste. It is a powerful decision support tool necessary to make consumption and production more sustainable.

LCA methodology identifies the different life stages (A, B, C, D) of a product with division into modules (e.g. A1-A5). There are currently four major scopes of LCA:

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[171] Thomaßen, G., Kavvadias, K., & Navarro, J. P. J. (2021). The decarbonisation of the EU heating sector through electrification: A parametric analysis. *Energy Policy, 148*, 111929.
[172] European Commission – DG Energy Topics "Heat pumps. (2023)"
[173] *The Future of heat pumps – Analysis - IEA.* (n.d.). IEA
[174] European Commission – DG Energy Topics "Heat pumps. (2023)"
[175] *Life cycle assessment.* (n.d.). European Environment Agency – *Life cycle assessment definition*

- cradle-to-gate (A1-A4)
- cradle-to-handover (A1-A5)
- cradle-to-grave (full stages A, B, C)
- cradle-to-cradle (cradle-to-grave + module D).

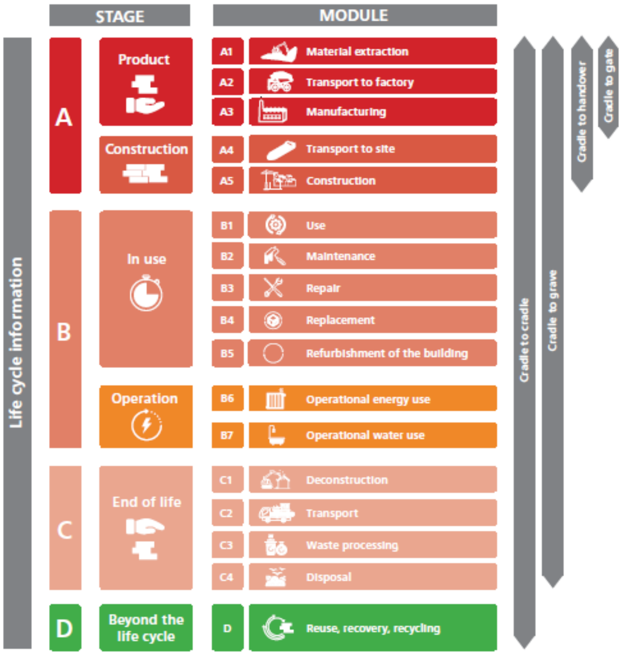


FIGURE 6.1 GRAPHICAL REPRESENTATION OF LIFE CYCLE ASSESSMENT. SOURCE: CIBSE (UK)

Since 2021, Daikin has performed **cradle-to-grave** LCA for heat pump products. This allows us to go beyond evaluating the environmental impacts of refrigerants only and get a holistic picture of the environmental footprint of our products from manufacturing stage till the end-of-life.

6.3.1 Whole life carbon

Cradle-to-grave assessment aligns with the concept of **whole life carbon** (WLC), which refers to the total carbon footprint associated with a product throughout its existence. By considering the entire life cycle of a product or building, including both operational and embodied carbon, decision-makers can make more informed choices to reduce its overall carbon impact.

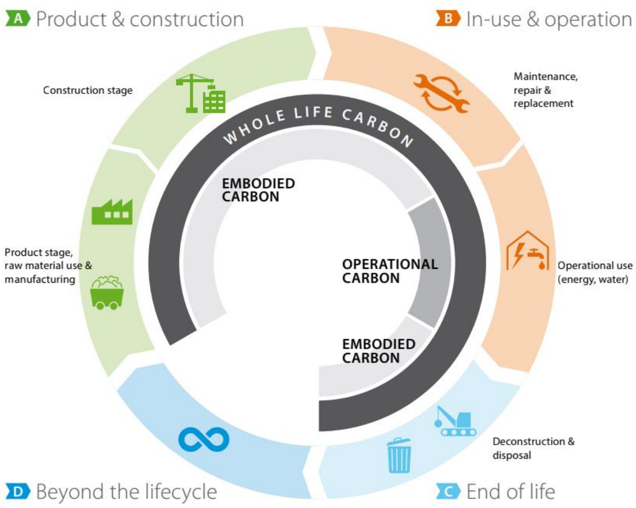


FIGURE 6.2 THE CONCEPTS OF WLC, EMBODIED AND OPERATIONAL CARBON.

6.3.1.1 Operational carbon

Operational carbon refers to the emissions associated with the ongoing use and operation of the product (Figure 2). In LCA methodology, this includes modules B1, B6 and B7. Currently, operational carbon represents the majority of emissions released through the lifetime of a building or heating product, including heat pumps and gas boilers.

6.3.1.2 Embodied carbon

Embodied carbon accounts for emissions associated with the extraction, manufacturing, transportation, construction, maintenance, repair and end of life of a product or building (Figure 2). In LCA methodology, this includes modules A1-A3, A4, A5, B2-B5, C1-C4. The importance of embodied carbon is rising, driven by two factors: the ongoing decarbonisation of the grid and the reduction of operational emissions resulting from improved efficiency.

6.3.2 Environmental Product Declaration

An Environmental Product Declaration (EPD) provides an independently verified summary of the environmental impact of a product throughout its life cycle, calculated via an LCA. An EPD includes quantitative data on various environmental indicators such as greenhouse gas emissions, energy consumption, ozone depletion potential, water usage, resource depletion and many others. EPDs are typically based on international standards, such as ISO 14025, 14040/14044, EN 15804 or ISO 21930. They are valid for five years and follow specific guidelines for conducting LCAs of the product.

There are two major types of EPDs:

- **An industry-wide, or generic EPD** covers a broad product type and applies to a group of similar products from one or more manufacturers.
- **A product-specific EPD** applies to a single product – or very similar products – from a single manufacturer. This is the most transparent approach, third party verified, and the one that Daikin is using.

The creation of EPD is based on the methodology defined by Product Category Rules (PCR) and Product-Specific Rules (PSR). PCR sets the standardised and generic rules for conducting LCAs and preparing EPDs for a product category. PSR provides additional and tailored rules specific to an individual product within that category. These are maintained by an EPD operator and verification, publication and product requirements differ from country to country. Together, PCR and PSR ensure a consistent and transparent approach to environmental assessment while allowing for customisation to address the unique aspects of each product being assessed.

Daikin supports two programme operators:

- TM65 mid-level calculation from CIBSE in the UK (Type II non-verified EPD).
- PEP (Product Environmental Profile) Ecopassport in France (Type III third party verified EPD)

TM65 focuses only on carbon impact, while PEP also covers other environmental input indicators.

PEP Ecopassport is an environmental declaration programme designed for electrical, electronic and HVAC-R (heating, ventilation, air conditioning and refrigeration) products. The program is managed by PEP Ecopassport Association, a non-profit organisation based in France. The association works with various stakeholders, including manufacturers, trade associations and environmental experts, to develop and maintain the PEP Ecopassport methodology and guidelines. Declarations are subject to independent verification by accredited third-party verification bodies to ensure the accuracy and reliability of the environmental information.

EPDs help to achieve EPD and LCA credits in certification schemes such as LEED, BREEAM and others. EPDs are also becoming required by country regulations. France has issued RE2020 environmental regulations[176] encouraging the building sector to declare its whole life carbon footprint. This regulation is a component of an ongoing initiative aimed at promoting buildings with lower energy consumption.

EPDs for France can be found in the PEP Ecopassport database or INIES database.

6.4 Case study: carbon footprint of Daikin heat pumps vs gas boiler

6.4.1 Products being compared

In this case study, we compare Daikin Altherma 3 R 180L (air-to-water heat pump) and a highly efficient gas boiler (90 % efficiency). EPDs for both products were calculated for France and verified by an independent third party. Both EPDs are available on the INIES database. The chosen products provide space and water heating and cooling.

[176] Ministère de la Transition écologique et de la Cohésion des territoires, Ministère de la Transition énergétique. (2023). Réglementation environnementale RE2020

Parameter	Heat pump	Gas boiler
Name	1 outdoor unit ERGA04EV 1 indoor unit EHVH04S18E (180L)	Reference gas boiler
Heating capacity	6 kW	18.5 kW
SCOP[177]	3.26[178]	-
Country of production	Czech Republic	Europe
Country of use	France	France
Refrigerant used	R32	-
Reference lifetime	17 years	17 years
Weight	197.5 kg including 18.7 kg of packaging	33 kg (including packaging)
Material composition	Metals: 76.1 % Plastics: 12.0 % Other: 11.9 %	Metals[179]: 64.65 % Plastics: 9.89 % Other: 26.46 %

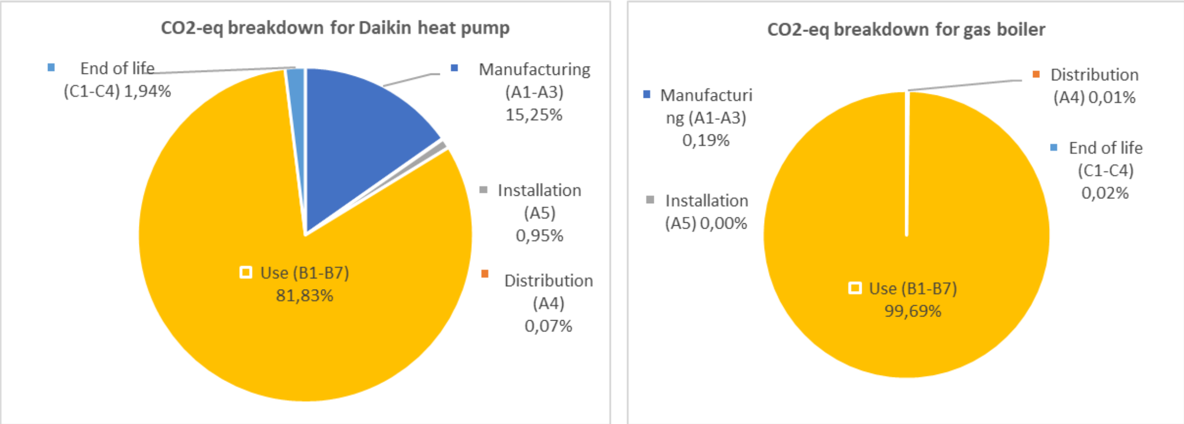


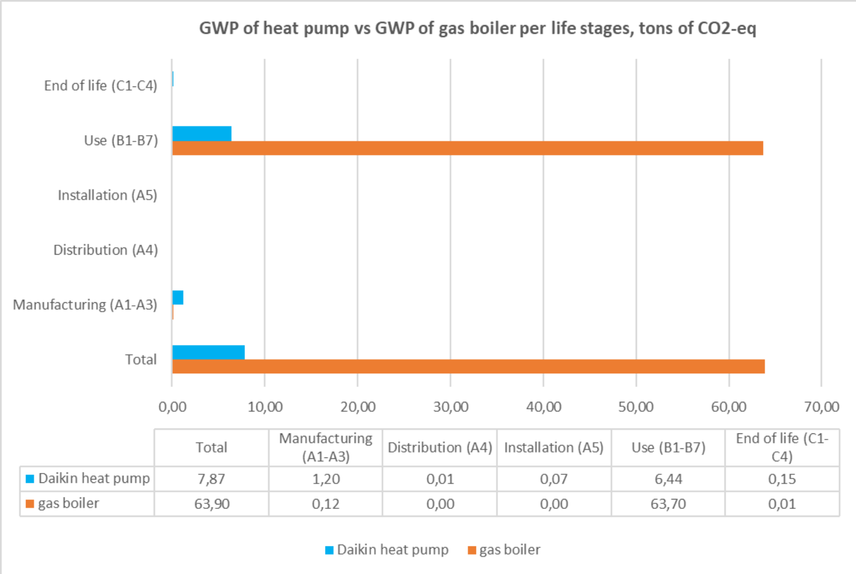
FIGURE 6.3 BREAKDOWN OF CO2-EQ PER LIFE STAGES FOR HEAT PUMP AND GAS BOILER, %

As seen from the pie charts (Figure 3), the use phase is dominant for both heat pump and gas boiler. However, for a gas boiler, it constitutes almost 100 % of the total carbon footprint due to high CO_2 emissions produced while burning gas. The use phase for this specific heat pump account for nearly 82 % of the total carbon emissions. The use phase is calculated for France, therefore France's energy mix was taken to calculate carbon emissions from electricity use. It is important to mention that precise LCA calculations and EPDs are country-specific as a country's energy mix has a big influence on the use phase and total carbon emissions. The manufacturing stage for a heat pump constitutes 15 % higher CO_2 emissions than for a gas boiler. This can be explained by the relativeness of this value: compared to high emissions during the use phase, the gas boiler manufacturing stage is almost 0 %.

[177] The Seasonal Coefficient of Performance (SCOP). Seasonal efficiency is a new way of measuring the true energy efficiency of heating and cooling technology, over an entire year. This new measure gives a more realistic indication of the energy efficiency and environmental impact of a system. The new method of rating energy efficiency is driven by the EU's Energy Related Products (ErP) Directive (the Eco-design Directive) which specifies the minimum Eco-design requirements that manufacturers must integrate into their energy-using products. More information here.
[178] The value is chosen for average climate.
[179] Materials used for the gas boiler are assumed numbers, based upon a screening and analysis of gas boilers on the European market.

6.4.2 Whole life carbon

For the analysis we used the "Contribution to global warming" environmental impact indicator translated from kg CO_2-eq to tons of CO_2-eq. The results per each life stage are presented below.



	Total	Manufacturing (A1-A3)	Distribution (A4)	Installation (A5)	Use (B1-B7)	End of life (C1-C4)
Daikin heat pump	7,87	1,20	0,01	0,07	6,44	0,15
gas boiler	63,90	0,12	0,00	0,00	63,70	0,01

FIGURE 6.4 COMPARISON OF FULL LCA FOR DAIKIN HEAT PUMP AND GAS BOILER SOURCE: OWN CALCULATIONS

The total global warming potential (GWP) of a Daikin heat pump is nearly eight times less than total GWP of gas boiler: 7.87 tons of CO_2-eq versus 63.9 tons of CO_2-eq (over a period of reference life time = 17 years). This difference is explained by the high contribution of the use phase to the total values of both products where a Daikin heat pump consumes less energy and works on electricity with lower GWP (here: France electricity mix). The rest of the phases require a closer look.

6.4.3 Embodied carbon

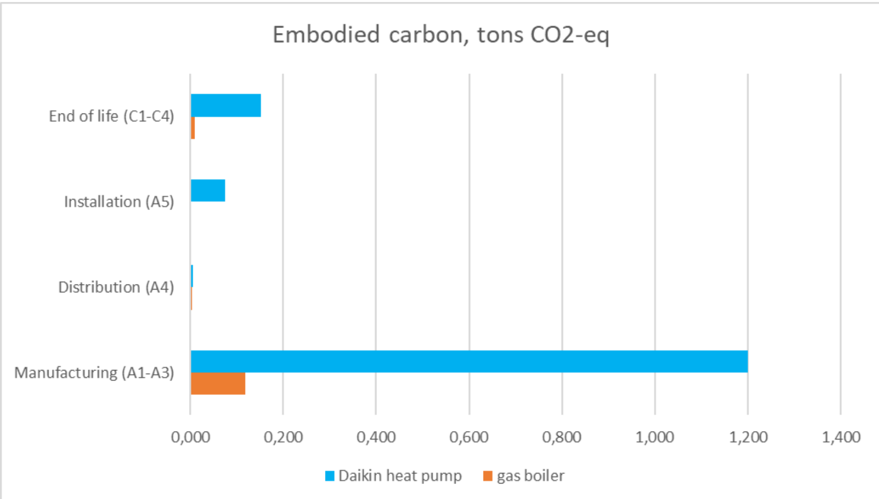


FIGURE 6.5 COMPARISON OF EMBODIED CARBON FOR DAIKIN HEAT PUMP AND GAS BOILER .SOURCE: OWN CALCULATIONS

The total embodied carbon of a Daikin heat pump is higher than a gas boiler's. This is mostly due to the bigger results for heat pump in the manufacturing and end-of-life stages: the weight of a heat pump is 197.5 kg vs 33 kg for the gas boiler (both values include packaging). Additionally, a Daikin heat pump use more printed circuit boards (PCB) than a gas boiler due to the complexity of the product. PCB has high GWP (369.83 kg CO_2-eq/ kg) which contributes greatly to the carbon footprint of manufacturing stage.

6.4.4 Operational carbon

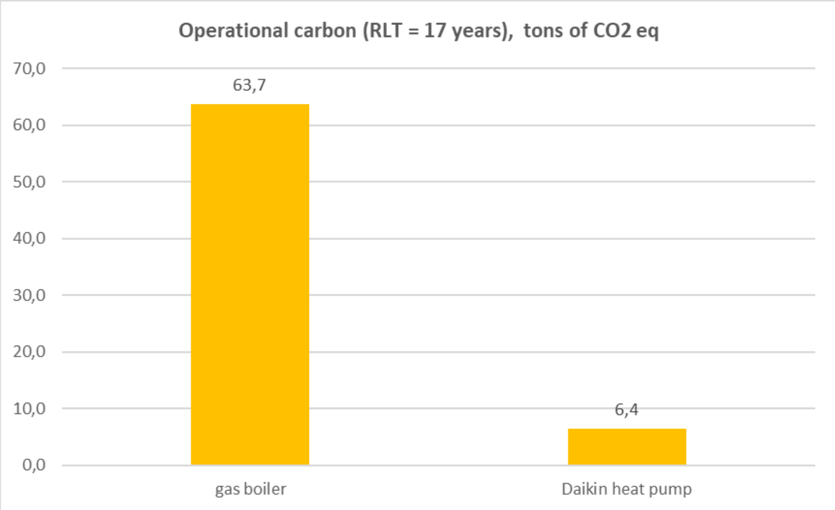


Figure 6.6 Comparison of operational carbon for Daikin HP and natural gas boiler. Source: own

Emissions from the gas boiler used in this study are almost 10 times bigger than from the heat pump. The energy use was calculated for France. The carbon footprint of the use phase of the heat pump will vary in each country due to the specific emission factor of their electricity grid.

6.4.5 Heat pump carbon emission benefits during use stage per country

Replacing a gas boiler with a heat pump will result in significant CO_2 emission savings in a typical single-family buildings in European countries. To illustrate this, we have calculated the CO_2 emissions over one year in different European markets for a typical medium-sized household with 10,000 kWh annual energy consumption – representative for the new build market. The countries considered in this study are France, UK, Italy, Spain, Netherlands, Belgium, Germany and Poland. The countries were divided into two groups based on their average minimum temperature, indicated as Td – design temperature: Td= -7 and Td= -11.6.

To estimate yearly CO_2 emissions, we need to calculate yearly electricity and gas consumption for a Daikin heat pump and reference gas boiler. Below are the parameters used to calculate their electricity consumption:

Heat pump solutions

	Td = -7°C	Td = -11,6°C
Daikin air-source heat pump	ERGA04EV	ERGA08EVH7
	EHVH04S18E6V	EHVH08S18E6V
Energy label - SH	A++	A++
Yearly heating demand for SH [kWh]	10.000	
Yearly electricity consumption [kWh]	**2,272**	**2,541**

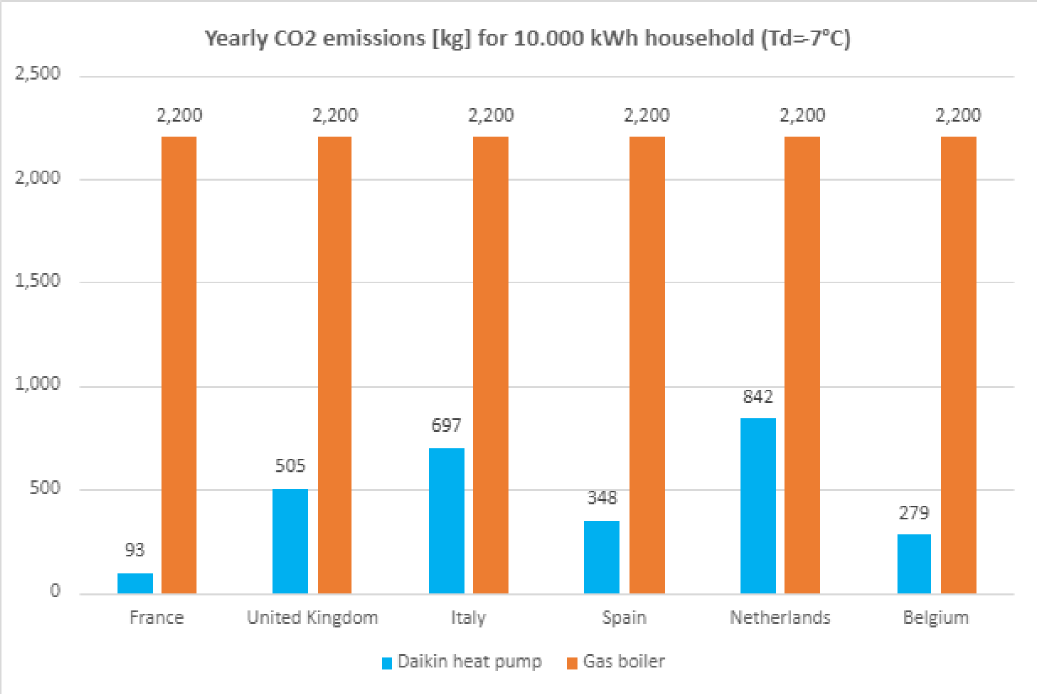
Gas boiler

Gas boiler efficiency [%]	90
Yearly heating demand for SH [kWh]	10,000
Yearly gas consumption [kWh]	**11,111**

The yearly electricity consumption was calculated by the Daikin heating solutions navigator ,which considers the application temperature of Daikin Altherma and climate condition. It is assumed for this exercise that Daikin Altherma is used in combination with underfloor heating. For climate condition Td=-7, the yearly consumption is 2,272 kWh, while for Td= -11,6, it is equal to 2,541 kWh. **The yearly gas consumption** was calculated by dividing the yearly heating demand with the gas boiler efficiency, which resulted in 11,111 kWh.

To proceed with **yearly CO_2 emissions** per country, we need to multiply the yearly energy consumption by the **CO_2 emission factor (EF).** This is a coefficient that allows us to convert human activity data into greenhouse gas – in this case CO_2 – emissions. The EF for natural gas is taken as 0.198 kg/kWh for each country. The EFs for electricity vary per country since electricity is produced from different sources like fossil fuels, nuclear power, renewables etc.

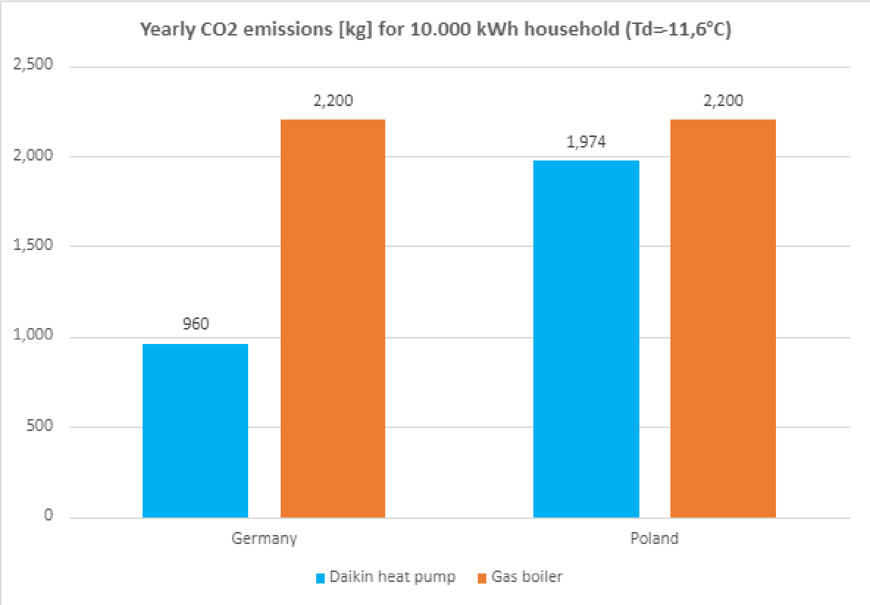
Countries with Td=-7°C



	Daikin heat pump		Gas boiler		Absolute Delta	Relative Delta
	CO_2 EF electricity [kg/kWh]	Yearly CO_2 emissions [kg]	CO2 EF gas [kg/kWh]	Yearly CO_2 emissions [kg]	Yearly difference in CO_2 emissions [kg]	Times less of yearly CO_2 emissions
France	0.041	93	0.198	2,200	2,107	24
United Kingdom	0.2223	505	0.198	2,200	1,695	4
Italy	0.3069	697	0.198	2,200	1,503	3
Spain	0.1533	348	0.198	2,200	1,852	6
Netherlands	0.3704	842	0.198	2,200	1,358	3
Belgium	0.1226	279	0.198	2,200	1,921	8

FIGURE 6.7 COMPARISON OF YEARLY CO2 EMISSIONS FROM DAIKIN HEAT PUMP AND GAS BOILER IN COUNTRIES WITH TD= -7. SOURCES:OWN CALCULATIONS

Countries with Td=-11.6°C



	Daikin heat pump		Gas boiler		Absolute Delta	Relative Delta
	CO2 EF electricity [kg/kWh]	Yearly CO2 emission [kg]	CO2 EF gas [kg/kWh]	Yearly CO2 emission [kg]	Yearly difference in CO2 emissions [kg]	Times less of yearly CO2 emissions
Germany	0.3776	960	0.198	2,200	1,240	2.3
Poland	0.7766	1,974	0.198	2,200	226	1.11

FIGURE 6.8 COMPARISON OF YEARLY CO2 EMISSIONS FROM DAIKIN HEAT PUMP AND GAS BOILER APPLIED IN COUNTRIES WITH TD= -11.6. SOURCES: OWN CALCULATIONS

As seen from the graphs, yearly emissions from the use of heat pumps are significantly lower than emissions from gas boiler providing the same air and water heating and cooling for the household in all the countries studied. Since the EFs of electricity are only expected to decrease in the near and long term due to investments in renewable energy by the EU and UK, heat pumps will also continue to have less use phase emissions, helping them to achieve their climate goals. Below is more detailed analysis of emission savings per country:

Thanks to the lowest EF of electricity grid in the study (0.041 kg/kWh), a Daikin heat pump in **France** saves the most CO_2 emissions among the countries studied. Installing a Daikin heat pump instead of a gas boiler in France can help decrease yearly CO_2 emissions by 2,107 kg: 24 times less carbon intensive during the use phase.

A Daikin heat pump installed instead of a gas boiler in the **UK** saves 1,695 kg of CO_2 every year and is four times more carbon efficient than a gas boiler during the use phase.

A Daikin heat pump installed instead of a gas boiler in **Italy** saves 1,503 kg of CO_2 every year and is three times more carbon efficient than a gas boiler during the use phase.

A Daikin heat pump installed instead of a gas boiler in **Spain** saves 1,852 kg of CO_2 every year and is six times more carbon efficient than a gas boiler during the use phase.

A Daikin heat pump installed instead of a gas boiler in the **Netherlands** saves 1,358 kg of CO_2 every year and is three times more carbon efficient than a gas boiler during the use phase.

A Daikin heat pump installed instead of a gas boiler in **Belgium** saves 1,921 kg of CO_2 every year and is eight times more carbon efficient than a gas boiler during the use phase.

A Daikin heat pump installed instead of a gas boiler in **Germany** saves 1,240 kg of CO_2 every year and is 2.3 times more carbon efficient than a gas boiler during the use phase.

In **Poland**, with the highest EF for electricity grid (0.7766 kg/kWh), the yearly carbon footprint of heat pump use is 11 % lower than a gas boiler, with savings of 226 kg every year. This is an advancement in decarbonisation of the heating sector in Poland, which will only accelerate with the transition from electricity generated from coal combustion (most used in Poland) to less carbon intensive alternatives.

6.5 Conclusion

The urgency of addressing climate goals and taking immediate action is becoming increasingly apparent. Investment in technologies that align with these goals is crucial as we look ahead. In the EU, the widespread adoption of heat pumps holds significant potential in achieving the region's decarbonisation and climate objectives. By significantly reducing greenhouse gas emissions, enhancing energy efficiency and facilitating the transition to renewable energy sources, heat pumps can play a pivotal role in shaping a sustainable future. This is supported by comprehensive life cycle assessments and the production of environmental product declarations, which are readily available and can be used to evaluate the sustainability of heat pumps. A case study comparing heat pumps to gas boilers further emphasises the superiority of heat pumps, especially as countries increasingly rely on renewable energy and see a decrease in the carbon intensity of the electricity grid. With these advances, heat pumps emerge as a climate-positive solution with far-reaching environmental benefits over traditional gas boilers.

To share your comments with the authors or for additional information, email heatpumpadoptioneuhsbu@daikin.eu

6.6 Environmental impact of refrigerant

6.6.1 Definition and function of refrigerants

Refrigerants are fluid substances or mixtures used in a heat pump and refrigeration cycle to cool or heat a space. They capture heat and release it to another space using the thermodynamic phenomena of phase changes, in which a fluid changes to a gas or vice-versa. They usually undergo transitions from a liquid to a gas and back again [180].

Refrigerant is essential for heat pumps. It circulates through the heat pump to absorb heat from the heat source and transport it to the heat sink where the heat is released. See image below[181].

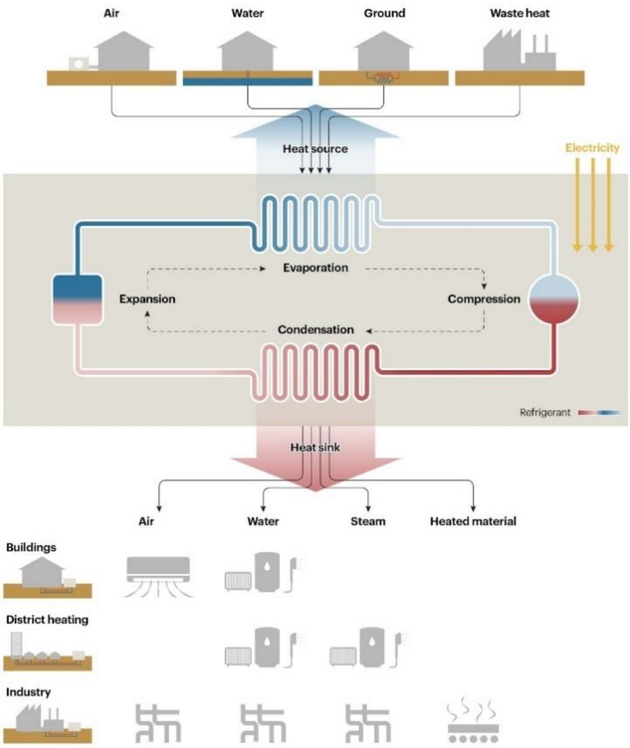


FIGURE 6.9 HOW A HEAT PUMP WORKS SOURCE: IEA THE FUTURE OF HEAT PUMPS (2022)

[180] Daikin Applied Europe An insight on refrigerants and Daikin philosophy (2020, July 2)
[181] IEA (2022), The Future of Heat Pumps, IEA, Paris, License: CC BY 4.0

There are three major types of refrigerants currently used in the market[182]:

- Hydrofluorocarbons or HFCs (e.g. R-410A, R-134a, R-32)
- Hydrofluoro-olefins or HFOs/HFO blend (e.g. R-513A, R-1233zd(E))
- Natural refrigerants (e.g. propane/R-290, CO2/R-744)

The full list of refrigerants used by Daikin and their properties can be found here.

6.6.2 Refrigerant choice

Each application has different characteristics, so there is no one-size-fits-all solution. It is necessary to select the appropriate refrigerants for each application based on an overall assessment. Daikin believes it is necessary to assess four basic factors comprehensively: safety, environmental impact, energy efficiency and cost-effectiveness[183].

6.6.2.1 Safety

A refrigerant must be safe to use through the entire lifecycle of the equipment. This includes transport, storage, installation, use, servicing, recovery and recycling. This means that possible hazards such as toxicity or flammability characteristics, as well as the risk of human error, must be evaluated for each application. While non-flammable and low-toxicity refrigerants may have safety benefits, they may not be ideal from an environmental point of view.

In addition, some refrigerants may be acceptably safe for one type of equipment but not for others. Thorough risk assessments are therefore needed for each application.

6.6.2.2 Environmental impact

A core consideration in refrigerant choice is environmental impact. This includes a refrigerant's ozone depleting potential (ODP)[184] and its potential global warming impact: this is expressed as its CO_2 equivalent, which is the refrigerant quantity multiplied by its global warming potential (GWP)[185].

Heat transfer capacity and heat exchange efficiency of refrigerants are important characteristics that result in reductions in refrigerant quantity and allow more compact equipment design. Environmental considerations also include the impact of the refrigerant production process and a refrigerant's potential to be recycled and reused.

6.6.2.3 Energy efficiency

Daikin carefully considers a refrigerant's potential to improve the energy efficiency of its equipment in both cooling and heating functions across an extreme range of climate conditions, including very hot and very cold environments. This is an important consideration, as energy consumption for cooling, heating and refrigeration has a substantial impact on the total energy consumption of buildings and countries.

Depending on how electricity is generated in each country, its efficient use has a large indirect impact on climate change by reducing CO_2 emissions. Energy efficiency is therefore critical in choosing the right refrigerant for a given application.

6.6.2.4 Cost-effectiveness

It is important to provide consumers access to affordable solutions for their homes and businesses. In addition, to reduce the environmental impact, cost-effectiveness should be considered in terms of dissemination. For instance, is the refrigerant easy and inexpensive to install and maintain? Does it allow for compact cost-efficient designs to minimise investment costs? Does it contribute to reducing overall system operation and maintenance costs? Is recycling feasible and cost-effective? Would possible risk mitigation measures be cost-effective? These are factors to consider when selecting cost-effective refrigerants.

In this paper we will focus on the environmental impacts of the refrigerant.

6.6.3 Environmental impacts: ODP and GWP

6.6.3.1 Ozone depletion potential

Among the first commonly used refrigerants were chlorofluorocarbons (CFCs). However, in the 1980s it was found that they contributed to ozone layer depletion alongside nearly 100 synthetic chemicals. When released to the

[182] FAQ | Impact of refrigerants | Influence | Daikin Global. (n.d.).
[183] Key considerations for refrigerant choice | Influence | Daikin Global. (n.d.).
[184] Ozone-depleting potential: A value indicating the intensity of ozone layer destruction by various substances based on the ODP of CFC-11 as a standard.
[185] Global warming potential: A value indicating the degree of contribution to global warming of various GHGs based on CO2 as a standard.

atmosphere, those chemicals damage the stratospheric ozone layer, the shield that protects humans and the environment from harmful levels of ultraviolet radiation from the sun[186].

In 1987, with the adoption of the Montreal Protocol, restricting the production, consumption and trade of particular substances in order to protect the ozone layer, CFCs, having high ODP, were completely abandoned and hydrochlorofluorocarbons (HCFCs, an alternative to CFCs) were phased out almost entirely in developed countries and will be by 2030 in developing countries. Aligned measures under the Montreal Protocol successfully restrained ODP, which is projected to recover by the middle of this century[187].

Currently used and developed refrigerants must have zero ODP value.

6.6.3.2 Global warming potential

To eliminate impact on the ozone layer, HFC refrigerants have been used as an alternative to HCFCs because of their zero ODP value. However, HFCs and most conventional refrigerants absorb infra-red radiation and therefore trap heat, and thus are greenhouse gases[188] that contribute to climate change. The second most important environmental criteria of refrigerants became their GWP, a relative measure that compares the warming potential of a particular gas to CO_2 over a specific time period, usually 100 years. The higher the GWP value, the more potent the greenhouse gas is in terms of its ability to trap heat compared to CO_2.

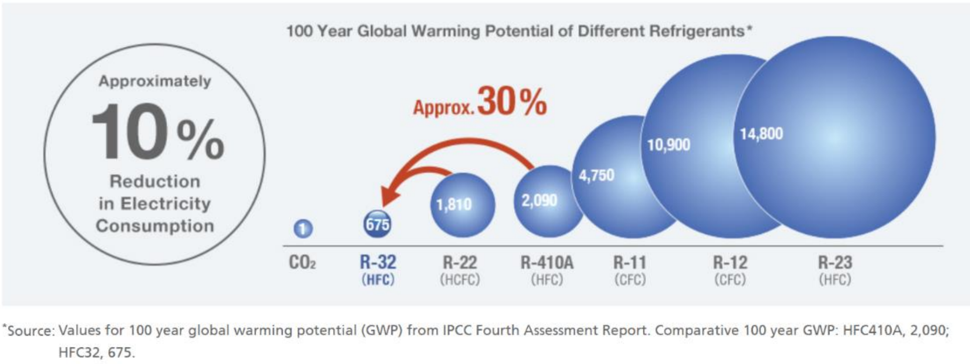


FIGURE 6.10 GWPS OF VARIOUS REFRIGERANTS[189]. SOURCE: DAIKIN GLOBAL

As seen from the infographic, the GWP of R410A, a commonly used HFC refrigerant, is 2,088, while the newer refrigerant R-32 has about three times less GWP: 675. The environmental impact of refrigerants also depends on factors such as leakage rates, energy efficiency of the equipment using them, and proper handling during installation, maintenance and disposal.

Daikin has identified R-32 as a very beneficial refrigerant for single and multi-split air conditioners, packaged air conditioners and heat pumps. Daikin believes the transition to R-32 will help to meet both the HFC phase-down schedule and the HCFC phase-out schedule (see "Commitment to use lower GWP refrigerants"). If all currently used R-410A refrigerant was replaced with R-32, the total CO_2 equivalent impact of HFCs could be reduced by up to 800 million tons of CO_2 compared to business-as-usual scenarios, with a significantly reduced amount of indirect CO_2 emissions due to lower energy consumption. We will continue to challenge ourselves in the technical development to expand the range of our products using R-32 .

6.6.4 Refrigerant in the LCA approach

As described in the section "Carbon footprint of heat pumps", Daikin performs cradle-to-grave LCA of its products. We assess the environmental impacts of our products from manufacturing to waste disposal. Within the LCA approach, refrigerant is considered at the following stages:

- Manufacturing (A1-A3)

[186] UN Environment Programme. (n.d.). About Montreal Protocol.
[187] UN Environment Programme. (n.d.). About Montreal Protocol.
[188] Wuebbles, D. J. (1994). The role of refrigerants in climate change. International Journal of Refrigeration-revue Internationale Du Froid, 17(1), 7–17.
[189] R-32, The Most Balanced Refrigerant | Benefits of Daikin Technology | Daikin Global. (n.d.).

- Momentary leakage of refrigerants during manufacturing stage is taken as 2 % on average.
- Installation (A5)
  - The installation resources included are copper tubes for refrigerant.
  - In accordance with regulation 1516/2007, all necessary measures are taken to avoid momentary emissions. Thus, refrigerant leaks during the installation stage are considered zero.
- Use phase (B1-B7)
  - The impacts of refrigerant leakage, equipment maintenance and refrigerant refilling.
- End of life (C1-C4)
  - The EOL scenario is based on the methodology described in PSR-0013-ed2.0-EN-2019 12 06.
  - 90 % of the total refrigerant is recovered at the EOL and the rest is considered direct emission. Of the refrigerant recovered, 10 % is incinerated without energy recovery and 90 % is regenerated for reuse.
- Beyond the life cycle (D)
  - Refrigerant recovery and recycling.

In terms of carbon footprint, refrigerants are in the top 5 most contributing materials used in heat pumps, with high carbon intensive materials such as printed circuit board and metals (aluminium, steel, copper).

Among all life cycle stages, the use phase (B1-B7) is currently dominant. B1-B7 stage considers a product's energy use over the reference life time (e.g. 22 years for Daikin heat pumps), refrigerant leakage (default value of 2 %) and refilling (the refill threshold is 90 % of the total load, the number of refills is usually three). While refrigerant refilling contributes to less than 1 % of a product's total carbon footprint, refrigerant leakage during use phase might constitute from 2 % up to 19 % of the footprint: the higher the GWP of refrigerant, the greater the impact.

6.6.5 No leakage, no carbon emission

As mentioned, the environmental impact of refrigerants also depends on factors such as leakage rates, energy efficiency of the equipment using them and proper handling during installation, maintenance and disposal. The standard refrigerant leakage rate considered in LCA for Daikin heat pumps is 2 % (defined by PSR rules[190]). However, if refrigerant is safely contained, there is no leakage and therefore, refrigerant is not released into the atmosphere.

Daikin follows a comprehensive approach to decreasing refrigerant's impact on environment and focuses on leakage prevention and recovery.

- Daikin products are constructed in such a way to prevent refrigerant leakage e.g. by limiting vibrations of piping and by decreasing influence of the environment that might cause aging of coil materials.
- Most units are of hermetic type and use the Daikin Tightfit[191] connection, which is a connection of refrigerant piping without brazing or using special tools. It meets stringent safety requirements and provides leak-free tightness.
- Every unit produced goes through a thorough leakage test before it is charged with refrigerant and leaves the manufacturing site.
- Units are installed by certified technicians who perform their work in accordance with the latest F-gas regulation (valid in the EU) to ensure no leakage happens at the installation phase.
- At the end-of life stage, Daikin provides the best refrigerant treatment available in the region.

6.6.6 Refrigerant treatment

6.6.6.1 Why assess the carbon footprint of refrigerant treatment methods?

As a leading provider of heating, cooling, ventilation, air purification, service and refrigeration solutions, we are committed to reducing our greenhouse gas emissions to net zero by 2050. To achieve this, we assess the **whole life cycle of our equipment**, including materials, factory, use, end of life etc.

[190] Product-specific rules (PSR). PSR is an addition to product category rules (PCR). PCR sets the standardised and generic rules for conducting LCAs and preparing EPDs for a product category. PSR provides additional and tailored rules specific to an individual product within that category. Daikin follows PSR-0013-ed2.0-EN-2019 12 06.
[191] Daikin Europe N.V. (n.d.). Tightfit. Fireless copper pipe connector designed for HVAC equipment.

Part of this involves evaluating and comparing the impact of two refrigerant treatment methods after recovery: refrigerant reclamation for reuse versus refrigerant destruction and virgin production. A third party, TCO2 Co. Ltd, has assessed[192] the environmental impact of these two methods. TCO2 Co. Ltd is an independent Japanese consulting firm focusing on sustainability insights and providing environmental impact and cost calculation tools. The assessment was conducted in 2022 and validated by Prof Norihiro Itsubo from Tokyo City University.

Assessed treatments methods

1. Treating refrigerant as waste: Destruction of used refrigerant and virgin production of new refrigerant.
2. Treating refrigerant as a resource: Reclaimed refrigerant for reuse.

Results

When comparing method 1with method 2, the study shows that the carbon footprint of reclaimed refrigerant reuse lies between 72 % and 90 % less than that of virgin refrigerant production, depending on the refrigerant. Expressed in kg CO_2-eq/kg of refrigerant, the study shows a reduction of **72 % for R-410A**, and **90 % for R-134a and R-32**. The assessment is based on averaged primary data from seven locations in Japan and Europe for R-410A and R-134a. For R-32, it is based on the average of primary data and estimated data based on R-410A.

The study took into account the impact of the production, destruction and reclamation process, as well as the impact of collection, transport etc. related to this activity.

	Scenario	Region	Treatment detail	Total (kgCO2eq/kg of refrigerant)	Destruction	Avoid HF production	Refrigreant production
R-410A	Destruction + virgin production	Europe	Gaseous/fume oxiation	11.35	1,70	-0,70	10.35
	Reclamation	Europe	Batch rectification	3.2 72% REDUCTION			
R-134a	Destruction	Europe	Gaseous/fume oxiation	11.47	1.68	-0,68	10.48
	Reclamation	Europe	Batch rectification	1.12 90% REDUCTION			
R-32	Destruction	Japan	Superheated steam incineration	11.54	3.77	0	7.77
	Reclamation	Japan	Batch distillation/Simple distillation	1,20 90% REDUCTION			

Graphic: Comparison of results of the impact of reclaimed refrigerant production vs. virgin refrigerant production for R-410A, R-134a, R-32, expressed in kgCO$_2$eq/kg of refrigerant

FIGURE 6.11 FROM ASSESSING THE CARBON FOOTPRINT OF RECLAIMED REFRIGERANT FOR REUSE AND VIRGIN REFRIGERANT PRODUCTION (DAIKIN EUROPE, 2023) pdf

6.6.7 Daikin Loop for refrigerant recycling

Loop by Daikin is our revolutionary refrigerant programme. It is an essential part of our commitment to creating a sustainable future. In 2019, Daikin established its own refrigerant reclamation facility in Germany.

Recover, Reclaim, Reuse form the core principle of our new all-in-one Loop by Daikin service.

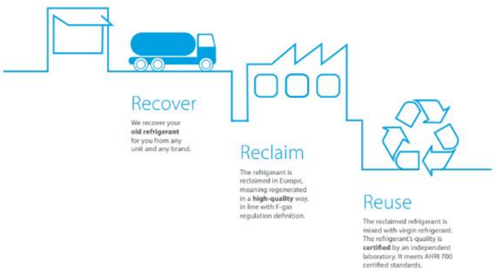


FIGURE 6.12 SOURCE: DAIKIN

[192] Assessing the carbon footprint of reclaimed refrigerant for reuse and virgin refrigerant production (Daikin Europe, 2023)

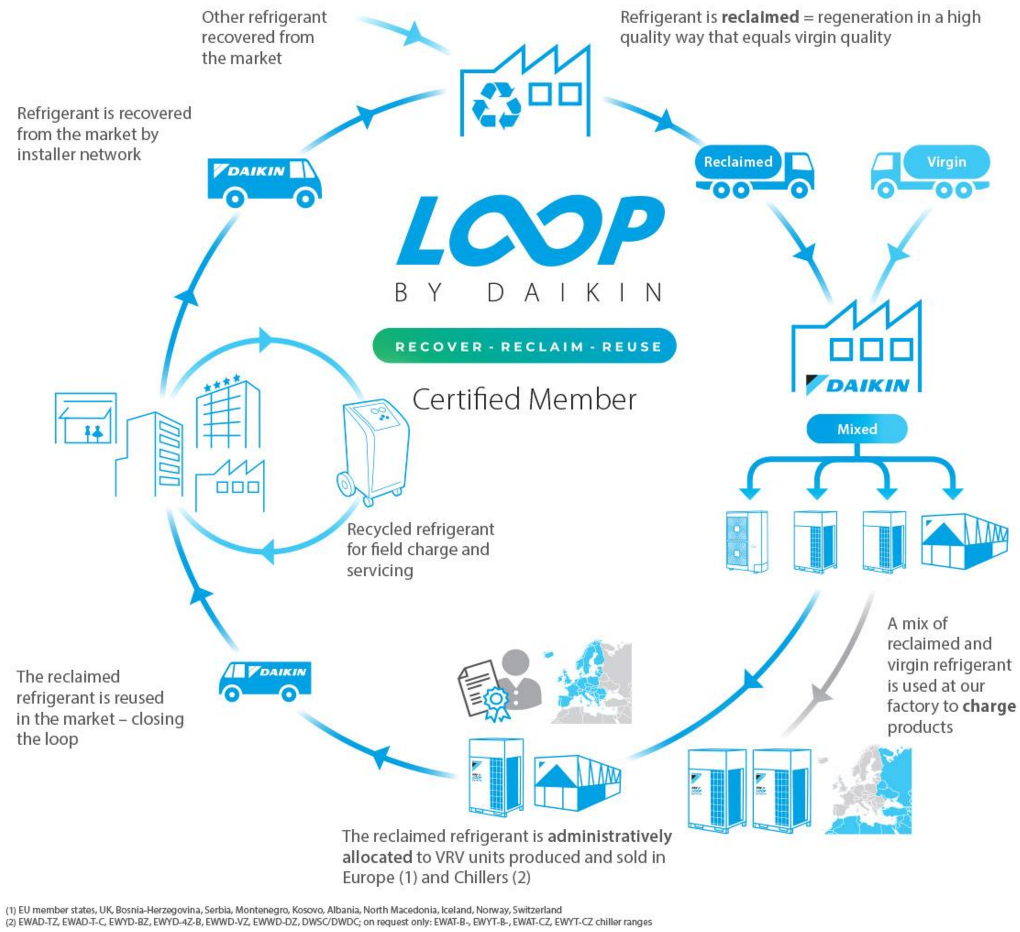


FIGURE 6.13 SOURCE: DAIKIN

Daikin Loop helps to avoid the production of more than 400,000 kg of virgin refrigerant every year. More than 20,000 Loop by Daikin Variable Refrigeration Volumes (VRV) units (using reclaimed refrigerant) have already been sold[193].

6.6.7.1 Scope of LOOP by Daikin

Countries

Loop by Daikin is currently applicable only for units sold in EU member states, UK, Bosnia-Herzegovina, Serbia, Montenegro, Kosovo, Albania, North Macedonia, Iceland, Norway and Switzerland.

Refrigerants

- R-410A
- R-134a
- R-32 (Daikin Loop for R-32 refrigerant is currently only available on request and on a project basis for chillers/heat pumps produced in Italy (EWAT-B-, EWYT-B-, EWAT-CZ, EWYT-CZ).)

Products

The Daikin Loop programme currently covers multiple VRV units (including VRV + heat pump products) and chillers (see full list in Annex X). The recovery programme for low GWP refrigerant R32, used in new heat pump products, is under consideration. Daikin uses a mix of reclaimed and virgin refrigerant to charge new products. It is the only

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[193] Loop by Daikin. (n.d.). Daikin website.

manufacturer actively promoting and supplying units with reclaimed refrigerants, for a wide range of products, from screw and scroll compressor units to centrifugal compressor machines.

6.6.8 Commitment to use lower GWP refrigerants

After the conclusion of the Paris Agreement in 2015, the Montreal Protocol parties agreed to phase down HFCs in CO_2 equivalent under the Kigali Amendment in October 2016. The Kigali Amendment entered into force in January 2019 and provides a roadmap (see Figure below) for gradual elimination of refrigerants with high GWP.

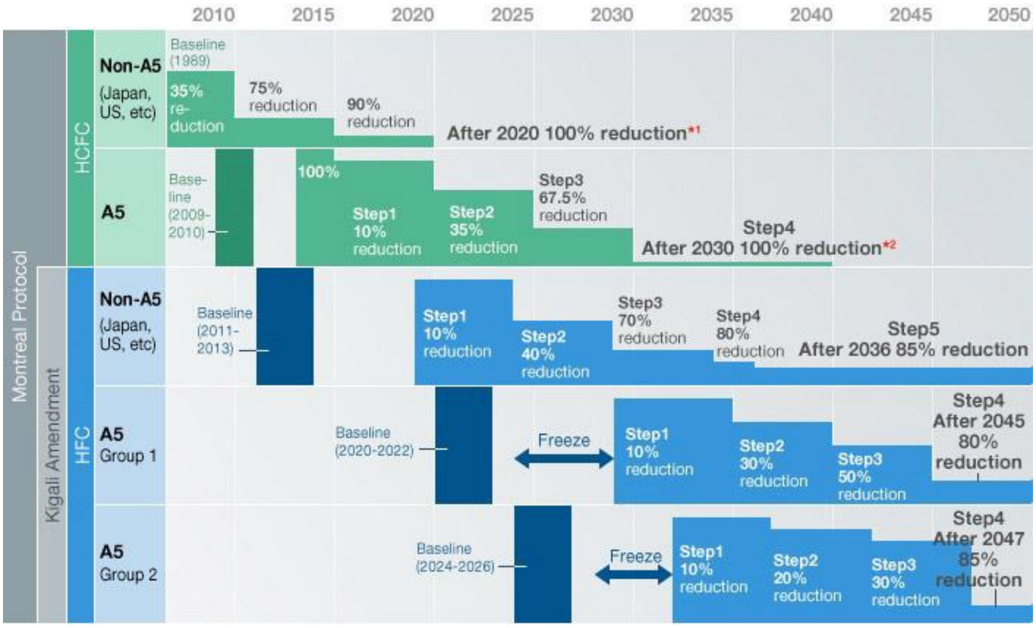

FIGURE 6.14 HCFC PHASE-OUT AND HFC PHASE-DOWN SCHEDULE IN MONTREAL PROTOCOL. SOURCE: DAIKIN GLOBAL "REASONS THAT DAIKIN ADDRESSES THE ENVIRONMENTAL IMPACT OF REFRIGERANTS"

Conversion to lower GWP refrigerants is essential to achieve the goals set in the Paris Agreement and reach global climate goals. Lower GWP refrigerants are used more every year. In 2011, Daikin began offering free access to multiple patents related to the production of equipment using R-32 refrigerant to help curb global warming.

6.6.8.1 Daikin's position on the Kigali Amendment

Daikin welcomes the Kigali Agreement for an HFC phase -down in CO_2 equivalent under the Montreal Protocol and follows a comprehensive approach to choosing refrigerants that have no impact on the ozone layer and a lower global warming impact.

- Daikin is aligned with the Kigali Amendment for an HFC phase-down under the Montreal Protocol.
- The main tenet of Daikin's policy is diversity of refrigerants and reducing impact via a lifecycle approach.
- Daikin has identified R-32 as a very beneficial refrigerant for single and multi-split air conditioners, packaged air conditioners and heat pumps.
- Daikin believes the transition to R-32 will help to meet both the HFC phase-down and HCFC phase-out schedule. We are in the process of evaluating and identifying suitable refrigerants for other applications.
- To mitigate future global climate change, it is important to take a "sooner, the better" approach. As soon as the most balanced and feasible solution for an application is found, Daikin will commercialise and disseminate the technology to contribute to efforts to mitigate global climate change.

6.7 Conclusions

Refrigerants are essential for heat pumps, allowing them to efficiently transfer heat and satisfy user demands for air and water heating and cooling. Refrigerants are carefully chosen for each application based on an overall assessment. In this assessment, Daikin considers four basic factors: safety, environmental impact, energy efficiency and cost-effectiveness. The current most suitable solution for Daikin heat pumps is R-32 refrigerant with GWP three times lower than its predecessors. Our Daikin Loop programme gives new life to old refrigerants.

Daikin fully supports the 2016 Kigali Amendment to the Montreal Protocol. We will continue to challenge ourselves technically to expand the range of our products using R-32 and continue developing appropriate refrigerants for each application with a lower GWP.

To share your comments with the authors or for additional information, email heatpumpadoptioneuhsbu@daikin.eu

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Bibliography

Foreword

Legal documents

[1] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions REPowerEU Plan COM/2022/230 final

Section 1: Impact of heat pump installation on property value

Legal documents

[6] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast)[2010]OJ L 153/13

[8] DIN V4108-6 Wärmeschutz und Energie-Einsparung in Gebäuden - Teil 6: Berechnung des Jahresheizwärme- und des Jahresheizenergiebedarfs

[9] DIN V4701-10 Energetische Bewertung heiz- und raumlufttechnischer Anlagen - Teil 10: Heizung, Trinkwassererwärmung, Lüftung

[10] DIN V18599 Energetische Bewertung von Gebäuden - Berechnung des Nutz-, End- und Primärenergiebedarfs für Heizung, Kühlung, Lüftung, Trinkwarmwasser und Beleuchtung - Teil 1: Allgemeine Bilanzierungsverfahren, Begriffe, Zonierung und Bewertung der Energieträger

[11] Gesetz zur Vereinheitlichung des Energieeinsparrechts für Gebäude und zur Änderung weiterer Gesetze Vom 8. August 2020

[12] Richtlinie für die Bundesförderung für effiziente Gebäude – Einzelmaßnahmen (BEG EM) vom 9. Dezember 2022 (Fundstelle: BAnz AT 30.12.2022 B1)

[14] Code de la construction et de l'habitation

[15] LOI n° 2018-1021 du 23 novembre 2018 portant évolution du logement, de l'aménagement et du numérique

[16] Décret n° 2021-19 du 11 janvier 2021 relatif au critère de performance énergétique dans la définition du logement décent en France métropolitaine

[17] Décret n° 2002-120 du 30 janvier 2002 relatif aux caractéristiques du logement décent pris pour l'application de l'article 187 de la loi n° 2000-1208 du 13 décembre 2000 relative à la solidarité et au renouvellement urbains

[21] SAP 10.2: Government's standard assessment procedure for energy rating of dwellings: Version 10.2 (11-04-2023)

[22] Appendix S: Reduced Data SAP for existing dwellings

[23] Ofgem Energy Company Obligation (ECO4) Guidance: Delivery V1.1

[27] Le norme tecniche di riferimento per la stima delle prestazioni energetiche degli edifici UNI/TS 11300

[28] Decreto legislativo 19 agosto 2005, n. 192 Attuazione della direttiva 2002/91/CE relativa al rendimento energetico nell'edilizia. (GU Serie Generale n.222 del 23-09-2005 - Suppl. Ordinario n. 158)

[35] Real Decreto 235/2013, de 5 de abril, por el que se aprueba el procedimiento básico para la certificación de la eficiencia energética de los edificios.

[37] Ley Orgánica 2/2006, de 3 de mayo (BOE del 4 de mayo), de educación (LOE)

[38] Real Decreto 1627/1997, de 24 de octubre, por el que se establecen disposiciones mínimas de seguridad y de salud en las obras de construcción.

[39] Dz.U. 2014 poz. 1200 Ustawa [act] z dnia 29 sierpnia 2014 r. o charakterystyce energetycznej budynków

[40] Rozporządzenie Ministra Infrastruktury i Rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

[41] Dz.U.2015.376 Rozporządzenie [Ordinance] ministra infrastruktury i rozwoju z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

[43] Dz.U.2015.376 ROZPORZĄDZENIE [Ordinance] MINISTRA INFRASTRUKTURY I ROZWOJU 1 z dnia 27 lutego 2015 r. w sprawie metodologii wyznaczania charakterystyki energetycznej budynku lub części budynku oraz świadectw charakterystyki energetycznej

[71] LOI n° 2021-1104 du 22 août 2021 portant lutte contre le dérèglement climatique et renforcement de la résilience face à ses effets (1)

[90] DECRETO-LEGGE 19 maggio 2020, n. 34 Misure urgenti in materia di salute, sostegno al lavoro e all'economia, nonche' di politiche sociali connesse all'emergenza epidemiologica da COVID-19. (20G00052) (GU Serie Generale n.128 del 19-05-2020 - Suppl. Ordinario n. 21)note: Entrata in vigore del provvedimento: 19/05/2020

Web pages

[7] European Commission – DG Energy: Certificates and inspections

[18] Diagnostic de performance énergétique – DPE; Ministère de la Transition écologique et de la Cohésion des territoires, Ministère de la Transition énergétique

[19]Energy balance – Engie.fr

[24] Gemserv – part of Talan International Consulting Group

[26] UK findings of the IEE funded project Episcope

[29] Acea Energia - Nuova classificazione energetica edifici: cos'è e come migliorarla

[30] Descrizione dell'edificio di riferimento e parametri di verifica – Requisiti minimi Appendice A

[31] Davide Rosa – Studio tecnico Home page

[32] Edilclima Engineering & Software – About us

[36] Calificación de la eficiencia energética de los edificios – Ministerio de Industria, Energía y Turismo

[45] Nederlandse technische afspraak NTA 8800:2023 (nl) Energieprestatie van gebouwen - Bepalingsmethode

[46] Woonbewust.com - Het nieuwe energielabel voor woningen. Wat verandert er in 2021?

[48] Energy performance certificates (Flanders) – Belgium.be

[49] Energy performance certificate for a dwelling – Service Public de Wallonie

[50] EPB certificate for residential units – Brussels-Capital Region

[51] What is seasonal efficiency (SCOP and SEER)-Daikin.eu

[64] Collins Dictionary, definition of "utility function"

[75] Knight Frank "Improving your EPC rating could increase your home's value by up to 20%" (2022)

[77] Buyers paying significantly more for homes with low-carbon technology, as energy prices rise (2022)

[85] NVM "De waarde van het energielabel – investeren in duurzaamheid loont steeds meer" (2022)

[86] NVM "Effect van beter energielabel op woningwaarde groter dan ooit" (2023)

[92] REbuild 2023: l'efficienza energetica della casa ne aumenta il valore fino al 40% (2023)

Official Reports

[53] BPIE Energy performance certificates across the EU (2014)

[69] Notaires de France "*La valeur verte des logements en 2021*" (2022)

[73 – 74] Energy performance ratings and house prices in Wales: An empirical study (2016)

[76] Better home, cooler planet: how low-carbon technologies can reduce bills and increase house value (2022)

[84] Tilburg and Maastricht University "Rood energielabel doet steeds meer pijn bij woningverkoop" (2021)

[93] European Commission (DG Energy) "Energy performance certificates in buildings and their impact on transaction prices and rents in selected EU countries" (2013)

Scientific research

[42] A. Alsabry, K. Szymański, B. Michalak "Energy, Economic and Environmental Analysis of Alternative, High-Efficiency Sources of Heat and Energy for Multi-Family Residential Buildings in Order to Increase Energy Efficiency in Poland" Alsabry, Szymánski, Michalak (2023)

[54] D.Brounen, N.Kok, J. Menne "Energy Performance Certification in the Housing Market Implementation and Valuation in the European Union" (2009)

[55] D.Popescu, S. Bienert "Impact of energy efficiency measures on the economic value of buildings" (2012)

[56] M. Hyland, R.C. Lyons, S. Lyons "The value of domestic building energy efficiency — evidence from Ireland" (2013)

[57] A. Pérez-Alonso, A. Ramos, S. Silva "Valuing Energy Performance Certificates in the Portuguese Residential Sector" (2015)

[58] S. Stanley, R.C. Lyons, S. Lyons "The price effect of building energy ratings in the Dublin residential market" (2015)

[59] F. Fuerst, E. Oikarinen, O. Harjunen "Green signalling effects in the market for energy-efficient residential buildings" (2016)

[60] M. H. Wahlström "Doing good but not that well? A dilemma for energy conserving homeowners" (2016)

[61] P. Taltavull, I. Anghel, C. Ciora "Impact of energy performance on transaction prices: Evidence from the apartment market in Bucharest" (2017)

[62] A. Khazal, O.J. Sønstebø "Valuation of energy performance certificates in the rental market – Professionals vs Non professionals" (2020)

[63] Cajias, Fuerst, and Bienert "*Tearing down the information barrier: the price impacts of energy efficiency ratings for buildings in the German rental market*" (2019)

[65] Taruttis and Weber "*Estimating the impact of energy efficiency on housing prices in Germany: Does regional disparity matter?*" (2022)

[66] *Leboullenger et al. "Is there a market value for energy performance in a local private housing market?"* (2018)

[67] Civel "*Capitalization of energy labels versus Techno-economic assessment of energy renovations in the French housing market.*" (2020)

[68] C. Qin and C. Stuart "Bertrand versus Cournot Revisited" (1997)

[70] Creti "*Greenium or manipulation? An analysis of the French housing market*" (2021)

[72] Fuerst, McAllister, Nanda and Wyatt "*Does energy efficiency matter to home-buyers? An investigation of EPC ratings and transaction prices in England*" (2015)

[78] A. de Ayala, I. Galarraga, J. V. Spadaro "The price of energy efficiency in the Spanish housing market" (2015)

[80] C.M. Duarte, A. Chen "The evolution of energy efficiency impact on housing prices. An analysis for Metropolitan Barcelona" (2018)

[81] C.M. Duarte, A. Chen "Uncovering the price effect of energy performance certificate ratings when controlling for residential quality" (2022)

[82] D. Brounen and N. Kok "On the economics of energy labels in the housing market" (2011)

[83] A. Chegut, P. Eichholtz, R. Holtermans "Energy Efficiency and Economic Value in Affordable Housing" (2016)

[87] E.Fregonara, D.Rolando, P.Semeraro, M.Vella "The impact of Energy Performance Certificate level on house listing prices. First evidence from Italian real estate" (2014)

[88] S.Copiello "Achieving affordable housing through energy efficiency strategy" (2015)

[89] F.Tajani,P. Morano,F. Di Liddo, E. Doko "A Model for the Assessment of the Economic Benefits Associated with Energy Retrofit Interventions: An Application to Existing Buildings in the Italian Territory" (2022)

[91] A. Bisello, V. Antoniucci, G. Marella "Measuring the price premium of energy efficiency: A two-step analysis in the Italian housing market" (2020)

Section 2: Savings Projections in time

Web pages

[100] Link to the European Commission webpage "EU Emissions Trading System (EU ETS)"

[101] Global Energy and Climate Outlook - CO2 intensity of electricity generation (Enerdata)

[105] Daikin ERGA Low-temperature Heat Pump (Refrigerant Split)

Official Reports

[94] Cambridge Econometrics and The European Climate Foundation "Modelling the socioeconomic impact of zero carbon housing in Europe final" (2022 – 2023)

[95] Cambridge Econometrics and The European Climate Foundation "Modelling the socioeconomic impact of zero carbon housing in Europe final" (2022 – 2023)

[96] Eurostat Electricity prices for household consumers– second half of 2022

[97] Eurostat Natural gas prices for household consumers – second half of 2022

[98] Eurostat Electricity prices for household consumers– second half of 2022

[99] Eurostat Natural gas prices for household consumers – second half of 2022

[102] Cambridge Econometrics and The European Climate Foundation (2022 – 2023); European Commission "Excel files for MIX-CP scenario"

[103] EU reference scenario 2020 - Energy, transport and GHG emissions : trends to 2050

[104] Amounts provided by Cambridge Econometrics, originally computed for the paper "Modelling the socioeconomic impact of zero carbon housing in Europe final" (2022 – 2023)

Section 3: Ban on existing technologies

Legal documents

[112] Gesetz zur Einsparung von Energie und zur Nutzung erneuerbarer Energien zur Wärme- und Kälteerzeugung in Gebäuden* (Gebäudeenergiegesetz - GEG)

[113] Voorstel van decreet tot wijziging van artikel 4.1.16/2 van het Energiedecreet van 8 mei 2009

[114] Belgische Federatie der Brandstoffenhandelaars vzw and Others and Lamine v. Flemish Government - Climate Change Litigation (climatecasechart.com)

[127] DECRETO LEGISLATIVO 8 novembre 2021, n. 199 Attuazione della direttiva (UE) 2018/2001 del Parlamento europeo e del Consiglio, dell'11 dicembre 2018, sulla promozione dell'uso dell'energia da fonti rinnovabili. (21G00214)

Web pages

110 New heating systems: using renewable energy sources as of 2024 | Federal Government (bundesregierung.de)

115 Brussels brings together air, climate and energy in an integrated vision: COBRACE and the PACE regional plan | Citizen - Brussels Environment (environnement.brussels)

117 Commission de Régulation de l'Énergie – Natural gas network

125 Government of the Netherlands - News "Netherlands to phase out public funding for new fossil fuel exports"(2021)

126 Heat pumps mandatory to replace boiler | Business.gov.nl

Official Reports

106 IEA "Net Zero by 2050: A Roadmap for the Global Energy Sector"(2021)

107 International Energy Agency "The Future of Heat Pumps" (2022)

108 Communication from the Commission to the European Parliament, the Council, the European Economic and social Committee and the Committee of the Regions Eu 'save energy' 2018

109 IEA "Net Zero by 2050: A Roadmap for the Global Energy Sector"(2021)

111 Wohnsituation privater Haushalte - Fachserie 15 Sonderheft 1 - 2018 (destatis.de)

116 International Energy Agency (IEA) "France 2021 Energy Policy Review" (2021)

118 Ministére de la transition écologique et solidaire "Stratégie francaise pour l'énergie et le climat - Programmation pluriannuelle de l'énergie 2019-2023; 2024-2028" (2019)

119 Premiére Ministre; Secrétariat general á la planification écologique "La planification écologique dans les bâtiments – 12 jiun 2023 – Réunion de travail sur la renovation énergétique

120 Gouvernement Francaise – Décarbonation des Bâtiments Ce qui va changer en 2024

121 Gouvernement Francais - Dossier de concertation "Accélérer la decarbonation du secteur du bâtiment" (2023)

123 Department for Business, Energy and Industrial Strategy "Opportunity areas for district heating networks in the UK - National Comprehensive Assessment of the potential for efficient heating and cooling"(2023)

124 Ministry of Housing, Communities and Local Government "The Future Homes Standard: 2019 Consultation on changes to Part L (conservation of fuel and power) and Part F (ventilation) of the Building Regulations for new dwellings - Summary of responses received and Government response"(2021)

Section 4: Incentive schemes

Legal documents

129 Bundesförderung für effiziente Gebäude - Infoblatt zu den förderfähigen Maßnahmen und Leistungen

156 Testo del decreto-legge 22 giugno 2012, n. 83 (in supplemento ordinario n. 129/L alla Gazzetta Ufficiale - serie generale - n. 147 del 26 giugno 2012), coordinato con la legge di conversione 7 agosto 2012, n. 134 (in questo stesso supplemento ordinario alla pag. 1), recante: «Misure urgenti per la crescita del Paese.» (12A08941) (GU n.187 del 11-8-2012 - Suppl. Ordinario n. 171)

157 DECRETO 16 febbraio 2016 Aggiornamento della disciplina per l'incentivazione di interventi di piccole dimensioni per l'incremento dell'efficienza energetica e per la produzione di energia termica da fonti rinnovabili. (16A01548) (GU Serie Generale n.51 del 02-03-2016)

Web pages

128 Förderprogramm im Überblick - Bundesamt für Wirtschaft und Ausfuhrkontrolle (2023)

130 Afbraak en wederopbouw - Nieuwe maatregel (programma wet bs 30.12.2020) - Federale Overheidsdienst Financiën

131 A federal crisis plan to combat soaring energy prices – Belgium Official information and services

[132] Réduction temporaire de la tva : panneaux solaires, chauffe-eaux solaires et pompes à chaleur – Service Public Féderal webstite

[133] My Renovation Premium for heat pump – Vlaanderen.

[134] Who can apply for My Renovation Premium? | Vlaanderen.be

[135] Mijn verbouwpremie - Vlaanderen

[136] Simulator premie-aanvragen 2023 – Vlaams Energie & Klimaatagentschap

[137] Prime temporaire - Appareil de chauffage et d'eau chaude sanitaire (jusqu'au 30 juin 2023) – Wallonie énergie SPW

[138] Wallonie énergie SPW "Primes Habitation 2023 (à partir du 1er juillet 2023)"

[139] Wallonie énegie SPW "Primes Toiture et petits travaux sans audit"

[140] Energy Saving Trust 2023

[141] Energy Company Obligation (ECO) – Ofgem.gov.uk

[142] Notice: Apply for the Social Housing Decarbonisation Fund: Wave 2.1 (closed to applications)

[143] Home Upgrade Grant: successful local authorities – Gov.uk

[144] Prime énergie "MaPrimeRénov'" - Vous êtes propriétaire occupant - Service PublicRepublique Francaise

[145] TVA à taux réduits : pour quels travaux ? | economie.gouv.fr

[146] French Government "MaPrimeRénov' 2024 : accélérons la rénovation énergétique"press kit

[147] French Republic webpage "Certificats d'économie d'énergie (CEE) "Standard""

[148] French Republic "Éco-prêt à taux zéro (éco-PTZ)" webpage

[149] Program Czyste Powietrze – Ministerstwo Klimatu i Srodowiska

[150] Program Czyste Powietrze - Ulga termomodernizacyjna – Ministerstwo Klimatu i Srodowiska

[151] RVO - Subsidie voor duurzame energie en energiebesparing koopwoning aanvragen-isde

[152] National Government webpage "€210 million extra for insulation and heat pumps"

[153] RVO "ISDE: Warmtepomp woningeigenaren"

[154] Spanish Government webpage "Plan de Recuperación, Transformación y Resiliencia"

[155] European Parliament website "Spain's National Recovery and Resilience Plan: Latest state of play"

Section 5: Optimized utilisation of solar PV technology

Web pages

[159] Rijksoverheid - Plan kabinet: afbouw salderingsregeling zonnepanelen

[160] Engie Belgium - Zonnepanelen - Je terugdraaiende teller in Vlaanderen: behouden tot 2025 of niet?

[162] H. Wirth, Fraunhofer ISE "*Recent Facts about Photovoltaics in Germany*" (2023)

Scientific research

[158] Photovoltaics report – Frauenhofer Institute for Solar Energy Systems, ISE with support of PSE Projects GmbH – 21/2/2023 –

[161] H. Wirth, Fraunhofer ISE "Recent Facts about Photovoltaics in Germany" (2023)

Official report

163 Solar Power Europe "Solar Powers Heat 2023" (2023)

Section 6: Carbon footprint of heat pumps

Web pages

166 European Union. (2020, March 6). Long-term low greenhouse gas emission development strategy of the European Union and its Member States.

167 Press corner. (2021, December 15). European Commission - European Commission

169 Building decarbonization: How electric heat pumps could help reduce emissions today and going forward. (2022, July 25). McKinsey & Company

172 European Commission – DG Energy Topics "Heat pumps. (2023)"

174 European Commission – DG Energy Topics "Heat pumps. (2023)"

175 *Life cycle assessment*. (n.d.). European Environment Agency – *Life cycle assessment definition*

176 Ministère de la Transition écologique et de la Cohésion des territoires, Ministère de la Transition énergétique. (2023). Réglementation environnementale RE2020

177 What is seasonal efficiency (SCOP and SEER) | Daikin

180 Daikin Applied Europe An insight on refrigerants and Daikin philosophy (2020, July 2)

181 IEA (2022), The Future of Heat Pumps, IEA, Paris, License: CC BY 4.0

182 FAQ | Impact of refrigerants | Influence | Daikin Global. (n.d.).

183 Key considerations for refrigerant choice | Influence | Daikin Global. (n.d.).

186 UN Environment Programme. (n.d.). About Montreal Protocol.

187 UN Environment Programme. (n.d.). About Montreal Protocol.

189 R-32, The Most Balanced Refrigerant | Benefits of Daikin Technology | Daikin Global. (n.d.).

191 Daikin Europe N.V. (n.d.). Tightfit. Fireless copper pipe connector designed for HVAC equipment.

192 Assessing the carbon footprint of reclaimed refrigerant for reuse and virgin refrigerant production (Daikin Europe, 2023)

193 L∞p by Daikin. (n.d.). Daikin website.

Official Reports

165 AR6 Synthesis Report: Climate Change 2023 — IPCC. (2023). IPCC.

168 Eurostat. (2022, June). *Energy consumption in households*

169 "European heat pump market and statistics report 2023." (2023). European Heat Pump Association

170 "Building decarbonization: How electric heat pumps could help reduce emissions today and going forward". (2022, July 25). McKinsey & Company.

173 "The Future of heat pumps – Analysis" IEA. (n.d.). IEA

Scientific research

171 Thomaßen, G., Kavvadias, K., & Navarro, J. P. J. (2021). The decarbonisation of the EU heating sector through electrification: A parametric analysis. *Energy Policy*, *148*, 111929.

188 Wuebbles, D. J. (1994). The role of refrigerants in climate change. International Journal of Refrigeration-revue Internationale Du Froid, 17(1), 7–17.