Comprehensive Assessment of the Potential for Efficient Heating and Cooling in Ireland

Report to the European Commission

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July 2021

The National Comprehensive assessment and associated reports were commissioned by a project team across the SEAI Research and Policy Insights Directorate and developed with the assistance of Element Energy and Ricardo Energy and Environment.

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Sustainable Energy Authority of Ireland

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1 Introduction and Background

1.1 Introduction

This report to the European Commission provides Ireland's second national comprehensive assessment of the potential for efficient heating and cooling in accordance with Article 14 (1 & 3) of Directive 2012/27/EU on energy efficiency and the revised Annex VIII to the Directive as set out in Delegated Regulation (EU) 2019/826.

The requirement to undertake the comprehensive assessment is transposed into Irish national law through Statutory Instrument No. 426 of 2014[1], the Sustainable Energy Authority of Ireland (SEAI) being designated as the responsible body. The analysis for this report has been carried out by Element Energy and Ricardo Energy & Environment on behalf of SEAI and the report has been prepared by Ricardo Energy & Environment, Element Energy and SEAI.

1.2 Relevant EU legislation and guidance

Article 14 (1) & (3) of Directive 2012/27/EU (the Energy Efficiency Directive, or EED) requires all Member States to carry out and submit to the Commission a comprehensive assessment of the potential for efficient heating and cooling, containing the information set out in Annex VIII.

The first cycle of comprehensive assessments had to be notified to the Commission by Member States by the end of 2015. Assessments must then be updated and notified every five years if the Commission requests.

Since the first cycle, Annex VIII of the EED has been revised via Commission Delegated Regulation (EU) 2019/826.[2] The revised Annex VIII is more technically neutral than the original, which was particularly focussed on high efficiency cogeneration (CHP) and efficient district heating and cooling. Furthermore, Annex VIII now has greater focus on renewable sources of energy to satisfy heating and cooling demands in addition to energy efficiency.

The assessments must now be closely linked with Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action (the Governance Regulation) in respect of the planning of policy measures and Member State's National Energy and Climate Plans. Also, assessments should be better linked to Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources (RED II) and the amended Energy Performance of Buildings Directive (EPBD).

In support of the revised Annex VIII, the Commission has published Recommendation (EU) 2019/1659[3] on the content of the comprehensive assessment. It is against this framework that the 2020 comprehensive assessment for Ireland has been undertaken and this report prepared.

As part of this analysis a detailed examination of the potential for waste heat and cold was carried out at high spatial resolution, pursuant to Article 15(7) of Directive 2018/2001/EU. Section 2 of this report details this analysis. In addition, the potential and costs of household level renewable heating technology options has been assessed in Section 4. The analysis of energy from renewable sources is focused on the heat sector. The background spatial analysis of the potential bioenergy resource in

1 European Union (Energy Efficiency) Regulations 2014, http://www.irishstatutebook.ie/eli/2014/si/426/made/en/print

2 COMMISSION DELEGATED REGULATION (EU) 2019/826 of 4 March 2019 amending Annexes VIII and IX to Directive 2012/27/EU

3 COMMISSION RECOMMENDATION (EU) 2019/1659 of 25 September 2019 on the content of the comprehensive assessment of the potential for efficient heating and cooling under Article 14 of Directive 2012/27/EU

Ireland filtered land on the basis of several environmental and accessibility related criteria. Section 4.2.1 shows the potential and net present value of deploying these technologies and fuels. The impact of renewable energy deployment on the electricity grid is captured through the consumer price impacts. The deployment trajectory is informed by analysis carried out by the Irish electricity Transmission System Operator report entitled Tomorrow's Energy Scenarios.

1.3 Ireland's National Climate Objective

Ireland's 2020 National Energy and Climate Plan (NECP)[4] was prepared in accordance with the Governance Regulation to incorporate all planned policies and measures that were identified up to the end of 2019, which collectively deliver a 30% reduction by 2030 in non-ETS greenhouse gas emissions (from 2005 levels).

Subsequent to the NECP 2020, legislation is being brought forward that commits Ireland to an average 7% per annum reduction in overall greenhouse gas emissions from 2021 to 2030 (a 51% reduction over the decade) and to achieving net zero emissions by 2050. These objectives, amongst others, will be given a legal basis via the Climate Action and Low Carbon Development (Amendment) Bill 2021[5], which once enacted will support Ireland's transition to Net Zero and achieve a climate neutral economy by no later than 2050. It will establish a legally binding framework with clear targets and commitments set in law, and ensure the necessary structures and processes are embedded on a statutory basis to ensure Ireland achieves its national, EU and international climate goals and obligations in the near and long term.

The Bill includes the following key elements:

- Placing on a statutory basis a 'National Climate Objective', which commits the Government to pursue and achieve no later than 2050, the transition to a climate resilient, biodiversity-rich, environmentally sustainable and climate-neutral economy.
- Embedding the process of carbon budgeting into law whereby the Government is required to adopt a series of economy-wide five-year carbon budgets, including sectoral targets for each relevant sector, on a rolling 15-year basis, starting in 2021.
- Updating annually the Climate Action Plan, which will detail actions for each sector.
- Preparing every five years a National Long Term Climate Action Strategy.

1.4 Modelling approach

SEAI's National Energy Modelling Framework (NEMF) is a tool that examines aspects such as the variation in technology readiness, technical suitability, cost data, and performance data, to assess various scenarios (including potential decarbonisation paths) in Ireland. The stock model developed for the NEMF contains data on over 640 heat demand archetypes that provide a detailed description of demand in industry, services, and residential sectors. Technology suitability and performance are mapped to each archetype and the model contains representations of bioenergy and hydrogen resources and fuel supply chains as well as an infrastructure module that calculates the costs of infrastructure deployment linked to technology uptake. The model uses this technoeconomic data to generate payback estimates for the various technology options available, accounting for policy incentives, taxes, and regulations. This payback information is used with other data on consumer decision-making behaviour to help understand how much uptake may result in various scenarios and in response to policy measures. This simulation approach is used in this analysis to examine what impact a given set of policy measures the NEMF can have on the energy system.

4 https://www.gov.ie/en/publication/0015c-irelands-national-energy-climate-plan-2021-2030/
5 https://www.gov.ie/en/publication/984d2-climate-action-and-low-carbon-development-amendment-bill-2020/

Where technology deployment is based on centralised decisions, these are accounted for outside of the consumer decision-making framework. Industrial Carbon Capture, Utilisation and Storage (CCUS) and District Heating have been dealt with in this way. Industrial sites which utilise CCUS/BECCS[6] abatement technologies are not considered for other abatement technologies (e.g. electrification or hydrogen) and relevant parameters for their decarbonisation are calculated off model. This includes an analysis conducted for CCUS technologies separately for each of the industrial sectors. The analysis has assessed energy and fuel requirements, costs and emissions reductions from CO_2 capture on the relevant industrial sites, including costs related to CO_2 transport and storage. A similar approach is taken for the allocation of district heating. This is determined by a geographical approach based on linear heat density. The results of this analysis are integrated with the NEMF to assign district heating to relevant proportions of archetypes, where most cost effective in the highest heat dense areas. These aspects are then integrated into the NEMF outputs and feed into the results of the wider project.

The two scenarios investigated in this study are summarised as follows:

- a '**Baseline**' or 'Business as Usual' scenario including bottom-up modelled existing policy measures. Aligned to the submission requirements, this scenario seeks to reflect the most likely trajectory for the heating and cooling sector in the absence of further policy support for decarbonisation.
    - All sectors continue to use carbon-intensive practices unless cost-effective to switch.
    - There is limited deployment of heat networks, new technologies, or fuel switching.
    - It does not achieve net zero by 2050.

- an **Alternative** or **Decarbonisation** scenario including a heightened support of policy measures and other factors designed with the intention to achieve (or align as closely as possible to) Ireland's climate ambitions (further detailed in Section 3.3). The Alternative scenario seeks to represent a plausible, 'central' scenario for the decarbonisation of heat (by 2050), utilising a mix of technologies where each is cost effective.
    - Progresses steadily and consists of a mix of cost-effective deployment of low-carbon technologies (electricity, bio-derived gases, and/or H_2).
    - There is a medium level of industrial CCUS, heat networks, and energy efficiency deployed.
    - It achieves net zero by 2050.

1.5 Structure of this report

This report follows as closely as possible the structure of Annex VIII to the EED, each main Section addressing the Parts of Annex VIII as follows:

Section of this report	Part of Annex VIII addressed
2	Part I, Overview of Heating and Cooling
3	Part II, Objectives, Strategies and Policy Measures
4	Part III, Analysis of the Economic Potential for Efficiency in Heating and Cooling
5	Part IV, Potential New Strategies and Policy Measures

6 Bio-Energy with Carbon Capture and Storage (BECCS)

2 Overview of Heating and Cooling in Ireland

2.1 Data sources and assumptions

The latest available data was used to estimate heating and cooling demand and supply for each of the following sectors in Ireland:

- **Residential**: The Building Energy Rating (BER) database, which includes estimates of heating fuel use for nearly 700,000 of the 1.7 million occupied homes in Ireland, was combined with data from the Central Statistics Office (CSO) on the total number of homes in Ireland and their distribution by main heating fuel, in order to estimate the total heating demand of all residential buildings in Ireland.
- **Commercial and Public**: There are approximately 134,000 commercial buildings and 24,000 public buildings in Ireland[7]. The non-domestic BER database, which includes estimates of heating and cooling fuel use for nearly 70,000 of these commercial and public buildings, was combined with data from the GeoDirectory[8] on the total number of commercial and public buildings by activity type, in order to estimate the total heating and cooling demand of all commercial and public buildings in Ireland.
- **Agriculture**: Whilst the available data for the agriculture sector is relatively limited, the latest datasets from the Central Statistics Office (CSO) and Teagasc[9] were used to estimate the heating and cooling demand of buildings in the sector.
- **Industry**: Several data sources were used to estimate heating and cooling demand across the 4,200 sites in the industry sector, including mandatory reported data under the EU ETS, Ireland's Energy Balance 2019, and environmental permits. The data was combined with insights from external stakeholders to arrive at final estimates of heating and cooling demand for all industrial facilities in Ireland.

2.2 Current heating and cooling demands and final energy consumption

The following section outlines the useful energy demand and final energy consumption for heating and cooling for all sectors in Ireland, based on 2019 data.

Whilst all building sectors consume energy for heating, the use of energy for cooling is not recorded for the residential sector. The best available data sources for the residential sector do not include estimates of cooling demand. This is consistent with the fact that no cooling degree days requiring active cooling were recorded in Ireland in recent years.

2.2.1 Heating

Figure 1 and Figure 2 show respectively the total useful heating demand and final energy consumption for heating in Ireland split by the residential, commercial, public, agriculture, and industry sectors.

The majority of energy used for heating is consumed by the residential and industry sectors. Combined, the useful heating demand from the residential and industrial sectors constitutes 79% of

7 This is an update to previous estimates by SEAI, and aligned to GeoDirectory data.
8 GeoDirectory is a private organisation which was jointly established by An Post and Ordnance Survey Ireland (OSI). It maintains a database of all buildings in Ireland. (https://www.geodirectory.ie/)
9 Teagasc – the Agriculture and Food Development Authority – is the national body providing integrated research, advisory and training services to the agriculture and food industry and rural communities. (https://www.teagasc.ie/)

the total for all sectors in Ireland. By contrast, the useful heating demand from the agriculture sector is only 1% of the total.

Figure 1 Total useful heating demand (TWh) for buildings and industry by sector, 2019. Demand from solid fuel use in secondary heating systems shown separately for the residential sector (in grey)

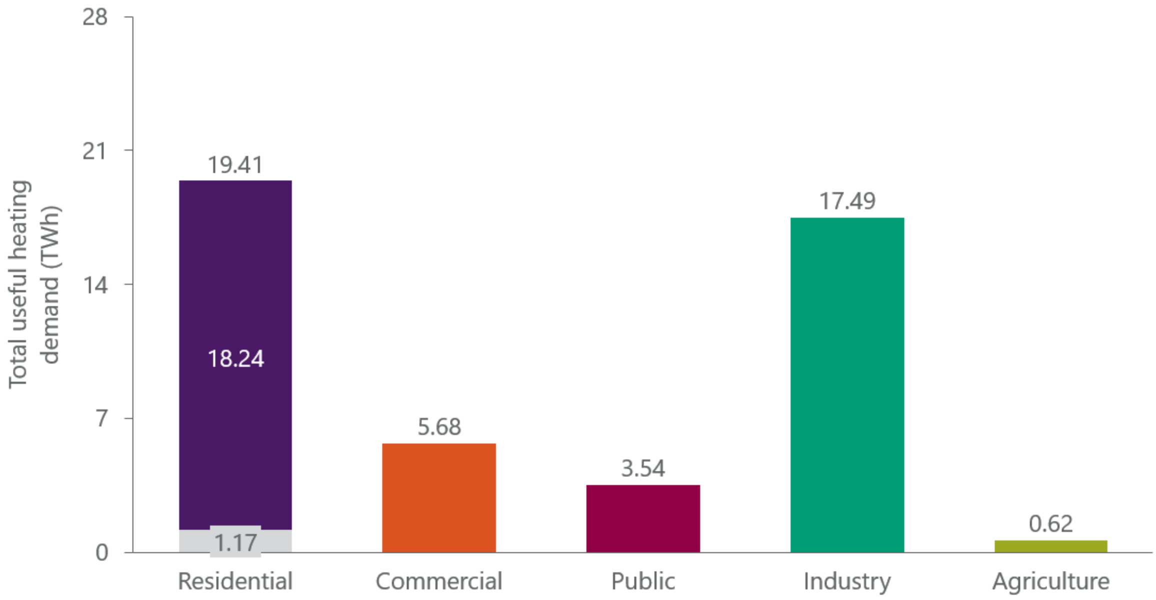
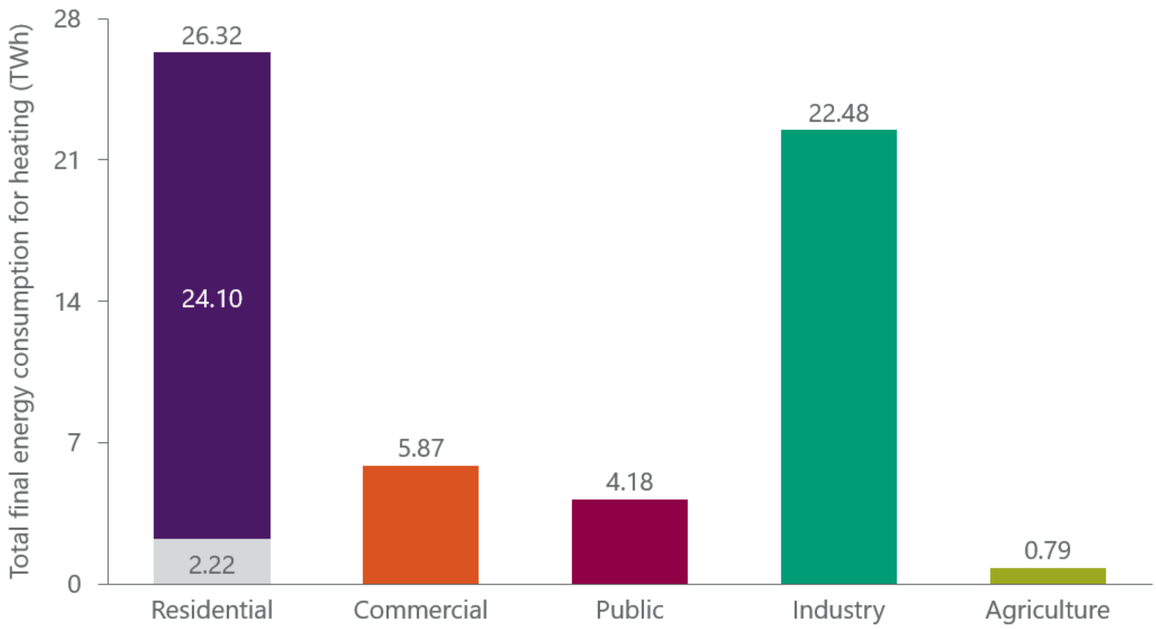


Figure 2 Total final energy consumption (TWh) for heating in buildings and industry by sector, 2019. Consumption from solid fuel use in secondary heating systems shown separately for the residential sector.



2.2.2 Cooling

Figure 3 and Figure 4 respectively show the useful cooling demand and final energy consumption for cooling in Ireland, split across industry, agriculture, commercial, and public sectors. As previously noted, there is no measurable cooling demand from the residential sector. Cooling demand from data centres is also shown separately.

As explained later in the report (Section 2.7.2), the cooling demand figure for data centres is based on the assumption that one kWh of electricity consumption generates one kWh of waste heat within data centres, hence the annual data centre cooling demand is modelled to be equal to the annual data centre electricity consumption. This approach assumes that the heat gains from the environment (e.g. from incoming solar radiation) are negligible compared to the waste heat generated within data centres. It also assumes negligible passive cooling, which in reality will likely be used to meet a significant amount of the cooling demand.

For the commercial and public sectors, useful cooling demand data (useful energy) is derived by combining final cooling consumption data (final energy) with cooling efficiency data available in the relevant datasets. Because the equivalent data is not available for the industry and agriculture sectors, sectors, the cooling demands for those sectors are assumed equal to the electricity consumption for cooling (i.e. a 100% technology efficiency is used to convert from final energy to useful energy).

The majority of cooling demand in Ireland comes from the commercial sector, which accounts for 63% of the total.

Figure 3 Total useful cooling demand (TWh) for buildings and industry by sector, 2019.

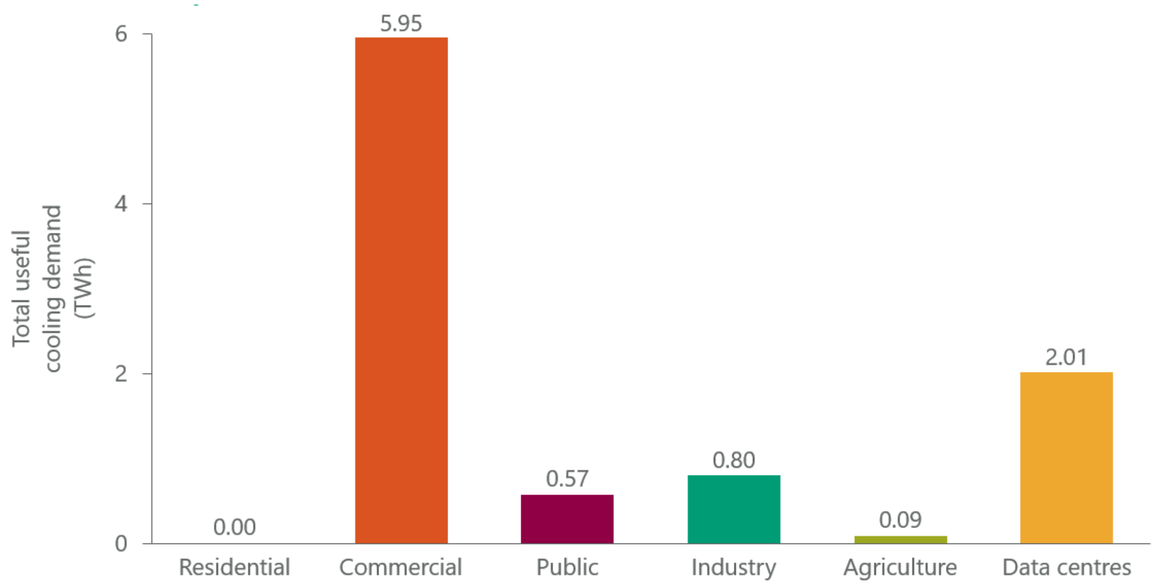
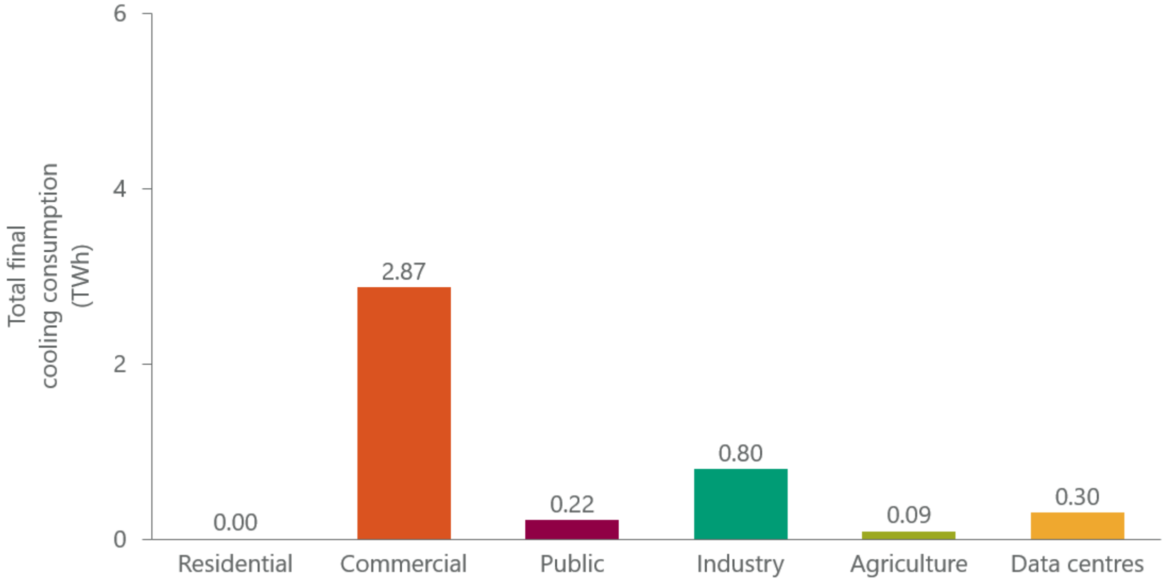


Figure 4 Total final energy consumption (TWh) for cooling in buildings and industry by sector, 2019



2.3 Heating and cooling supply by fuel/technology

The following section includes details on the current (2019) energy supply for heating and cooling, namely splits by sector and technology type. The available data for Ireland does not allow for full disaggregation by technology type in on-site facilities, particularly for cooling supply. Information available on heat supply from district heating is also limited. However, a total heat supply of 0.17 TWh per year has been estimated from district heating systems spread across the residential, commercial and public sectors but has not been disaggregated in the following section.

2.3.1 Heating supply

This section describes the breakdown of heating supply by fuel and technology in each of the economic sectors in Ireland.

Figure 5 shows the current heating supply by heating fuel in the **residential sector,** presented in terms of useful energy demand and final energy consumption. The available data (BER records) distinguishes homes by main heating fuel, rather than heating technology. Therefore, only a broad distinction between heating technology groups is possible (e.g. between gas-powered systems and electric systems). However, the data includes details on the efficiency of the main heating system. This allows the heating demand from electric heating technologies to be broken down further, into likely heat pumps and direct electric heating technologies, such as electric storage heaters. The breakdown is shown in Figure 6, and is based on the assumption that electric heating systems with an efficiency exceeding 150% are heat pumps. Generally, oil- and gas- fuelled heating systems are mostly boilers, with a relatively modest amount of high efficiency combined heat and power (c. 0.2MWe) serving communal heating systems[10]. Electrically-powered heating systems are either direct electrical technologies (such as electric storage heaters) or heat pumps, and solid fuel heating systems are mostly stoves or open fires.

10 SEAI. (2020). Combined Heat and Power in Ireland – 2020 Update. https://www.seai.ie/publications/CHP-Update-2020.pdf

Heating supply from renewable systems, such as solar thermal or biomass boilers, is not shown separately as such systems are mainly used as secondary heating systems, and their total contribution to fuel use, according to the Energy Balances, is only 2.5% of the total fuel use in the residential sector, equivalent to 0.85 TWh.

Many dwellings in Ireland also use fuel for secondary heating. The BER records capture this data in the same way as for primary fuel – each record has data for both primary and secondary fuel sources. While this is often the same fuel as for the primary heating source, solid fuel use for secondary heating is common in Ireland – particularity in dwellings where oil is defined as the primary heating source. Approximately 60% of total solid fuel used for space heating is consumed via secondary heating systems, mostly in homes which use oil as the primary heating fuel. This corresponds to 1.17 TWh of useful energy demand or 2.22 TWh of final energy consumption.

To estimate the consequent useful energy demand for each building archetype and account for this solid fuel aspect the following steps were implemented:

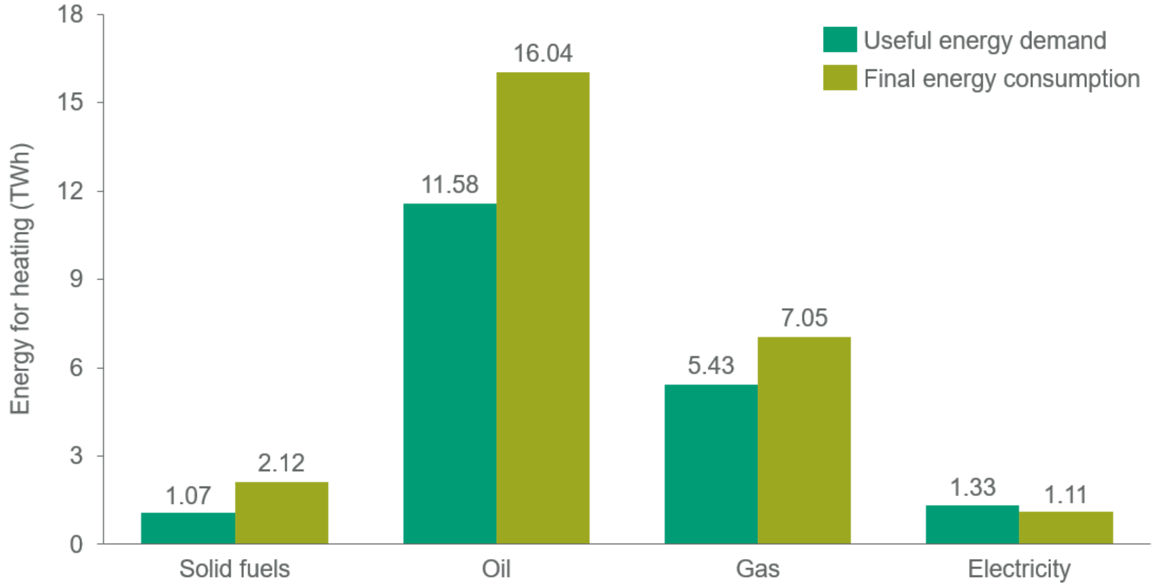
- Where the primary and secondary fuel source are the same in the BER record, the total fuel demand is attributed to the primary fuel source. The split between primary and secondary fuel in these cases is 86%-14% and hence this assumption allows a representative estimate of total useful heating demand.
- For solid fuel, the total fuel demand in Ireland was split between primary and secondary use. The primary share is used to calibrate the useful energy demand in dwellings where solid fuel is the primary heating source. The secondary heating share is attributed to oil homes and included in the estimates of useful and final energy for those archetypes.

Further data collection is required to attribute secondary use of solid fuels more accurately across archetypes.

Based on the data available, the heating supply from heat pumps corresponds to around 50,000 units, which is broadly consistent with the latest estimates of the number of heat pumps in Ireland.[11]

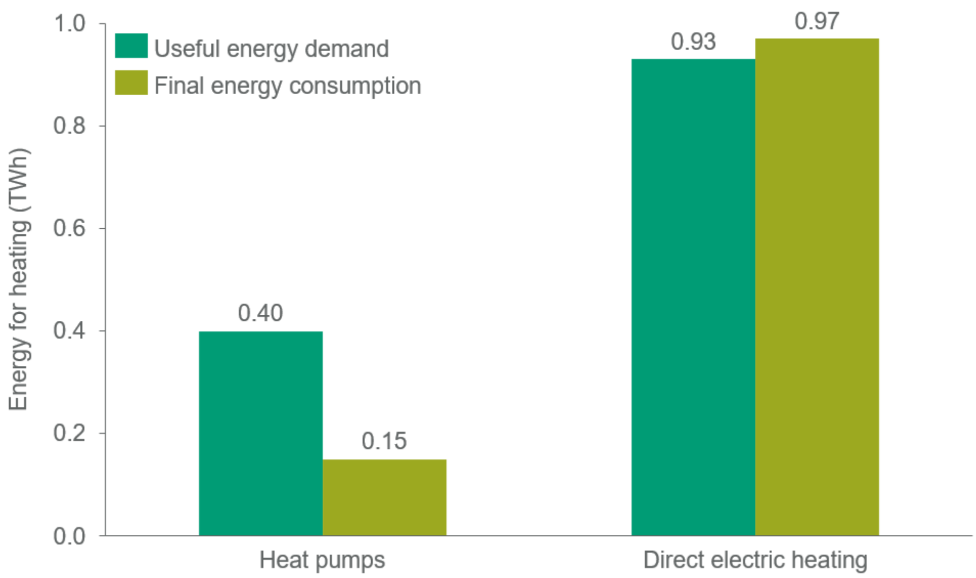
11 EHPA (2020). http://www.stats.ehpa.org/hp_sales/country_cards/

Figure 5 Heating supply by fuel in the residential sector presented in terms of useful energy demand and final energy consumption, 2019



** Values for solid fuel use in secondary space heating systems – 1.17 TWh useful energy demand / 2.16 TWh final energy consumption – are included in the "Oil" column.*

Figure 6 Heating supply from electric heating technologies in the residential sector, split between heat pumps and direct electric heating technologies,2019



** Values for useful energy demand and final energy consumption presented.*

Figure 7 shows the breakdown of heating demand in the **commercial sector,** by technology type, presented in terms of useful energy demand and final energy consumption. Demand from solid fuel heating systems and renewable heating systems is not shown, as macroeconomic data indicate that the associated fuel use is less than 3% of the total in the commercial sector. The majority of heating demand is attributable to gas boilers and electric heating, with oil boilers contributing a smaller share.

Not shown separately in Figure 7, there are also some 24.7 MWe of mainly natural gas fired CHP capacity in the commercial sector estimated to be providing around 0.12 TWh pa of useful heat.[10]

Figure 7 Heating supply by technology in the commercial sector, 2019, presented in terms of useful energy demand and final energy consumption

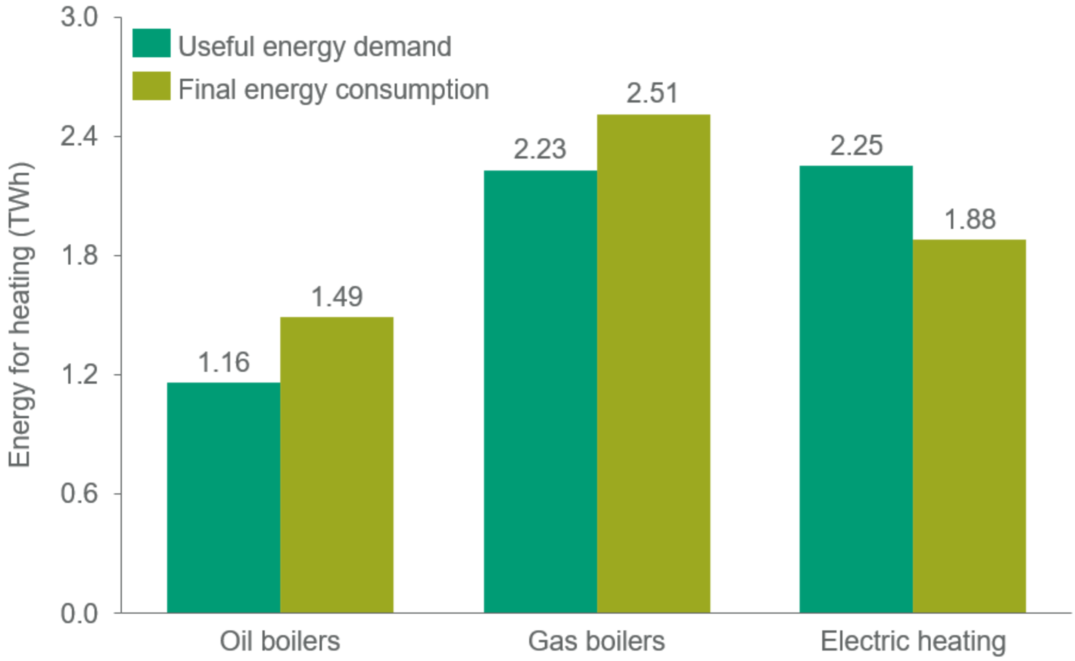


Figure 8 shows the breakdown of heating demand in **the public sector**, by technology type, presented in terms of useful energy demand and final energy consumption. Demand from solid fuel heating systems and renewable heating systems is not shown, as macroeconomic data indicates that the fuel use associated with these fuels is ~ 2% of the total in the public sector. The majority of heating demand is met by gas boilers. Oil boiler use is less widespread, and electric heating is rare.

Not shown separately in Figure 8, there is also some 16.5 MWe of mainly natural gas fired CHP capacity in the public sector (including education and health sectors) estimated to be providing around 0.07 TWh pa of useful heat[10].

Figure 8 Heating supply by technology in the public sector, 2019, presented in terms of useful energy demand and final energy consumption

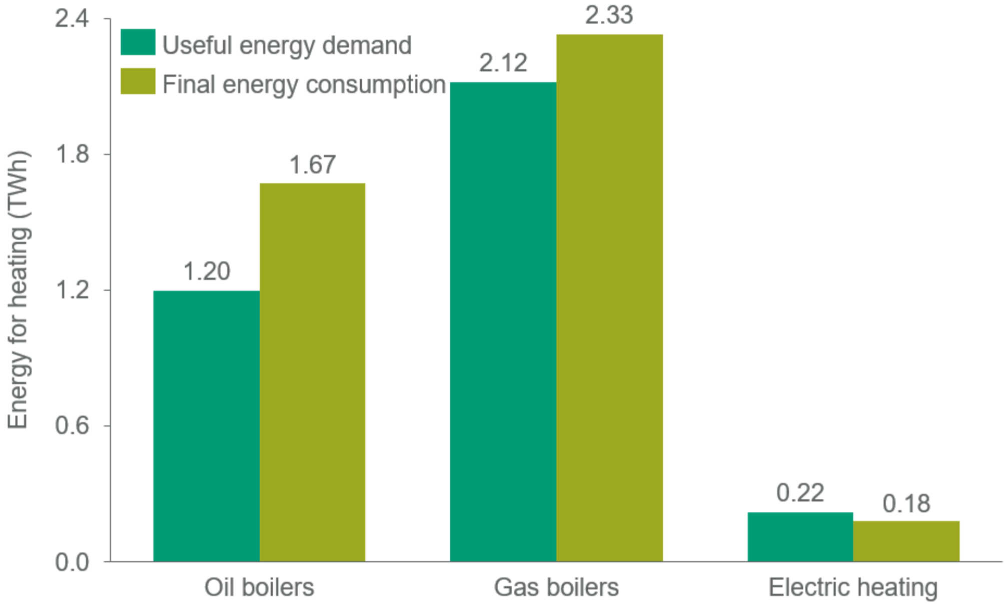


Figure 9 shows the breakdown of heating demand in the **agriculture sector**, by technology type, presented in terms of useful energy demand and final energy consumption. The majority of heating demand in the agriculture sector is met by oil boilers, with a smaller role for electric heating. Gas and solid fuels are rarely used for heating in the sector.

Figure 9 Heating supply by technology in the agriculture sector, 2019, presented in terms of useful energy demand and final energy consumption

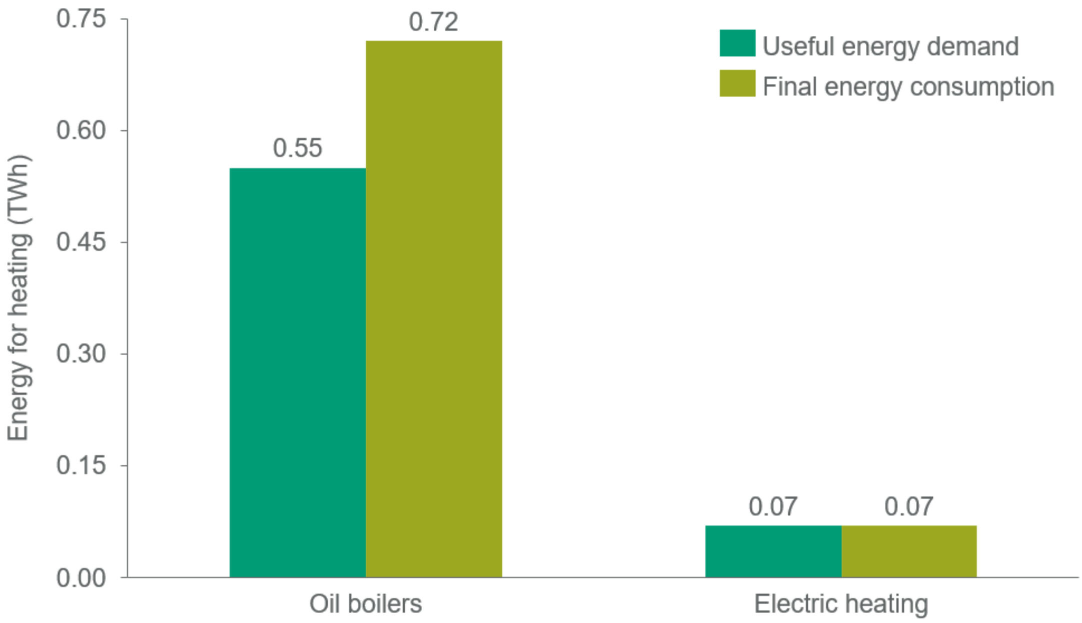
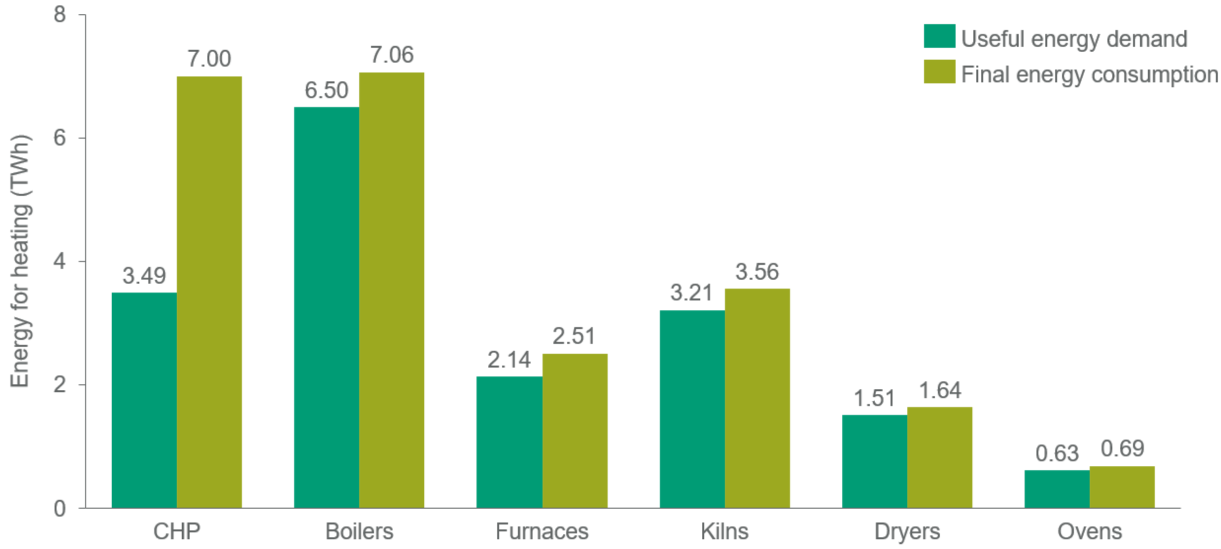


Figure 10 shows the breakdown of heating demand in the **industry sector**, by technology type, presented in terms of useful energy demand and final energy consumption. Compared to other building sectors, a larger number of heating technologies are used in the industry sector. In terms of final energy consumption, CHP units and boilers are used to meet a majority of heating demand, with the remainder met by furnaces, kilns, dryers and ovens.

Figure 10 Heating supply by technology in industry, 2019, presented in terms of useful energy demand and final energy consumption



2.3.2 Cooling Supply

Data for cooling is collated at an aggregated level in Ireland. As such, it does not provide a comprehensive breakdown of on-site cooling supply by technology (see Section 2.1 and Section 2.7.2 for the data sources for each sector). The vast majority of cooling demand in Ireland comes from the commercial sector, specifically retail.

The use of energy for cooling is not recorded for the residential sector. The best available data sources for the residential sector do not include estimates of cooling demand. This is consistent with the fact that no cooling degree days requiring active cooling were recorded in Ireland in recent years.

Brief descriptions of the most common technologies used for cooling are given below:

- **Vapour compression chillers** are the most common type of plant for producing cooling. They operate by the working fluid (refrigerant) being mechanically compressed and then allowed to evaporate within a heat exchanger such that the refrigerant takes in heat from the secondary side of the heat exchanger, thus cooling the medium passing over it, which depending on the application is typically air (e.g. for air conditioning) or water in a secondary circuit (e.g. where a centralised chiller is providing cooling to a number of processes).
- **Absorption chillers** work on similar principles as mechanical chillers but use heat, instead of a compressor, to create pressure and drive the cycle and rely on the properties of a secondary fluid for the absorption of the refrigerant. Absorption chillers can be used with CHP plants where it is advantageous to use CHP generated heat that is surplus (e.g. during warmer months) to produce useful cooling rather than be discarded. This is often referred to as trigeneration or combined cooling heat and power (CCHP).

All existing cooling demands are satisfied by on-site facilities. There are no known existing off-site facilities in Ireland providing cooling to users via district energy networks.

2.4 Existing potential sources of waste heat and cold

2.4.1 Thermal power stations

Annex I, Paragraph 2.2 of Commission Recommendation (EU) 2019/1659 on the EU methodology for estimating waste heat highlights power stations which can supply or can be retrofitted to supply waste heat with a total thermal input exceeding 50 MW. 16 Irish power stations were initially considered under this category.

Analysing the potential waste heat available from power plants was based on data available for Ireland. It should be noted that for power stations and waste incineration with pass-out steam turbines, heat would be extracted at the relevant temperature for district heating (60-80ºC). Assumptions used in estimating the heat extraction potential from power plants are shown below in Table 1

Table 1: Assumptions used in estimating waste heat potential from power stations in Ireland

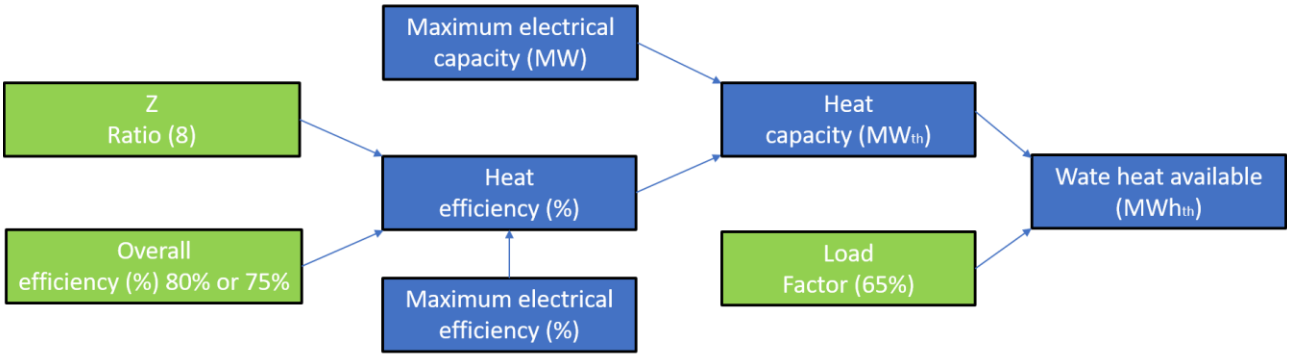
Parameter	Assumption	Description
Overall efficiency	80% for CCGT and pass-out / condensing steam turbine; 75% for open cycle gas turbine (OCGT)	This assumes CHP achieves high efficiency CHP (HECHP) status. According to EED / Annex I, this requires overall efficiency of 80% for CCGT and pass-out steam turbines and 75% for all other CHP technologies. The overall efficiency for power stations (electrical & heat) to convert to CHP was assumed to be 80% for combined cycle gas turbines (CCGT) and pass-out (i.e. condensing) steam turbines, whilst 75% was used for open cycle gas turbine (OCGT) power stations. The overall efficiency assumption is based on Annex I of the EED for cogeneration plants (The European Parliament, 2012). This cap on overall efficiency allows the estimation of heat which can be extracted from a power station should it be converted to CHP mode.
Load factor	65%	The load factor of 65% was derived based on EirGrid data[12] 'All-Island Generation Capacity Statement 2019-2028'.
Z-ratio[13]	8	A Z-ratio of 8 is chosen on the assumption that sites will tend to maximise heat extraction to feed into a district heating network. This means sites will operate in a non-condensing /maximum heat mode. For CCGT and steam turbine prime movers the Z-ratio was assumed equal to 8. This assumption means that the power stations for which the waste heat is to be established maximise their heat extraction. The waste heat determined in this way is the maximum waste heat potential. The previous NCA study used a ratio of ~6.3. However, we believe that a Z ratio of 8 is more reasonable based on typical data of Z ratio vs. steam export pressure (Bar_a, for purpose of feeding into district heating) for different capacities of steam turbine.

12 EirGrid (2019), All-island Generation Capacity Statement 2019-2028. Available at: https://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Group-All-Island-Generation-Capacity-Statement-2019-2028.pdf

13 For CHP Schemes that include fully or partially condensing (pass-out) steam turbines, power efficiency will decline as steam extraction increases for a given fuel consumption, so there is a balance between increasing heat recovery and reducing power output. The trade between heat to site and power for these CHP Schemes is known as the Z ratio. For further information, see: BEIS (2021), Guidance Note 28 – Determination of Z ratio. Available at: Combined heat and power quality assurance (CHPQA) guidance notes - GOV.UK (www.gov.uk) [Accessed 19th May 2021]

The methodology for calculating waste heat potential from power plants is depicted in Figure 11 below. The fundamental data comprising power station name and type (CCGT, condensing steam turbine, OCGT), fuel type, maximum electrical capacity and hourly heat input (GJ/h) were provided by dataset from Economic Consulting Associates.[14] Assumptions were made on overall efficiency, Z-ratio and load factor in order to estimate the thermal capacity and waste heat available.

Figure 11 Waste heat from power station estimation methodology



Power stations that are expected to cease operation by 2025, peaking plants and those with low operating hours were excluded from the analysis. Out of an initial 16 power stations, this left 6 suitable power stations. Four plants had a heat extraction potential in the range 150-300 MWth and two plants were in the 300-400 MWth range. The total heat extraction potential for all 6 power stations is 1,570 MWth.

In addition, it is likely that around 2 GWe of new gas-fired power plant will be commissioned over the next decade[15], though the locations are currently unknown and are not included in the total potential shown in Table 1.

2.4.2 Cogeneration installations

In Ireland there are 315 CHP installations, most of which consume natural gas. Services, such as airports and hospitals, make up 262 of these, whilst the rest (53 sites) are installed in industry. Of all these systems, a CHP at an alumina site is the only substantial producer of energy.[16]. This site uses large quantities of process heat to generate alumina and is already optimised to produce the heat needed for the site with no excess waste heat available for extraction. There is therefore no significant additional heat that can be recovered from existing cogeneration installations in Ireland.

2.4.3 Waste incineration plants

According to Annex I, Paragraph 2.2 of Commission Recommendation (EU) 2019/1659, to be considered, energy from waste (EfW) sites must have a fuel input exceeding 20MWth. Two EfW, one located in Meath, and a second located in Dublin were identified. Based on a range of sources and assumptions, it was estimated that the Meath site has a waste heat potential of 14 MWth and the Dublin EfW site a potential of 35 MWth.

14 Economic Consulting Associates. (2020). Generator Technical Data – PUBLIC

15 EirGrid GCS: https://www.eirgridgroup.com/newsroom/gcs-2020-2029/#:~:text=The%20All%2DIsland%20Generation%20Capacity,the%20years%202020%20to%202029.&text=In%20Ireland%2C%20total%20electricity%20demand,of%20which%20are%20data%20centres.

16 SEAI. (2020). *Combined Heat and Power in Ireland – 2020 Update.* https://www.seai.ie/publications/CHP-Update-2020.pdf

2.4.4 Renewable energy installations

According to EU ETS data there are several sites in Ireland that consume a mix of renewables and fossil fuels. However, none of these sites are solely renewable, and hence they are considered in the 'industrial installations' category instead.

Of the 315 CHP installations in Ireland, there are two biomass and 20 biogas CHP sites. These are all small installations and do not achieve the threshold of 20MW fuel input. Therefore, these renewable CHP sites were excluded from evaluation as they do not meet the threshold.

2.4.5 Industrial installations

Whilst the method for assessing heat recovery from power stations is well established, there is no such set of steps for industrial sites. An ETS dataset detailing the fuel consumption of the largest industrial fuel consumers in Ireland was used as the basis for estimating waste heat potential from industrial sites.

Sites were grouped into the following sectors: cement, ceramics, chemicals, refineries, food & beverage, pharmaceuticals, lime, and magnesia production. From the fuel consumption of each site (given by ETS dataset) and utilising modelling undertaken by Element Energy on the potential for heat recovery from different industries[17], it was possible to estimate the waste heat potential for industrial sites in Ireland. The Element Energy UK modelling data was used to develop best-fit line relationships between waste heat recovery (MWh) and fuel consumption for various industries. A series of linear relationships (for cement, chemicals, refineries, and food & beverage) were found to be the best line fit for the data available. These linear relationships were then applied to the ETS fuel consumption data available for Irish sites to determine waste heat recovery potential. However, UK data was not available for the pharmaceutical and lime production sectors. Waste heat potential for the pharmaceutical sites in Ireland was estimated using the chemical sector linear relationship. For lime production, waste heat potential was also derived based on the UK data.[18]

2.4.6 Data centres

The electricity consumption of data centres in Ireland was determined to be 2,900 GWh/year. Combined with an energy recovery factor (ERF) of 25%, there is the potential to recover a total of 725 GWh (83 MW_{th}) of waste heat from data centres in Ireland. A review of several sources on data centres indicated that there are currently 24 data centres across Ireland, most of which are based in Dublin. However, there is a lack of public information regarding the size of each site and hence the total heat potential was evenly distributed across all 24 centres. This method yields a heat potential of 30 GWh/year/site (3.5 MW_{th}). Out of the 24 centres, 4 did not have publicly disclosed locations, hence they were excluded. The remaining 20 centres are shown in Figure 14 and Figure 15
Figure . While data centres show promising potential for waste heat recovery in Ireland, these calculations carry high uncertainty and hence more public information regarding Irish site operation is required to fully characterise these sites.

2.4.7 Geothermal

High resolution and robust data are available in Ireland to depths of 400m. Beyond this depth significant further potential may exist but there is great uncertainty about the potential and suitability of sites. In the absence of suitability data for depths below 400m, this study is unable to quantify the potential for geothermal energy below this level. This is a significant limitation of this work. The focus

17 Element Energy. (2014). The Potential for Recovering and using Surplus Heat from Industry – Final Report for DECC.

18 Heatcatcher. (2020). *UK's First Waste Heat to Power System Completed at Thrislington*. Available at: https://heatcatcher.com/insights/uks-first-waste-heat-to-power-system-completed-at-thrislington-plant [Accessed: 24/12/2020].

for this analysis is on geothermal potential for up to 400m. It should, however, be noted that using geothermal for heat at depths up to 400m would require heat pump technology so is considered under GSHP and no separate category is included for geothermal energy.

2.4.8 Total potential

In total there are six power stations, two EfW facilities, and 17 industrial sites that meet the EED-defined fuel input thresholds and are suitable for waste heat recovery, as shown in Table 2. The grade of heat recoverable would in most cases be as hot water at relatively low temperature, but this is a site specific issue.

The total waste heat potential equates to 1,813 MWth. The estimates for the six power stations are based on a well-established methodology and assumptions while for the two EfW sites and the 17 industrial sites, a less established methodology has been followed. As the heat recovery potential is mostly from power stations (86.7%), it can be said that the potential reported here is with high confidence.

Table 2 Potential existing sources of waste heat

Installation name *	Type	Fuel input [MW]	Heat extraction / Heat recovery potential [MW_{th}]
PS-1	Power Station	810	267
PS-2	Power Station	810	210
PS-3	Power Station	1270	377
PS-4	Power Station	1623	342
PS-5	Power Station	754	187
PS-6	Power Station	763	189
EfW-1	Energy from Waste	77	14
EfW-2	Energy from Waste	192	35
Ind-1	Refinery	173	67
Ind-2	Food & Beverages	50	11
Ind-3	Food & Beverages	34	7
Ind-4	Food & Beverages	45	10
Ind-5	Food & Beverages	54	11
Ind-6	Food & Beverages	21	5
Ind-7	Food & Beverages	40	8
Ind-8	Food & Beverages	27	6
Ind-9	Food & Beverages	31	7
Ind-10	Food & Beverages	21	5
Ind-11	Food & Beverages	35	7
Ind-12	Pharmaceutical	22	3
Ind-13	Cement	83	9

Installation name *	Type	Fuel input [MW]	Heat extraction / Heat recovery potential [MW_{th}]
Ind-14	Cement	150	16
Ind-15	Cement	64	7
Ind-16	Cement	104	11
Ind-17	Magnesia	36	2

**Site names have been removed to anonymise data.*

2.5 Renewable and waste heat/cooling sources in district heating and cooling

Relative to other EU countries Ireland has a limited number of district heating networks, and those that have been constructed are small in size. Future schemes, such as the Clongriffin City DH Network, show greater ambition and suggest that district heating may become more prominent throughout Ireland in the coming decades. Key technologies for existing and proposed district heating schemes include boilers and CHP as well as heat pumps, while key fuels are biomass and waste in addition to gas. Applications for district heating include providing heat to residential premises, commercial centres, universities, and hospitals, and includes recovering heat from low temperature sources such as datacentres (e.g. Tallaght district heating scheme). A list of existing and proposed schemes that use renewable energy or waste heat is shown in Table 3. There is no available data on the share of energy from renewable sources and from waste heat in district heating schemes over the last five years.

No data is available on sources of waste cold in Ireland. In general, LNG terminals are the most likely sources of waste cooling supply. However, as Ireland currently has no LNG terminals in operation this has been discounted as a possible cooling supply source. Furthermore, there is very little demand for cooling throughout Ireland and only one district cooling network has been identified - University College Dublin provides cooling to science facilities on campus.

Table 3 Existing and Proposed District Heating Projects in Ireland

	Name	Plant	Fuel / Source	Consumers
Existing	Charlestown Mixed-Use Development	Biomass boiler Natural gas boiler Combined heat & power (Total: 4MWth and 228 kWe)	Biomass/natural Gas	285 Apartments 1 Shopping centre
	Glen District Heat Network	Biomass boiler	Biomass	58 Houses; 4 Apartments 1 Community centre
	Údarás na Gaeltachta – Gweedore Business Park	2 Wood pellet boilers & Solar thermal unit	Biomass	1 Office block
	Mitchells-Boherbee Tralee, Co. Kerry	Biomass boiler (1MW)	Biomass	42 Houses

	Teagasc Mellowes Campus, Athenry, Co. Galway	Wood chip boiler (250kW)	Biomass	1 Research & training facility
	Furbo Headquarters of Udarás na Gaeltachta, Co. Galway	Wood chip boiler (300kW) Oil boiler (500kW)	Biomass/Oil	1 Office block
	Leinster House DH, Kildare St, Dublin	Wood pellet boiler (1MW)	Biomass	2 Office buildings
	CRESCO, Callan, Co. Kilkenny	Wood chip biomass boiler (220kW)	Biomass	Residential dwellings
	Tralee District Heating System	2 Wood chip boilers (1MW total)	Biomass	56 Apartments; 78 Houses 5 Commercial buildings
	Elm Park, Dublin	2 Biomass boilers (1.5MW total) 4 Condensing gas boilers (4.1MW total) 4 CHP gas engines (1.8MW total)	Biomass/Natural Gas	Apartments & Offices
	University College Dublin	2 Gas CHP 3 Gas boilers 1 Biomass boiler (2 Heat pumps planned)	Natural gas/biomass	Educational, academic & living spaces Science facilities (cooling)
	Cloughjordan Ecovillage	2 Biomass boilers (1MW total)	Biomass	55 Houses
	Name	**Plant**	**Fuel / Source**	**Consumers**
Proposed	Dublin District Heating scheme	90 MW Dublin Waste to Energy Facility	Waste	Public sector, commercial, industrial and residential
	Tallaght District Heating Scheme	3 MW Heat Pump 3 MW Electric boilers	Electricity Waste heat from data centre	Civic centre, library, 3rd level institution and residential apartments
	Ringaskiddy Resource Recovery Centre	240,000 tonnes per year waste recovery facility	Waste	Includes Pharmaceutical plants and Port of Cork

2.6 Heating and Cooling Maps of Ireland

As well as identifying potential sources of waste heat (section 2.4) a detailed spatial assessment of heating and cooling demand disaggregated by Small Area[19] has been undertaken. There are 18,641 defined Small Areas in Ireland covering 70,264 km^2. Practical synergies between heat/cooling demand and potential sources can only be judged via specific and detailed analysis of particular geographic areas.

Total heating and cooling demand density maps for Ireland are shown as Figure 12 and Figure 13 respectively. Ireland's current demand for heat, based on the small area spatial disaggregation, is calculated to be 41.37 TWh pa. Ireland's current demand for cooling, based on the small area measurements, is calculated to be 7.32 TWh pa. As such, the current thermal demand of Ireland is 85% heat and 15% cooling. Table 4 shows the total annual heat and cooling consumptions split by sector.

Table 4: Total Demand by Sector [TWh/year]

	Residential	Commercial	Public	Industrial
Heating, TWh/year	19.41	5.68	3.54	12.74
Cooling, TWh/year	0.00	5.95	0.57	0.80

Table 5 shows average, minimum and maximum annual heat demand densities for Small Areas (kWh/m^2).

Table 5: Average, minimum and maximum Small Area heat and cooling annual demand densities

	Number of SAs with demand	Average SA demand density [kWh/m^2]	Minimum SA demand density [kWh/m^2]	Maximum SA demand density [kWh/m^2]
Heating	18,641	17.1	3.1×10^{-6}	3,571
Cooling	13,247	3.5	0.01	597.7

Sites deemed suitable for heat extraction from power stations or waste heat recovery from industrial sites in Ireland are shown in Figure 14. This map also presents the locations of 20 data centres that could feasibility be used for waste heat recovery, as well as the locations of existing and proposed district heating schemes. A number of these sites are positioned in Dublin and hence an enlarged map of Dublin is shown in Figure 15. These maps will be made publicly available on the SEAI website[20] in 2021.

19 Small Areas Small Areas are areas of population generally comprising between 80 and 120 dwellings created by The National Institute of Regional and Spatial Analysis (NIRSA) on behalf of the Ordnance Survey Ireland (OSi) in consultation with the Central Statistics Office (CSO). Small Areas were designed as the lowest level of geography for the compilation of statistics in line with data protection and generally comprise either complete or part of townlands or neighbourhoods. https://www.cso.ie/en/census/census2016reports/census2016boundaryfiles/

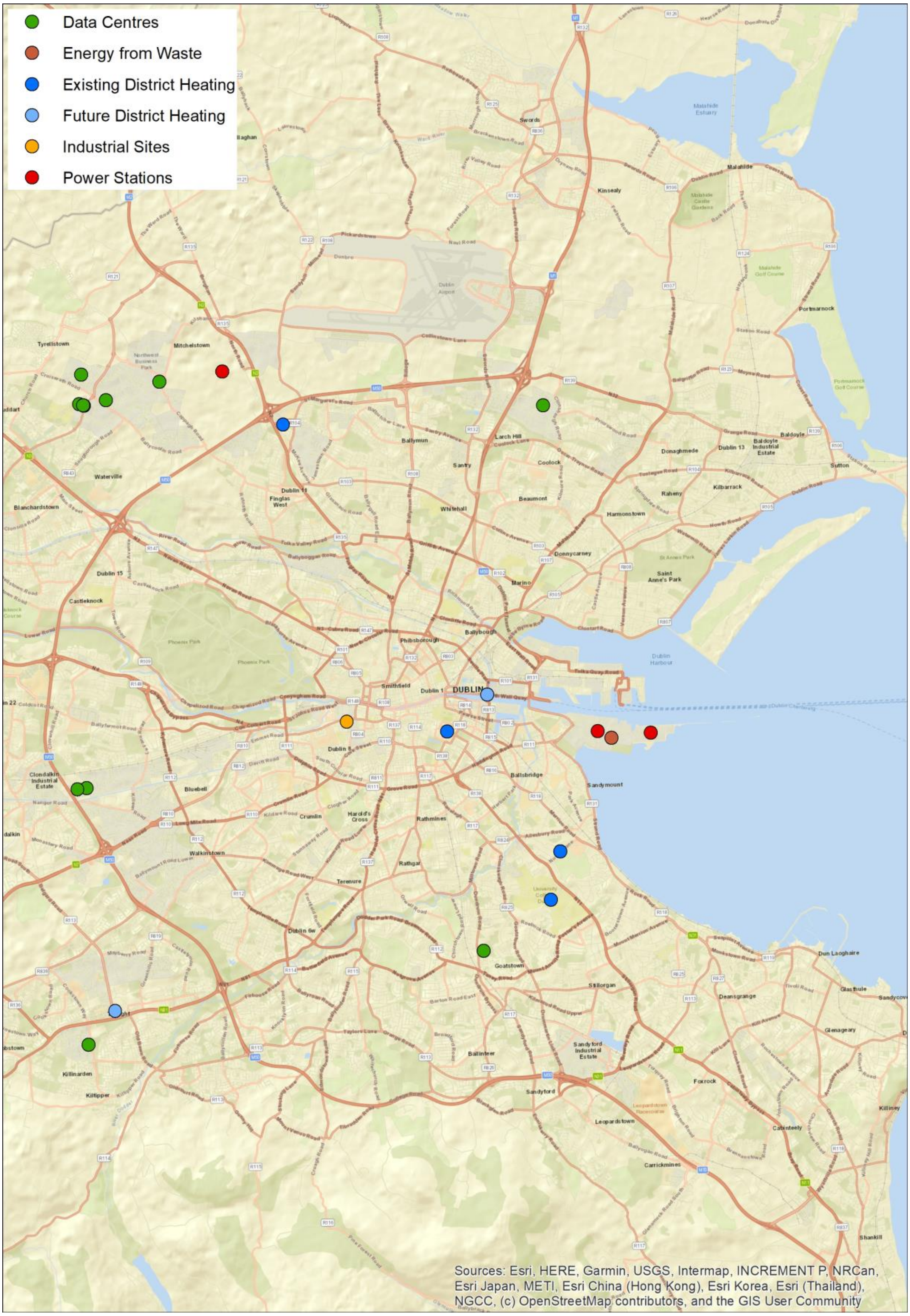
20 www.seai.ie

Figure 12 Total heating density, 2019

Figure 13 Total cooling density, 2019

Figure 14 Potential heat extraction/recovery sites and existing/planned district heating sites

Figure 15 Potential heat extraction/recovery sites and existing/planned district heating sites in Dublin



2.7 Projected demands for heating and cooling

This section covers the projected demands for heating and cooling in Ireland over the next 30 years (i.e. to 2050), but with emphasis over the next 10 years, taking account of existing policies and measures for demand management, building renovation strategies, the projected increase in data centres, and demolition/new build rates.

2.7.1 Heating Demand

Heating demand (Useful Energy) across sectors

Figure 16 shows the evolution of heating demand (useful energy) for all sectors between 2020 and 2050, for the decarbonisation scenario. While Figure 17 shows the evolution of heating fuel use (final energy) over the same period and scenario.

Figure 16 Heating demand (useful energy) by sector, in TWh per year, in the decarbonisation scenario. Demand from new builds included

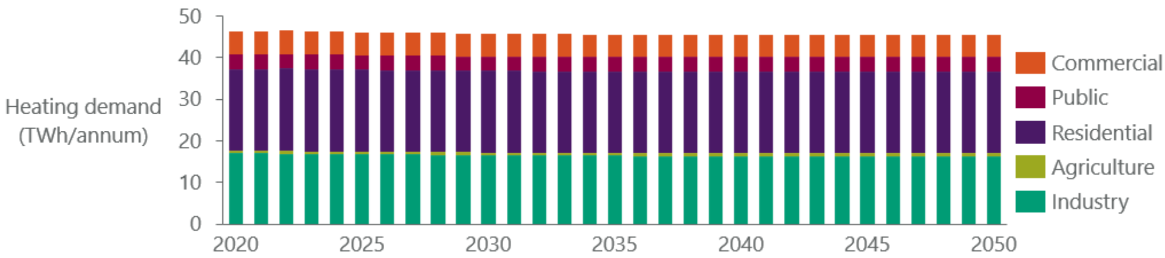


Figure 17 Heating fuel use (final energy) by sector, in TWh per year, in the decarbonisation scenario. New builds not included

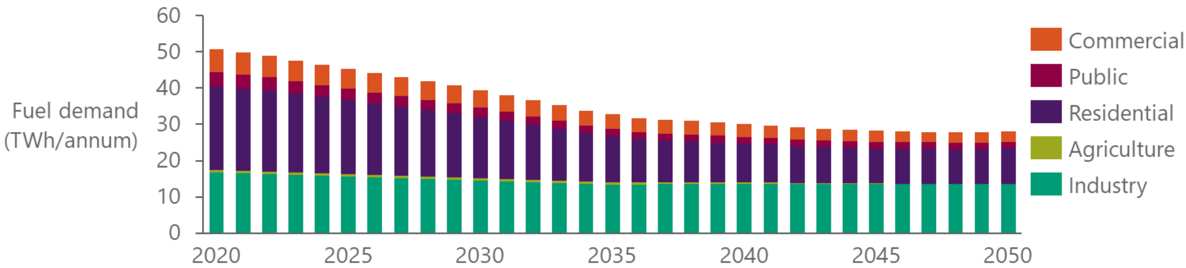


Figure 18 and Figure 19 show the relative change in heating demand from the 2020 value, by sector, for the baseline and decarbonised scenarios respectively. The reductions shown account for existing stock only (with additional heating demand from new builds not shown) and do not include macroeconomic demand changes (see Section 0). Therefore, the reductions in heating demand shown are solely the result of installing energy efficiency measures. The agriculture sector is not shown as no energy efficiency savings were modelled for that sector.

Overall, the decarbonised scenario achieves modestly higher reductions in heating demand, primarily due to modelling of more generous grant schemes for energy efficiency measures compared to the baseline scenarios, which improve the cost-effectiveness of installing energy efficiency. The relatively low savings in all sectors except Commercial are linked to the modelled technical potential of demand savings through energy efficiency, which on average is limited to 15% across the three sectors.

Figure 18 Change in heating demand by sector between 2020 and 2050 for the baseline scenario

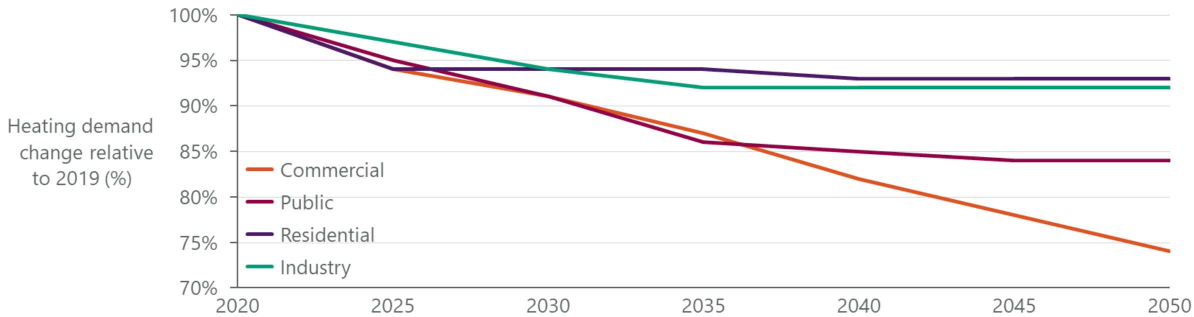
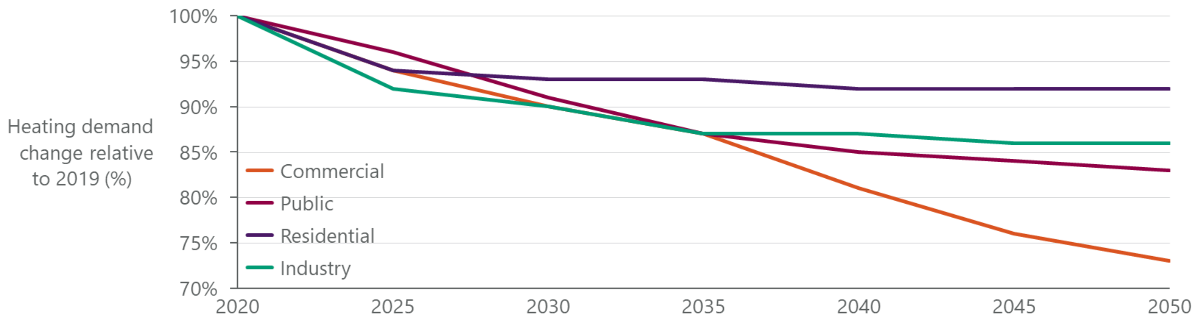


Figure 19 Change of heating demand by sector between 2020 and 2050 for the decarbonised scenario



2.7.2 Cooling Demand

Cooling demand in the residential sector

As a basis for analysis and to understand how Irish cooling demand will change over time, a review of cooling degree days in Ireland was conducted. A cooling degree day occurs when the outside temperature is warm enough to require active cooling inside (i.e. in a building / dwelling). According to Eurostat[21], there were zero cooling degree days between 2011 and 2019 in Ireland; in the nine-year period over which the data was collected, the outside recorded temperature in Ireland was not high enough to breach the threshold to require artificial cooling.

A study by the Joint Research Centre[22] (the European Commission's science and knowledge service) modelled the change in cooling degree days due to climate change across Europe. The results of this study show that even in the highest emissions scenario considered in the paper (RCP8.5, in line with a global 'business-as-usual' emissions trajectory, with projected global temperature increases of approximately 4.3°C by 2100) the number of cooling degree days per year in Ireland is expected to increase by only nine by 2050, and by twenty-four by 2100.

A European Commission study into the uptake of residential sector space cooling technologies[23] was considered when determining the proposed approach to the future demand of cooling in Ireland in the residential sector. This study describes how the uptake of residential cooling technologies (e.g. air conditioning) depends strongly on the number of cooling degree days in a location, based on the

21 Eurostat (2020), cooling and heating degree days by country – annual data

22 Spinoni, J., Vogt, J.V., Barbosa, P., Dosio, A., McCormick, N., Bigano, A. and Füssel, H.-M. (2018), Changes of heating and cooling degree-days in Europe from 1981 to 2100. Int. J. Climatol, 38: e191-e208. https://doi.org/10.1002/joc.5362 , https://rmets.onlinelibrary.wiley.com/doi/epdf/10.1002/joc.5362

23 Mindaugas Jakubcionis, Johan Carlsson, Estimation of European Union residential sector space cooling potential, Energy Policy, Volume 101, 2017, Pages 225-235, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2016.11.047

relationship between the uptake of residential cooling technologies and cooling degree days. The study found that residential air-cooling technologies only start to be installed when the annual cooling degree day count surpasses approximately twenty. This value is only expected to be reached in Ireland by 2090 in the high emissions trajectory, and never in the more moderate scenarios considered in the previous study.

While this analysis suggests there will be no cooling demand, in reality there may be some future uptake of cooling technologies in residential properties for the purpose of maintaining comfort levels on warmer days in Ireland. In these cases, building design, passive cooling, and potentially reversible heating/cooling technologies can be an important consideration for the general consumer. However, this is beyond the scope of the present study.

Due to low current requirements for residential cooling, and no significant projected demand increase (as explained earlier in this section), the uptake of domestic cooling technologies is not considered in this study. Furthermore, in the domestic BER database (which formed the basis of the domestic archetype method used here) there is no domestic cooling demand data, so any attempt to quantify the domestic cooling demand in Ireland would be ineffective.

Cooling demand in the commercial, public, industry and agriculture sectors

The current cooling demand for the commercial, public, industrial and agricultural sectors has been estimated, as described in Section 2.2.2 of this report, based on the best available data. Due to the low projected increase in cooling degree days in Ireland to 2050[22], it is not projected that the cooling demand will increase significantly above the existing demand due to climate-related temperature increases. As there is no reliable data predicting a significant increase in the cooling demand in Ireland in these sectors to 2050, the cooling demand in these sectors is modelled to stay constant.

Cooling demand in data centres

The one sector in which Irish cooling demand is projected to increase is data centres. Data centres can have significant cooling demand requirements, but the heating and cooling demands of data centres differ significantly from the other Irish sectors considered in this study. As a by-product of the data management processes that occur within data centres, large amounts of low-grade excess heat are generated. Because of this, and due to improved data centre operation at low temperatures, up to 40% of a data centre's total electricity consumption can be on cooling, depending on the efficiency of the data centre's servers and cooling method.[24]

This projected increase in electricity demand in data centres to 2050 has been modelled. Electricity consumption projections to 2029 are taken based on data from the Median Scenario in Eirgrid's latest All-Island Generation Capacity Statement[25], which are then extended to 2040 using data from the Central Scenario in EirGrid's latest Tomorrow's Energy Scenarios report.[26] The same rate of linear growth projected from 2029 to 2040 is extrapolated to 2050. The EirGrid electricity consumption projections include electricity consumption by other large energy users; these have been removed from the projections given below to avoid double-counting, as these are covered in the other sectors considered in this study. More information on this method is provided in a forthcoming report.[27] Using this method, the total electricity consumption by data centres across Ireland is projected to increase

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24 Nadjahi, C., Louahlia, H. and Lemasson, S., (2018). A review of thermal management and innovative cooling strategies for data center. Sustainable Computing: Informatics and Systems, 19, pp.14-28.

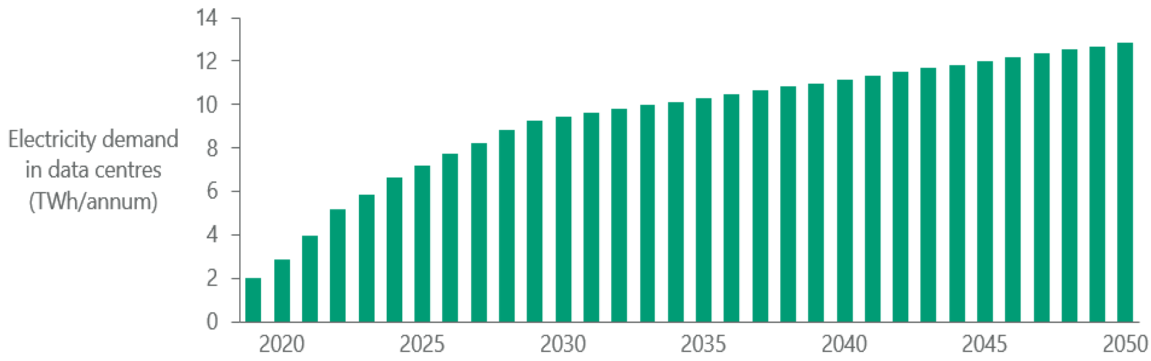
25 All-Island Generation Capacity Statement 2020-2029, EirGrid & Soni (2020)

26 Tomorrow's Energy Scenarios – 2019 Ireland, Eirgrid (2019)

27 Element Energy and Ricardo Energy & Environment for SEAI (2021), Heating and cooling in Ireland today*: Archetype Profiles, Spatial Analysis, and Energy Efficiency Potential*. Available at: https://www.seai.ie/data-and-insights/national-heat-study/

from 2.0 TWh/annum in 2019 to 9.5 TWh/annum in 2030, and 12.9 TWh/annum in 2050. This is shown below in Figure 20.

Figure 20 Annual electricity demand (TWh/annum) projection for data centres in Ireland between 2019 and 2050

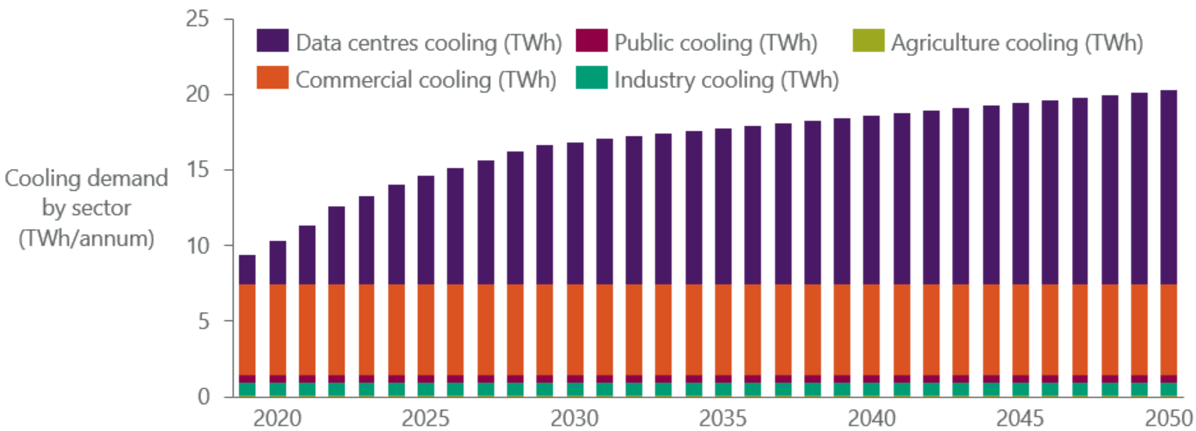


This electricity demand is consumed on-site within these data centres. Based on the assumption that one kWh of electricity consumption generates one kWh of waste heat within data centres, the annual data centre cooling demand is modelled to be equal to the annual data centre electricity consumption. This approach assumes that the heat gains from the environment (e.g. from incoming solar radiation) are negligible compared to the waste heat generated within data centres. Therefore, the electricity demand projection of data centres in Ireland to 2050 is assumed to be the same as the cooling demand projection of data centres in Ireland to 2050, shown in Figure 21 below.

Summary of cooling demand by sector

The cooling demand projection to 2050 for all sectors in Ireland is shown in Figure 21 below.

Figure 21 Modelled annual cooling demand (useful energy) (TWh/annum) by sector in Ireland between 2019 and 2050



2.7.3 Macroeconomic Projections

The macroeconomic projections are exogenous from the Economic and Social Research Institute (ESRI) Ireland Economy, Energy and Environment (I3E) model.[28] The I3E model is an intertemporal computable general equilibrium (CGE) model, which reproduces the structure of the economy in its entirety, including productive sectors, households, and the government, among others. In the model the nature of all existing economic transactions among diverse economic agents is quantified. According to micro economic behaviour, producers and consumers maximise their profits/utility given their budget constraints. In other words, a CGE model examines how inputs and outputs flow between production sectors of the economy and finally result in final goods consumed by households. The model combines theory and data to examine energy use changes due to developments in the economy, labour market, policies and international prices. Where the detailed representation of various fuel inputs into production and as consumption goods can fully capture the various mechanisms behind changed in fuel demand.

The I3E model includes energy flows and emissions in addition to the standard monetary flows. Each production sector produces an economic commodity using labour, capital, material inputs, and energy inputs. The I3E model explicitly comprises a set of carbon commodities including peat, coal, natural gas, crude oil, fuel oil, LPG, gasoline, diesel, kerosene, and other petroleum products. Production activities produce in the cheapest way possible by using the optimal set of capital, labour, energy and other intermediate inputs based on both relative prices and substitution possibilities. When an economy-wide or cross-cutting sectoral energy policy is implemented (e.g. an increase in carbon tax) or in case of an external shock (e.g. an increase in international energy prices or ETS price), production sectors will where possible substitute energy inputs for other inputs and/or decrease the carbon content of their energy inputs by demanding cleaner energy. From the consumers' perspective, higher prices of goods with higher carbon content will encourage them to consume less carbon-intensive products.

I3E is a dynamic model, which incorporates economic growth over the modelling horizon which runs from 2014 to 2050. Economic growth originates from three sources; the growth of employment driven by population growth, the growth in capital stock driven by investment, and the growth in total factor productivity or productivity of factors of production. It is assumed that the total population grows at a constant rate and the technology, i.e. the productivity of labour force grows at a constant rate. In the current version, the values of population growth and economic growth are retrieved from the medium-run estimates of the macroeconometric forecast model of the ESRI, namely COSMO (COre Structural MOdel for Ireland).[29]

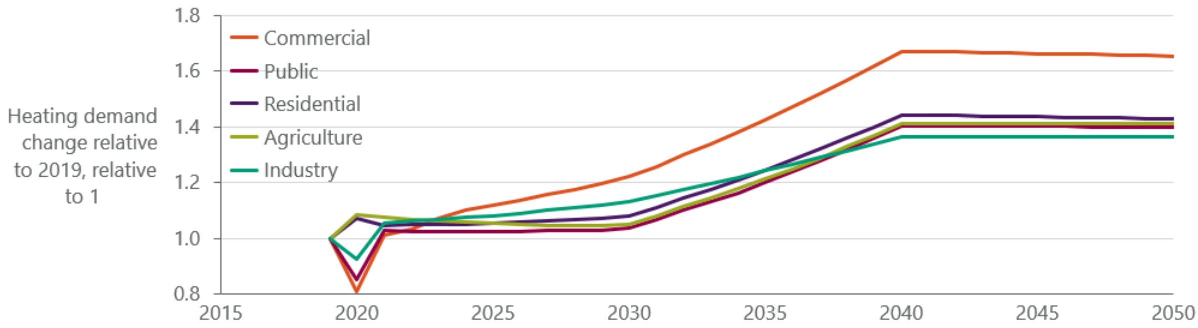
Due to projected increases in macroeconomic activity, the existing heating demand, by sector, is likely change going forward into the future. Figure 22 illustrates the relative rate at which each sector is likely to change (relative to a 2019 base year). As depicted, the commercial sector is likely to increase the most (~65%) in baseline heating demand by 2050 with other sectors increasing between 36% and 43%.

For the purposes of this report, and as noted in section 2.7.1, the heating demand across the existing stock is modelled separately and as such the results presented in this submission do not include the effect of the projections below. However, the yearly figures per the graph below, can be considered

28 https://www.esri.ie/current-research/the-i3e-model
29 https://www.esri.ie/current-research/modelling-the-irish-economy

calibration factors in that, at the highest level, these projections would effectively increase the heating demand, fuel use, costs, and emissions by the relative factors noted below.

Figure 22 Projected relative change in heating demand, by sector, from 2019 to 2050 due to macroeconomic activity



3 Objectives, Strategies and Policy Measures

Annex VIII of the Energy Efficiency Directive requires that the comprehensive assessment of national heating and cooling potentials includes an overview of existing policies and measures (PaMs) relevant to heating and cooling:

i. as described in the Member State's most recent Integrated National Energy and Climate Plan (NECP); plus
ii. any further PaMs implemented to date and not identified in the NECP.

As required by Article 1(2) of the Governance Regulation (EU) 2018/1999, PaMs are categorised by the five energy union dimensions, which are:

1. Decarbonisation;
2. Energy efficiency;
3. Energy security;
4. Internal energy market; and
5. Research, innovation and competitiveness.

Ireland's first NECP was submitted to the Commission in August 2020. Section 2 of the NECP describes national objectives and targets, Section 3 describes policies and measures and Section 4 of the NECP details projections of these measures. The NECP analysis is structured by the five energy union dimensions. PaMs relevant to heating and cooling are included in the NECP 'With Existing Measures' (WEM) scenario. Ireland's National Energy and Climate Plan also sets out that Ireland will have at least a 34.1% share of renewable energy by 2030 contributing to the overall EU target of achieving 32% renewable energy by 2030.

In October 2020, the European Commission raised its climate ambition and proposed a 55% cut in emissions by 2030. This increased level of ambition would set up the European Union on a pathway to climate neutrality by 2050. In-line with this, Ireland's Programme for Government 2020 commits to an average 7% per annum reduction in overall greenhouse gas emissions from 2021 to 2030 (a 51% reduction over the decade) and to achieving net zero emissions by 2050. In 2021, the Climate Action and Low Carbon Development (Amendment) Bill 2021 when passed, will place on a statutory basis a 'national climate objective', which commits to pursue and achieve no later than 2050, the transition to a climate resilient, biodiversity-rich, environmentally-sustainable and climate-neutral economy. The Climate Action and Low Carbon Development (Amendment) Bill 2021:

- Places on a statutory basis a 'national climate objective', which commits to pursue and achieve no later than 2050, the transition to a climate resilient, biodiversity-rich, environmentally-sustainable and climate-neutral economy.
- Embeds the process of carbon budgeting into law, Government are required to adopt a series of economy-wide five-year carbon budgets, including sectoral targets for each relevant sector, on a rolling 15-year basis, starting in 2021
- Actions for each sector will be detailed in the Climate Action Plan, updated annually
- A National Long-Term Climate Action Strategy will be prepared every five years
- Government Ministers will be responsible for achieving the legally-binding targets for their own sectoral area with each Minister accounting for their performance towards sectoral targets and actions before an Oireachtas Committee each year
- Strengthens the role of the Climate Change Advisory Council, tasking it with proposing carbon budgets to the Minister

- Provides that the first two five-year carbon budgets proposed by the Climate Change Advisory Council should equate to a total reduction of 51% emissions over the period to 2030, in line with the Programme for Government commitment
- Expands the Climate Change Advisory Council from eleven to fourteen members, and provides that future appointments to the Council provide for a greater range of relevant expertise and gender balance
- Introduces a requirement for each local authority to prepare a Climate Action Plan, which will include both mitigation and adaptation measures and be updated every five years. Local authority Development Plans will also align with their Climate Action Plan
- Public Bodies will be obliged to perform their functions in a manner consistent with national climate plans and strategies, and furthering the achievement of the national climate objective

At the time of writing the Climate Action Plan 2021[30] that supports these emissions reduction objectives is being developed. It is expected that the updated plan will develop sectoral targets focused on delivering the emissions reductions required in each sector of the economy. As this process is ongoing, the National Comprehensive Assessment work has focused on the targets and PaMs outlined in the most recent Climate Action Plan for Ireland published in 2020, and Ireland's NECP published in 2020. As new policy objectives will emerge from the forthcoming Climate Action Plan 2021, no new policies additional to the NECP are presented here.

This section outlines the objectives and the supporting PaMs. As these have not changed since the NECP, and in-line with the NCA guidance, this section does not present per measure estimates for impact metrics. However, the modelling exercise and supporting data used in the NCA work adds new analytical information, hence in Section 3.4 the objective impacts arising from the modelling work are presented here at a sectoral level.

3.1 National Energy Modelling Framework

SEAI's National Energy Modelling Framework (NEMF) is used to model the policy uptake. The model contains data on over 640 heat demand archetypes that provide a detailed description of demand in industry, services and residential sectors. Technology suitability and performance are mapped to each archetype. The model contains representations of bioenergy and hydrogen resources and fuel supply chains as well as an infrastructure module that calculates the costs of infrastructure deployment linked to technology uptake. The model uses this technoeconomic data to generate payback estimates for the various technology options available, accounting for policy incentives, taxes and regulations. This payback information is used with other data on consumer decision making behaviour to help understand how much uptake may result in various scenarios and in response to various policy measures. This simulation approach is used in this analysis to examine what impact a given set of policy measures the NEMF can have on the energy system.

As a single consumer can be eligible for several overlapping policy measures in the NEMF it is not feasible to quantify the individual impact of a policy measure in the model. However, the combined impact on the polices are available across the metrics at more aggregated levels. The impact of achieving the NECP objectives at a sectoral level are shown in this section. Section 5 presents more detail on where additional effort may be required over and above current the current PaMs to achieve the objectives and impacts outlined in this section.

30 Climate Action Plan 2021 – In Consultation.

3.2 Overview of existing policies and measures as described in Ireland's National Energy and Climate Plan 2020.

Table 6Table 6 summarises the main existing policies relating to efficiency and decarbonisation in heating and cooling included in Ireland’s National Energy and Climate Plan. The policies are of various types, including grants, tax incentives and obligation schemes. These are in addition to economy wide measures such as carbon tax.

Table 6 Overview of energy efficiency and low carbon heating policies in Ireland’s National Energy and Climate Plan

Policies	Description
Better Energy Programme	Various grants to support the installation of low carbon heating systems and energy efficiency measures in dwellings and community buildings
Social Housing Retrofit Programme	Energy efficiency renovation programme for the social housing stock
Excellence in Energy Efficient Design (EXEED)	Grant support to incentivise organisations to look at projects from the design stage, and consider the most efficient process when commissioning or designing a new project, process or asset
Accelerated Capital Allowance (ACA)	Tax incentive scheme to allow businesses to reduce their taxable profits by the full level of expenditure on energy efficient equipment in the year the investment is made’
Energy Efficiency Obligation Scheme (EEOS)	A scheme which obligates larger energy suppliers to achieve energy savings among end users
Support Scheme for Renewable Heat (SSRH)	A scheme designed to increase the energy generated from renewable sources that provides investment aid to heat pump technologies and operating aid to biomass technologies installed in non-domestic sites in the non-ETS sector.
High-efficiency CHP (HE CHP)	A tax exemption for high-efficiency CHP installations if certified by the Commission for Regulation of Utilities (CRU).
Smart meters	Combining digital technology with time of use tariffs to allow consumers to shift demand to match use energy at cheaper and less emissions intensive times.

3.3 Ireland's objectives and targets through efficiency in heating and cooling

Table 7 summarises the main objectives and targets relating to relating to efficiency and decarbonisation in heating and cooling included in Ireland's National Energy and Climate Plan and supporting PaMs. The targets primarily relate to improving energy efficiency in various building sectors, and the installation of low-carbon heating systems.

Table 7: Overview of Ireland's objectives and targets through efficiency in heating and cooling, as noted in the National Energy and Climate Plan

Objective	Sector(s)	Primary focus:	Supporting PaMs[31,32]
500,000 homes retrofitted to a B2 Building Energy Rating or cost optimal by 2030	Residential	Energy efficiency Energy security Decarbonisation	Social Housing Retrofit Programme, Energy Efficiency Obligation Scheme (EEOS), SEAI home energy grants and community energy grants, one stop shop delivery model
600,000 heat pumps to be installed over the period 2021-2030	Residential	Decarbonisation Energy Efficiency	Social Housing Retrofit Programme, Heat pump grants, Energy Efficiency Obligation Scheme (EEOS), one stop shop delivery model, effective ban on oil boilers in new dwellings from 2022, and gas boilers in new dwellings from 2025, Near Zero Energy Building (NZEB) regulations
Public sector buildings to have a B Building Energy Rating (or carbon equivalent) by 2030	Public sector	Energy efficiency Energy security	Excellence in Energy Efficient Design (EXEED), SEAI public sector partnership programme, SEAI community energy grants, SEAI energy management training and mentoring, Monitoring and Reporting (M&R) requirements, DECC Public Sector Energy Efficiency Strategy, Public sector pathfinder programme, NZEB regulations.
One third of all commercial (including mixed use) buildings to have a B Building Energy Rating (or carbon equivalent gains) by 2030	Commercial sector	Energy efficiency Energy security	EXEED, SEAI Large Industry Energy Network (LIEN), SEAI community energy grants, SEAI Energy Academy, SEAI business briefings, energy management workshops & guides, Energy auditing compliance scheme, Energy performance contracting support, Triple E product register, NZEB regulations.
Additional 1,600 GWh of renewable heat.	Commercial, Public and non-ETS industry	Decarbonisation	Support Scheme for Renewable Heat (SSRH), Heat pump grants, EXEED programme

31 Additional policy supporting the objectives in this table include carbon pricing, Ireland's Long-Term Renovation Strategy, and a range of public awareness initiatives and supports. At an EU level there is also: the EU Emissions Trading System (EU ETS), the Effort Sharing regulation (ERS), which sets a greenhouse gas emissions reduction target for Ireland of 30% by 2030 relative to 2005 levels, the Renewable Energy Directive (RED) II target of 32% of total EU-wide energy use to be renewable by 2030, and the European Green Deal target to be climate-neutral by 2050.

32 Further detail on these supporting Policies and Measures (PaMs) can be found in Ireland's Climate Action Plan 2019, Ireland's National Energy & Climate Plan, at www.seai.ie, and at www.decc.gov.ie.

Objective	Sector(s)	Primary focus:	Supporting PaMs[31,32]
1.6 TWh of indigenous biomethane by 2030	All sectors	Decarbonisation	No current measures
Additional district heating of 0.12TWh growing linearly from 2023 to 2028	All sectors	Decarbonisation Energy Efficiency	Develop a national policy framework for district heating, covering the key areas of regulation, planning, financing, and research, Develop experience and knowledge from two pilot programmes

Table 8 below presents the objectives outlined in Table 7 in the voluntary reporting template for objectives, strategies, and measures.

Table 8 - Voluntary reporting template – objectives, strategies, and policy measures

Name of policy, strategy, or objective	Main objective of policy or strategy	Indicative national energy contribution, based on primary or final energy consumption, primary or final energy savings, or energy intensity*	Short description (precise scope and operational arrangements)	Relevant energy union dimension and intended impact, if applicable	Implementation period	Status of implementation
500,000 homes retrofitted to a B2 Building Energy Rating or cost optimal by 2030	Improvement in building energy efficiency in the residential sector	N/A – no information available for specific objectives. See Section 3.4 for overall trajectories and sectoral breakdown.	The Climate Action Plan (CAP) 2019 sets a target to upgrade 500,000 existing residential buildings to a B2 BER, cost optimal equivalent or carbon equivalent by 2030. Current policy measures are listed in Table 6. Primary funding for these measures is linked to Ireland's National Development Plan (NDP), which runs until 2027, and the European Regional Development Fund.	Energy efficiency Energy security See Section 3.4 for policy impacts - overall trajectories and sectoral breakdown	To 2030	Measures in place, see Table 6 and Table 7 for specific measures
600,000 heat pumps to be installed over the period 2021-2030	Increase the use of renewable energy in the residential sector	N/A – no information available for specific objectives. See Section 3.4 for overall trajectories and sectoral breakdown.	The Climate Action Plan 2019 (CAP) sets a target to install 600,000 heat pumps in the residential sector by 2030. The 600,000 target is subdivided into a target for new builds and a target for the retrofit of existing homes. Macroeconomic projections suggest approximately 200k new homes may be constructed to 2030. This suggests that ~400,000 homes must retrofit to achieve the overall target. Current policy measures are listed in Table 6. Primary funding for these measures is linked to Ireland's National Development Plan (NDP), which runs until 2027.	Decarbonisation See Section 3.4 for policy impacts - overall trajectories and sectoral breakdown	To 2030	Measures in place, see Table 6 and Table 7 for specific measures

Public sector buildings to have a B Building Energy Rating (or carbon equivalent) by 2030	Improvement in building energy efficiency, and reducing emissions in the public sector, working towards net-zero 2050.	N/A – no information available for specific objectives. See Section 3.4 for overall trajectories and sectoral breakdown.	The Climate Action Plan 2019 (CAP) sets a target to upgrade all public sector buildings to BER B, cost optimal equivalent or carbon equivalent by 2030. Current policy measures are listed in Table 6. Primary funding for these measures is linked to Ireland's National Development Plan (NDP), which runs until 2027.	Energy efficiency Energy security See Section 3.4 for policy impacts - overall trajectories and sectoral breakdown	To 2030	Measures in place, see Table 6 and Table 7 for specific measures
One third of all commercial (including mixed use) buildings to have a B Building Energy Rating (or carbon equivalent gains) by 2030	Improvement in building energy efficiency, and reducing emissions in the commercial sector, working towards net-zero 2050.	N/A – no information available for specific objectives. See Section 3.4 for overall trajectories and sectoral breakdown.	Ireland's National Energy and Climate Plan (NECP) sets a target to upgrade one third of commercial sector buildings to BER B, cost optimal equivalent or carbon equivalent by 2030. Current policy measures are listed in Table 6. Primary funding for these measures is linked to Ireland's National Development Plan (NDP), which runs until 2027.	Energy efficiency Energy security See Section 3.4 for policy impacts - overall trajectories and sectoral breakdown	To 2030	Measures in place, see Table 6 and Table 7 for specific measures
Additional 1,600 GWh of renewable heat via SSRH.	Increase the use of renewable energy in the non-domestic, and non-ETS sectors	N/A – no information available for specific objectives. See Section 3.4 for overall trajectories and sectoral breakdown.	The Climate Action Plan 2019 (CAP) sets a target to produce an additional 1,600 GWh of renewable heat by 2025. Current policy measures are listed in Table 6. Primary funding for these measures is linked to Ireland's National Development Plan (NDP), which runs until 2027.	Decarbonisation See Section 3.4 for policy impacts - overall trajectories and sectoral breakdown	To 2025	Measures in place, see Table 6 and Table 7 for specific measures

1.6 TWh of indigenous biomethane by 2030†	Increase the cross-sectoral use of renewable energy	N/A – no information available for specific objectives. See Section 3.4 for overall trajectories and sectoral breakdown.	Ireland's National Energy and Climate Plan (NECP) sets a target to produce 1.6 TWh of indigenous biomethane for injection into the national gas grid by 2030. There are no current policy measures or funding for this objective, measures are currently under consideration. See Section 0 for further information.	Decarbonisation See Section 3.4 for policy impacts - overall trajectories and sectoral breakdown	To 2030	Measures currently under consideration, see Section 0 for further information
Additional district heating of 0.12TWh growing linearly from 2023 to 2028	Increase the cross-sectoral use of renewable energy, and maximise inter-sectoral synergies	N/A – no information available for specific objectives. See Section 3.4 for overall trajectories and sectoral breakdown.	Ireland's National Energy and Climate Plan (NECP) sets a target to deliver additional district heating of 0.12TWh growing linearly from 2023 to 2028. There are no current policy measures or funding for this objective, measures are currently under consideration. See Section 0 for further information.	Decarbonisation See Section 3.4 for policy impacts - overall trajectories and sectoral breakdown	To 2028	Measures currently under consideration, see Section 0 for further information

* in line with the approach chosen in the framework of the Governance Regulation.
† assumes that the biomethane injected to the grid is used in the heat sector.

3.4 Impact of policy objectives – a sectoral view

As an addition to work previously presented in the NECP, this section presents the overall and sectoral impacts of achieving the policy objectives outlined in Section 3.3, along with the associated technology uptake, and use of renewable fuels. These results are based on analysis carried out as part of the national comprehensive assessment, which benefits from additional data gathered and analytical tools developed since the NECP submission.

This work quantifies policy impacts across the energy efficiency and decarbonisation dimensions only. The energy security, research, innovation and competitiveness, and internal energy market dimensions have not been explicitly examined or quantified. The impacts of heating and cooling policy on land use are not presented here, as they are part of ongoing policy development work, including the forthcoming Climate Action Plan 2021. However, related to this, to support the national comprehensive assessment considerable and detailed attention was given to an assessment of the sustainability aspect of bioenergy used for heating and cooling, to be published separately.

Projected overall and sectoral policy impacts of achieving the policy objectives outlined in Section 3.3 are as follows:

- Greenhouse gas emissions annual trajectory and sectoral breakdown
    - See Figure 55 in Section 4.3.5.
- Useful energy savings related to energy efficiency
    - See Figure 56 in Section 4.3.5, and Table 9 below in this section.
- Renewable energy supply – heat (RES-H)
    - See Figure 23 RES-H Trajectory – Decarbonised Scenario below in this section.
- Technology mix in 2050
    - See Figure 57 in Section 4.3.5

Figure 23 RES-H Trajectory – Decarbonised Scenario

Table 9 Useful Energy Savings for Energy Efficiency (TWh)

Year	Commercial	Public	Residential	Agriculture	Industry	Total
2020	0.039	0.076	0.052	0.000	1.382	1.549
2021	0.127	0.146	0.100	0.000	1.427	1.799
2022	0.207	0.208	0.149	0.000	1.472	2.036
2023	0.279	0.263	0.196	0.000	1.517	2.256
2024	0.345	0.311	0.235	0.000	1.578	2.469
2025	0.399	0.338	0.269	0.000	1.640	2.646
2026	0.443	0.353	0.280	0.000	1.701	2.779
2027	0.483	0.369	0.292	0.000	1.763	2.908
2028	0.518	0.385	0.305	0.000	1.825	3.033
2029	0.550	0.402	0.318	0.000	1.886	3.156
2030	0.586	0.418	0.333	0.000	1.948	3.285
2031	0.619	0.437	0.349	0.000	2.008	3.413
2032	0.648	0.456	0.361	0.000	2.069	3.535
2033	0.675	0.474	0.374	0.000	2.129	3.652
2034	0.703	0.492	0.386	0.000	2.189	3.771
2035	0.767	0.513	0.410	0.000	2.229	3.918
2036	0.833	0.532	0.428	0.000	2.259	4.052
2037	0.897	0.547	0.437	0.000	2.288	4.170
2038	0.959	0.560	0.440	0.000	2.317	4.276
2039	1.019	0.571	0.444	0.000	2.335	4.369
2040	1.078	0.581	0.447	0.000	2.352	4.458
2041	1.135	0.589	0.449	0.000	2.369	4.542
2042	1.191	0.597	0.449	0.000	2.386	4.623
2043	1.246	0.604	0.450	0.000	2.402	4.702
2044	1.301	0.610	0.449	0.000	2.419	4.780
2045	1.349	0.616	0.447	0.000	2.436	4.849
2046	1.397	0.620	0.445	0.000	2.453	4.915
2047	1.443	0.624	0.444	0.000	2.470	4.981
2048	1.489	0.627	0.443	0.000	2.488	5.047
2049	1.530	0.631	0.443	0.000	2.505	5.108
2050	1.569	0.634	0.443	0.000	2.514	5.160

4 Potential for Efficiency in Heating and Cooling

The revised Annex VIII to the Energy Efficiency Directive requires that for the comprehensive assessment an analysis of the potential of different technologies for heating and cooling shall be carried out for the entire national territory by using cost-benefit analysis and shall identify alternative scenarios for more efficient and renewable heating and cooling technologies, distinguishing between energy derived from fossil and renewable sources where applicable.

The cost benefit analysis must include both an an economic analysis that takes into consideration socioeconomic and environmental factors, and a financial analysis performed to assess projects from the investors' point of view. Both economic and financial analyses use the Net Present Value (NPV) as the criterion for the assessment.

This work leverages SEAI's National Energy Modelling Framework (NEMF), which is a tool for modelling the whole energy system. It is a full national energy-economy model that assesses the impacts of packages of energy policies and measures (PaMs) on energy supply and demand. Additionally, it combines several SEAI sectoral energy models with data from ESRI's macroeconomic I3E model to produce policy-rich outlooks for the whole energy system. The updated version of this tool, combined with a refreshed set of inputs and assumptions, is basis of the results shown in this section.

4.1 Approach and Scenarios

The recommendations and requirements set out in the EU legislation and guidance have been reviewed and are followed in this work's approach. For this submission, two scenarios are analysed:

- a '**Baseline**' or 'Business as Usual' scenario including bottom-up modelled existing policy measures (further detailed in Section 3.2). Aligned to the submission requirements, this scenario seeks to reflect the most likely trajectory for the heating and cooling sector in the absence of further policy support for decarbonisation.
- an **Alternative** or **Decarbonisation** scenario including a heightened support of policy measures and other factors designed with the intention to achieve (or align as closely as possible to) Ireland's climate ambitions (further detailed in Section 3.3). The Alternative scenario seeks to represent a plausible, 'central' scenario for the decarbonisation of heat, utilising a mix of technologies where each is cost effective.

In both scenarios, "the evolution of energy demand" is interpreted to refer to the evolution of the demand for thermal comfort and for commercial and industrial processes. This energy service demand is mostly held constant for thermal comfort and for commercial and industrial processes, allowing for reductions as energy efficiency measures are deployed. Demand for data centres is treated differently – see section 2.7. Additionally, per the guidance, the scenarios account for additional criteria (supplementing the strict NPV selection approach) to determine the uptake of energy efficiency and heating systems. For example, consumer behaviour, non-reliance on a single technology, and the reduction of CO_2 emissions are utilised as additional criteria to support more comprehensive decision-making into a more plausible scenario.

The basis of the approach taken to develop coherent scenarios is detailed as follows:

1. **Agreement of key principles** providing context for and differentiating the **Baseline and the Alternative scenario**.
    - This is informed by existing policy, the level of ambition for decarbonisation (for the Alternative scenario), and potential increased level of policy (for the Alternative scenario).

2. **Determination of constraints on suitability, technical potential, performance, and cost** for the low carbon technologies under the scenario in relative isolation.
    - Data gathered on each technology, the Irish energy system, and the overarching context in each scenario is used to estimate the level of deployment that may be technically feasible under each scenario – the technical potential.
    - Constraints on suitability, barriers to uptake and/or deployment, and other system factors inform the estimate of technical potential.
    - The total stock relevant to a particular technology is considered (e.g. for heat pumps, domestic and commercial buildings) and the fraction which face technical barriers to system deployment (e.g. buildings with too high heat loss factors to be met by a heat pump, or buildings without the space to install a heat pump) are removed to leave those technically suitable for the technology.

3. **Creation of plausible scenarios and assessment of economic potential.**
    - Economic potential is a subset of technical potential that is economically cost-effective compared to other options including conventional supply-side energy resources.
    - The technical potentials, performance, and cost data collected and defined in Step 2 are brought together to allow an economic comparison of the low carbon technologies under each of the scenarios defined in Step 1.
    - The least negative NPV when all technologies, including the counterfactual, are compared indicate cost-effectiveness and therefore constitute the economic potential of that technology; the carbon abatement cost-effectiveness (€/tCO_2) may be used to support decision-making.
    - The modelling shows that leaving fossil fuel options in the model post-2035 results in significant residual emissions by 2050 as many in the decarbonised scenario as consumers do not see attractive paybacks on the renewable heating options.
    - To achieve the policy objective of net zero by 2050 actions will be required to address this. As the NCA does not require detailed policy modelling beyond 2030, this work makes the following simplifying assumptions to reach net zero by 2050:
        - Public sector not allowed to take up non-renewable heating systems from 2031.
        - Residential sector not allowed to take up non-renewable heating systems from 2032.
        - Commercial sector not allowed to take up non-renewable heating systems from 2034.
        - Agriculture sector not allowed to take up non-renewable heating systems from 2035.
        - Industry sector not allowed to take up non-renewable heating systems from 2035.
    - These assumptions do not imply any specific policy or regulatory approach but rather seek to capture what is needed to achieve the goal of net zero by 2050.

4. **Development of uptake trajectories.**
    - The uptake trajectories consider technical potential, suitability constraints and consumer willingness to upgrade existing systems for each technology in each scenario.
    - For the alternative scenario, where the final uptake of a given technology based on consumer uptake is initially inconsistent with policy targets and the scenario design, the modelled policy drivers are iterated until such point where the appropriate level of final uptake is observed.

In step 3 of the above, a set of economic potential Marginal Abatement Cost Curves (MACCs) are developed to understand, using solely economic potential, what technologies could a future scenario potentially consist of in 2030 and 2050. This informs the larger modelling of plausible scenarios. However, for the purposes of this submission (as required for the NCA), net present value (NPV) graphs are presented (see section 4.3) in two cases: (i) economic analysis cost-benefit analysis (CBA) and (ii) financial CBA. This is performed on a NUTS1 level (i.e. national level). The method used for the CBA is described in the next section.

Different versions of the MACCs noted above (e.g. using carbon abatement cost as the metric) are then developed to further inform potential heating system uptake for 2030 and 2050. In conjunction with steps 1-3, the scenario narrative, assumptions, suitability criteria and other relevant factors are finalised, and the model is used in iteration, aligned to step 4, to develop a more realistic set of scenarios which incorporate a more comprehensive set of factors, as described above.

The following technologies are considered:

a) Recovery of industrial waste heat:
   - For use in district heat networks.
   - For use in industry. This is addressed via improved industrial energy efficiency (i.e. improved process integration.
   - Waste cold is not included in the analysis as there is low availability as well as low demand for cooling due to the temperate Irish climate.

b) Waste incineration:
   - In industry, primarily in the cement sector.
   - Non-biogenic waste incineration is not considered for heating use in other sectors as the available supply will continue to be directed towards power generation.

c) High efficiency cogeneration
   - In district heat networks.
   - In industry.

d) Renewable energy sources
   - Geothermal in district heat networks.
   - Solar thermal in the residential, commercial, and public sectors.

e) Solid biomass in all heating sectors.

f) Biomethane in all heating sectors.

g) Air- and ground-source heat pumps
   - In all heating sectors.

h) Reduction of losses from existing district heat networks
   - Not included due to very low penetration of existing district heat networks.
   - Considered to be very low economic potential – if any – for reducing losses.
   - There is also a lack of data on existing losses from existing district heat networks.

4.2 Cost-benefit analysis (CBA)

As required by Annex VIII of the EED, the cost benefit analysis has been undertaken:

1. as an economic analysis that takes a societal point of view by incorporating socio-economic factors, such as a suitable social discount rate (SDR), and environmental externalities in determining net present values (NPVs); and
2. as a financial analysis that takes an investor's point of view by considering actual project cash flows and typical commercial rates of return that investors would require in determining NPVs.

The following sections summarise the factors and assumptions employed in the CBAs. All costs are expressed in 2019 real terms, discounted over the assumed lifetimes of technologies (15 years for most technologies).

4.2.1 Discount Rates

Social Discount Rate (SDR)

The SDR recommended by the Commission is 3% for non-cohesion Member States, though Member States may establish a different value. Ireland's Public Spending Code[33] currently specifies an SDR of 4%, which is supported by a Department of Public Expenditure and Reform (DPER) Staff Paper[34]. This value has therefore been employed for the economic analysis in the comprehensive assessment.

Financial Discount Rates

For most sectors, discount rates have been employed for the financial analysis based on the PRIMES model values provided in section 2.6.1 of the EU Reference Scenario 2016[35] as these represent the best sector specific information available. For regulated energy networks (including district heating) the Weighted Average Cost of Capital (WACC) specified by Ireland's Commission for Regulation of Utilities (CRU)[36] for price control purposes has been used. Discount rates are shown in Table 10 .

Table 10 Discount rates for the financial analysis

Sector	Discount rate	Source
Residential	12.0 %	Based on PRIMES model/EU Reference Scenario values
Commercial	11.0 %	
Public	7.5 %	
Industry	8.25 %	
Agriculture	9.0 %	
Network infrastructure – regulated (incl. DH)	3.8 %	CRU price control WACC
Other utility developers (incl. H_2 infrastructure)	7.5 %	PRIMES model/EU Reference Scenario: other network monopolies and grids. For other higher risk infrastructure, e.g. H_2.

33 Public Spending Code: Central Technical References and Economic Appraisal Parameters, Department of Public Expenditure and Reform, July 2019. https://assets.gov.ie/43554/70a378231f1540b0a09a0560dc9dd26f.pdf

34 O'Callaghan, D. and Prior, S. (2018) Central Technical Appraisal Parameters – DPER Staff Paper, Dublin. https://igees.gov.ie/wp-content/uploads/2019/07/Parameters-Paper-Final-Version.pdf

35 EU reference scenario 2016. Energy, transport and GHG emissions: trends to 2050, European Commission. https://op.europa.eu/en/publication-detail/-/publication/aed45f8e-63e3-47fb-9440-a0a14370f243

36 Financial issues for PR5 Final Determination final report, CEPA for Commission for Regulation of Utilities (CRU). https://www.cru.ie/wp-content/uploads/2020/12/CRU20151-Financial-issues-for-PR5-Final-Determination-1.pdf

4.2.2 Carbon Pricing

All sectors of the Irish economy are subject to actual costs directly related to their carbon emissions. This is achieved through carbon taxation levied on fuels and, for installations under the EU-ETS, the requirement to purchase allowances.

Carbon Tax

Administratively there are three carbon taxes in Ireland:

- the Natural Gas Carbon Tax (NGCT);
- the Solid Fuel Carbon Tax (SFCT); and
- the Mineral Oil Tax (MOT), carbon component B.

The full rate for all three is currently €33.50$_{(nom)}$[37] per tCO_2e. The Irish Government's intention is that this will increase by €7.50$_{(nom)}$ per tCO_2e each year, reaching €100.00$_{(nom)}$ per tCO_{2e} in 2030. Table 11 shows the anticipated carbon tax rates as 2019 real prices[38]. For the CBA, the carbon tax has been fixed at €100.00$_{(nom)}$ per tCO_2e beyond 2030 and thus decline in real terms from 2030.

The full rate of carbon tax applies to all consumers, except those installations covered by the EU-ETS, which are charged at partial relief or zero rates as also shown in Table 11. These are currently (2021) equivalent to €2.99$_{(nom)}$ and €1.59$_{(nom)}$ per tCO_2 for natural gas and coal respectively, and zero for peat and oil. These values (converted to real 2019 terms) have been used in both economic and financial CBAs as applicable.

EU-ETS Allowances

Traded shadow prices of carbon up to 2050 are also provided in Ireland's Public Spending Code[39] and have been used in both economic and financial CBAs to represent the price of allowances. These are also presented in Table 11 expressed in €$_{2019}$ per tCO_2e.

[37] In nominal terms.

[38] Rebasing undertaken using Consumer Price Index, CPA04, https://data.cso.ie/table/CPA04 and future 2% pa increase, https://www.gov.ie/en/policy-information/1a0dcb-project-discount-inflation-rates/#inflation-indices

[39] Public Spending Code: Central Technical References and Economic Appraisal Parameters, Department of Public Expenditure and Reform, July 2019. https://assets.gov.ie/43554/70a378231f1540b0a09a0560dc9dd26f.pdf

Table 11 Carbon tax and traded shadow price of carbon values 2019-2050,[38,39] €2019/tCO_2e

Year	Carbon tax full rate	Carbon tax relief rates for EU-ETS installations			Traded Shadow Price of Carbon
	Natural gas, coal, peat, oil	Natural gas	Coal	Peat and Oil	EU-ETS
2019	26.00	1.81	0.96	0.00	24.00
2020	26.08	1.81	0.96	0.00	24.00
2021	32.94	1.81	0.96	0.00	24.00
2022	39.52	1.80	0.96	0.00	24.00
2023	45.84	2.32	1.23	0.00	24.00
2024	51.89	2.32	1.24	0.00	24.00
2025	57.68	2.94	1.56	0.00	24.00
2026	63.23	3.52	1.87	0.00	25.12
2027	68.54	4.08	2.17	0.00	27.36
2028	73.62	4.62	2.46	0.00	29.59
2029	78.47	5.14	2.73	0.00	31.83
2030	82.28	5.64	3.00	0.00	34.07
2031	80.66	6.11	3.25	0.00	35.80
2032	79.08	6.56	3.49	0.00	37.52
2033	77.53	6.99	3.72	0.00	39.25
2034	76.01	7.33	3.90	0.00	40.98
2035	74.52	7.19	3.82	0.00	42.71
2036	73.06	7.05	3.75	0.00	44.34
2037	71.63	6.91	3.67	0.00	45.97
2038	70.22	6.77	3.60	0.00	47.59
2039	68.85	6.64	3.53	0.00	49.22
2040	67.50	6.51	3.46	0.00	50.85
2041	66.17	6.38	3.39	0.00	54.71
2042	64.87	6.26	3.33	0.00	58.58
2043	63.60	6.14	3.26	0.00	62.44
2044	62.36	6.02	3.20	0.00	66.30
2045	61.13	5.90	3.13	0.00	70.17
2046	59.93	5.78	3.07	0.00	74.03
2047	58.76	5.67	3.01	0.00	77.90
2048	57.61	5.56	2.95	0.00	81.76
2049	56.48	5.45	2.90	0.00	85.63
2050	55.37	5.34	2.84	0.00	89.49

4.2.3 Damage costs of non-greenhouse gas pollutants

Valuations for the estimated damage costs of non-greenhouse gas pollutants are set out in the Public Sector Code[39]; these are reproduced here as €$_{2019}$ per tonne in Table 12.

Table 12 Estimated damage costs in €2019 per tonne of pollutant[39]

PM2.5			NOx	NMVOCs	SOx
Rural	Suburban	Urban			
17,598	50,538	207,461	6,062	1,490	7,417

Since these costs are not borne directly by the polluters, they are only included in the economic CBA.

4.2.4 Value of energy outputs

The values of energy outputs to the consumer (heating, cooling, and electricity) have not been explicitly considered in the analysis but are implicit in comparing options with the Base (business as usual) scenario. In other words, everything is treated as a cost so present values are all negative, the least negative NPV being the most cost effective.

4.2.5 Energy costs

In the modelling, the total cost for a particular source of energy is split into four categories:

- wholesale cost – cost of energy, generation capacity and flexibility
- network cost – infrastructure
- fixed cost (per kWh) – network costs, levies, etc. (defined exogenously)
- other costs due to CO_2 content (as per 4.2.2)

The wholesale cost projections to 2050 for fossil fuels (oil, natural gas and coal) are taken from the BEIS 2019 Fossil Fuel Price Assumptions[40]. The wholesale cost for electricity and hydrogen are calculated dynamically within the power system and hydrogen infrastructure system modelling carried out. The wholesale costs for biogenic fuels are calculated within the modelling of resource price and availability.

The infrastructure network costs for natural gas, hydrogen and electricity are calculated dynamically, as part of the infrastructure system modelling. The fuels with no centralised transmission or distribution system network (such as coal or fuel oil) do not have any network infrastructure costs.

The total fuel costs differ by consumption band, and a simple average for the fuel price of each consumption band in each quarter over the last 3 years was taken from available historic data[41] to smooth any in-year variation in the base year. The fixed cost components of these consumption bands (including levies and non-infrastructure network costs) are taken from the Eurostat database for 2019. This data is provided to Eurostat by SEAI as per EU Regulation 2016/1952.

Table 13 below includes the initial total retail cost for each fuel type considered (excluding carbon taxes). Note that the values used in modelling varied by consumption band, in line with the available data on retail fuel costs, so the costs presented in this table are simple average across all consumption

40 BEIS 2019 Fossil Fuel Price Assumptions (2020), BEIS; https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/863717/beis-2019-fossil-fuel-price-assumptions.pdf

41 Fuel Cost Comparisons, SEAI Energy Data Downloads; https://www.seai.ie/data-and-insights/seai-statistics/key-statistics/energy-data/#comp00005c0fcbea00000088e671a3

bands. These retail costs change year-on-year, depending on the dynamic wholesale and infrastructure network costs.

Table 13 Initial total retail cost (c/kWh),[41] NCV for different types of fuels

Fuel	Use of fuel	Initial retail cost (c/kWh NCV)
Solid – residential**	Residential archetypes with CF solid boilers	3.9
Fuel oil - residential	Residential archetypes with CF oil boilers	7.7
Gas - residential	Residential archetypes with CF gas boilers	7.8
Electricity - residential heating	Used for heating purposes by heat pump technologies in the residential sector.	22.7
Electricity - residential	Electrical appliance consumption in residential archetypes, and for electric resistive heating.	26.1
Electricity - residential storage heating	Residential properties with electric storage heaters (no electric storage heaters are considered for the commercial and public sectors).	7.9
Fuel oil - commercial	Commercial archetypes with CF oil boilers	8.1
Electricity - commercial heating	Used for heating purposes by heat pump technologies in the commercial sector.	13.7
Electricity - commercial	Electrical appliance consumption and electricity consumption for cooling in commercial archetypes, and for electric resistive heating.	15.0
Gas - commercial	Commercial archetypes with CF gas boilers	4.5
Fuel oil - public	Public archetypes with CF oil boilers	8.1
Gas - public	Public archetypes with CF gas boilers	4.5
Electricity - public heating	Used for heating purposes by heat pump technologies in the public sector.	13.7
Electricity - public	Electrical appliance consumption and electricity consumption for cooling in public archetypes, and for electric resistive heating.	15.0
Non-bio waste - industry	Industry archetypes with industrial fuel 'Non-bio waste'	-2.8
Solid Fuels - industry	Industry archetypes with industrial fuel 'Solid fuels'	1.7
Oil - industry	Industry archetypes with industrial fuel 'Oil'	7.7
Gas - industry	Industry archetypes with industrial fuel 'Gas'	4.5
Electricity - industry heating	Not used in any CF heating technology. To be used in RT heating systems with fuel 'Electricity'.	12.9
Electricity - industry	Appliance electricity use & cooling electricity use in industrial archetypes.	15.0
Fuel oil - agriculture	Agriculture archetypes with oil boilers	7.7

* NCV is Net Calorific Value (also Lower Heating Value);** Costs for different consumption bands based on costs of different solid fuels. Lowest band cost is based on coal (61 c/kWh). Highest band is based on sod peat (0 c/kWh). Middle band is based on a use-weighted average of coal, peat briquettes and sod peat

In Ireland there is an Electricity Tax that is paid by all non-residential consumers at a current rate of €1 /MWh (€$_{2019}$ 0.98 /MWh). This is not linked to carbon and there are currently no indications that the rate will rise; it has therefore been incorporated into the fixed cost category for electricity prices. Similarly, the non-carbon related Mineral Oil Tax excise component A has been included under the fixed cost category for oils.

The following graphs (Figure 24 and Figure 25) show the price arising from the model of key fuels from 2020 to 2050 for each scenario. The large increase in gas cost in the decarbonised scenario is driven by the increasing network component of the retail cost – this is a fixed cost for maintaining the existing infrastructure. As such, as the total demand for gas decreases, the cost per kWh for the gas network increases.

Figure 24 Annual variation of retail cost of fossil / counterfactual fuel (€ / kWh) in the baseline scenario. The fuel costs are a simple average across all consumption bands

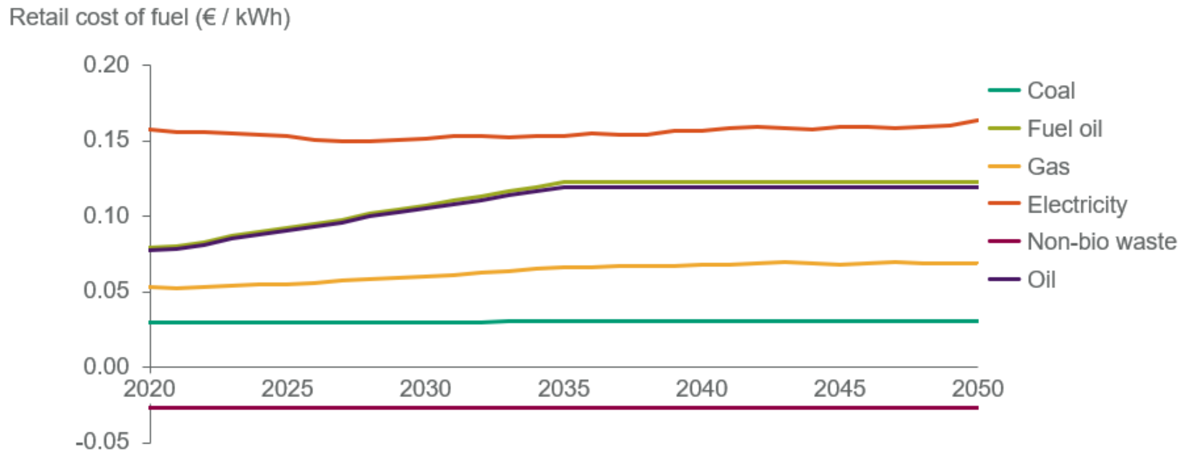
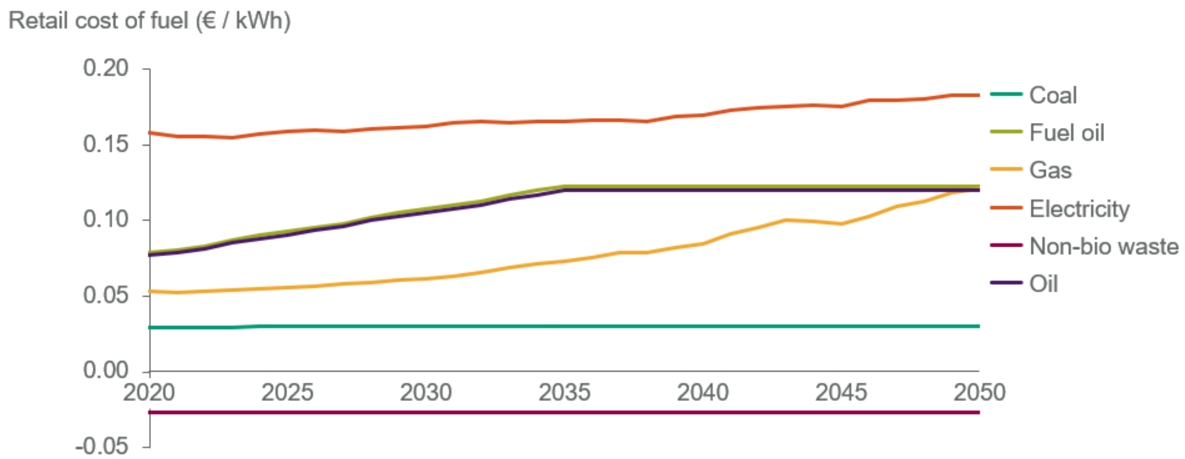


Figure 25 Annual variation of retail cost of fossil / counterfactual fuel (€ / kWh) in the decarbonised scenario. The fuel costs are a simple average across all consumption bands.



4.2.6 Heating technology costs

Several sources were used to estimate the costs of heating technologies in the modelling. The modelled capital and operating costs of selected renewable heating technologies and the sources used are summarised in Table 14. It should be noted that whilst only one unit size is shown, a range of unit sizes for each technology were considered in the modelling, each with their own unique costs (where relevant) For instance, in many cases larger sizes have lower marginal costs than smaller sizes. The most appropriate unit size for each archetype is chosen in the modelling, based on the demand associated with that archetype.

The capital costs quoted in Table 14 include the unit cost, fittings and controls costs, and labour costs, but do not include various additional costs included in the modelling, such as costs associated with upgrading radiators when installing heat pumps in residential buildings or the decommissioning of the previous system.

Table 14 Summary of costs of selected heating technologies in the modelling, and associated data sources.

Renewable heating technology	Unit size	Modelled capital cost (€)	Modelled operational cost (€/year)	Main sources
Air-source heat pump	10kW	9,233	120	*The Cost of Installing Heating Measures in Domestic Properties*[42] *Irish heat manufacturer data*
Ground-source heat pump	10 kW	16,310	120	*The Cost of Installing Heating Measures in Domestic Properties*
Air-source heat pump with solar thermal	10 kW	12,343	180	*The Cost of Installing Heating Measures in Domestic Properties* *UK Renewable Heat Incentive Monthly Deployment Data*[43]
Hybrid (Air-source heat pump + hydrogen boiler)	10 kW	10,941	180	*The Cost of Installing Heating Measures in Domestic Properties* *Hydrogen Supply Chain Evidence Base*[44]
Hydrogen boiler	10 kW	3,093	120	*Deep-Decarbonisation Pathways for UK Industry* [45] *Industrial Fuel Switching Market Engagement Study* [46]
Industrial electric boiler	3 MW	1,243,000	25,000	*Deep-Decarbonisation Pathways for UK Industry* *Industrial Fuel Switching Market Engagement Study*
Industrial hydrogen furnace	3 MW	267,000	6,000	*Deep-Decarbonisation Pathways for UK Industry* *Industrial Fuel Switching Market Engagement Study*

4.2.7 Other costs and benefits

Given the complexities of valuing labour market, energy security and competitiveness costs and benefits, and a lack of suitable reference data these factors have not been included in the analysis.

42 Delta-EE for BEIS (2018), The Cost of Installing Heating Measures in Domestic Properties, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/913508/cost-of-installing-heating-measures-in-domestic-properties.pdf
43 UK Renewable Heat Incentive (RHI) monthly deployment data: December 2019 (Annual edition), Table S2.1 - Average reported costs of domestic RHI installations, Great Britain, April 2014 to December 2019
44 Element Energy, Jacobs and BGS for BEIS (2018), Hydrogen Supply Chain Evidence Base, available at:
45 Element Energy for the CCC (2020), Deep-Decarbonisation Pathways for UK Industry, available at: https://www.theccc.org.uk/publication/deep-decarbonisation-pathways-for-uk-industry-element-energy/
46 Element Energy and Jacobs for BEIS (2018), Industrial Fuel Switching Market Engagement Study, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/760479/H2_supply_chain_evidence_-_publication_version.pdf
https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/824592/industrial-fuel-switching.pdf

4.3 Economic potential for efficiency in heating and cooling

4.3.1 Net Present Value

The following charts show the net present value (NPV) of each technology in 2030 and 2050 if that technology was installed in all suitable archetypes in the decarbonised scenario. An individual chart is produced for 2030 and 2050 using both economic and financial assumptions for each sector examined – residential, services and industry. The purpose of these charts is to give an indication of the what economic potential of each technology. As described in Section 4.1, this NPV analysis allows marginal abatement cost curves to be developed which inform the technology uptake trajectories examined in the decarbonised scenario. The equivalent charts as calculated under the baseline scenario are given in "Appendix B - Additional economic potential figures".

Each line represents a different heating system and the varied NPV across the stock; this is depicted using heating demand (or useful energy) as the metric on the x-axis. Each line stops at different points along the x-axis, where the width of the line represents the total technically suitable heating demand for each technology.

The exception to the above approach is the data shown for district heating. In the graphs below, the decarbonised scenario assumes an uptake of district heating restricted to 20% of the total heating demand across Ireland as a plausible take-up. However, based on dedicated analysis for district heating across Ireland, there are 9,783 small areas with economic potential for district heating; this equates to 54% of the total heat demand as this economic potential. Additional details surrounding the approach taken to district heating and the potential sensitivities regarding this analysis can be found in section 4.3.7.

Additionally, it should be noted that biomethane is modelled to be directly injected into the gas grid and therefore used via existing gas boilers. There is no separate uptake of a unique renewable technology that uses biomethane directly. As such, there is no biomethane noted in the graphs below.

The set of charts that follow present NPV under a (i) economic cost-benefit analysis, and (ii) financial cost-benefit analysis. They are determined based the methodology described in Section 4.2 (Cost-benefit analysis (CBA)).

Effectively these graphs present the economic potential scenarios for most cost-effective technology uptake (i.e. economic potential without competition), for each of the modelled archetypes, across the total heating demand in Ireland for the residential, services, and industry sectors, using net present value as the metric.

Economic – decarbonised scenario

Figure 26 Net present value (NPV) of the economic potential for the take up of heating systems in the residential sector, in 2030 under the decarbonised scenario, using the economic cost-benefit analysis

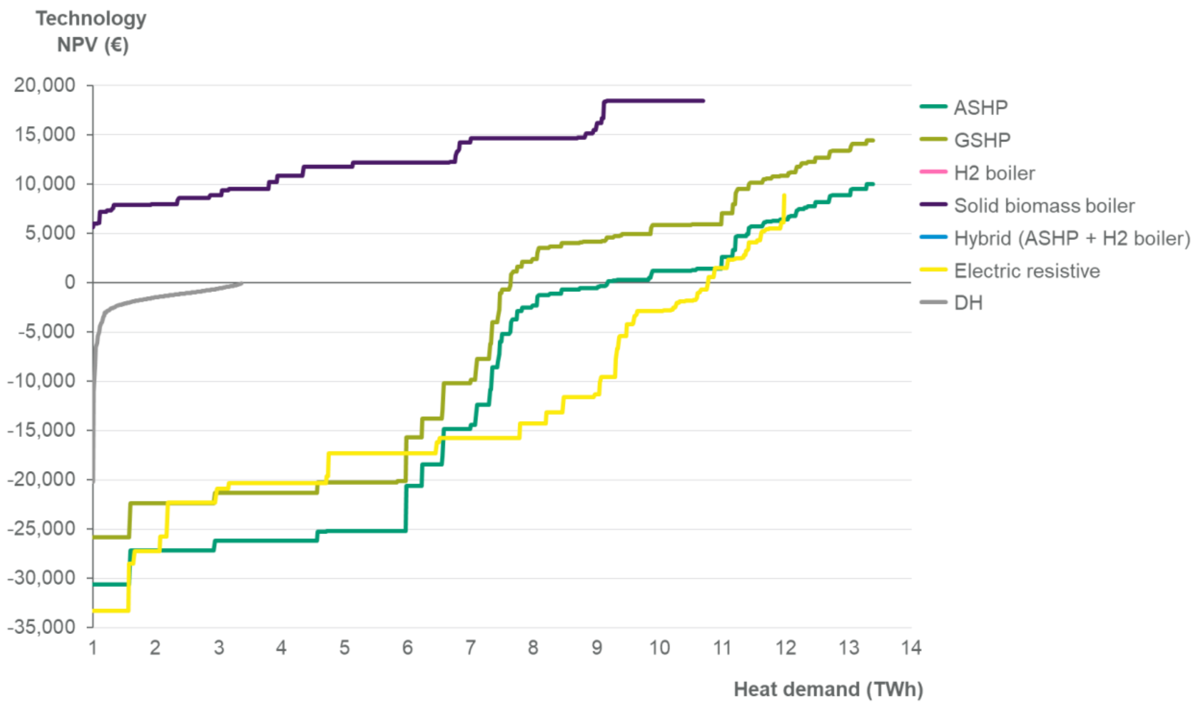


Figure 27 Net present value (NPV) of the economic potential for the take up of heating systems in the residential sector, in 2050 under the decarbonised scenario, using the economic cost-benefit analysis

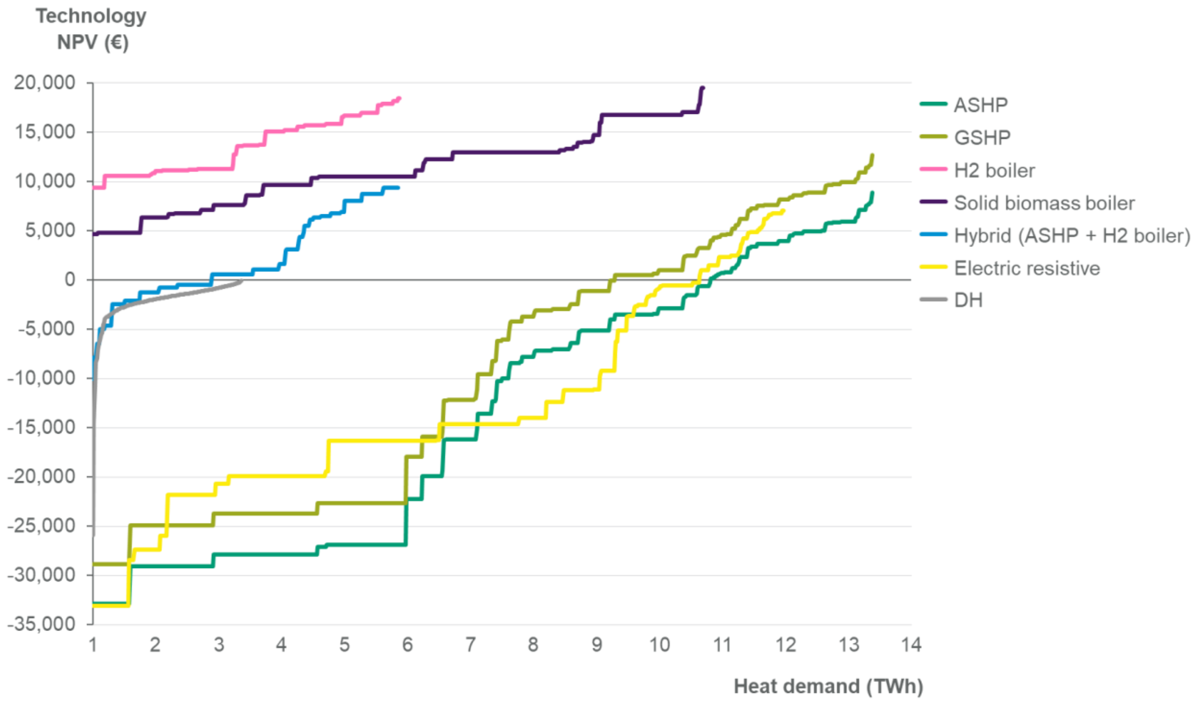


Figure 28 Net present value (NPV) of the economic potential for the take up of heating systems in the commercial and public sectors, in 2030 under the decarbonised scenario, using the economic cost-benefit analysis

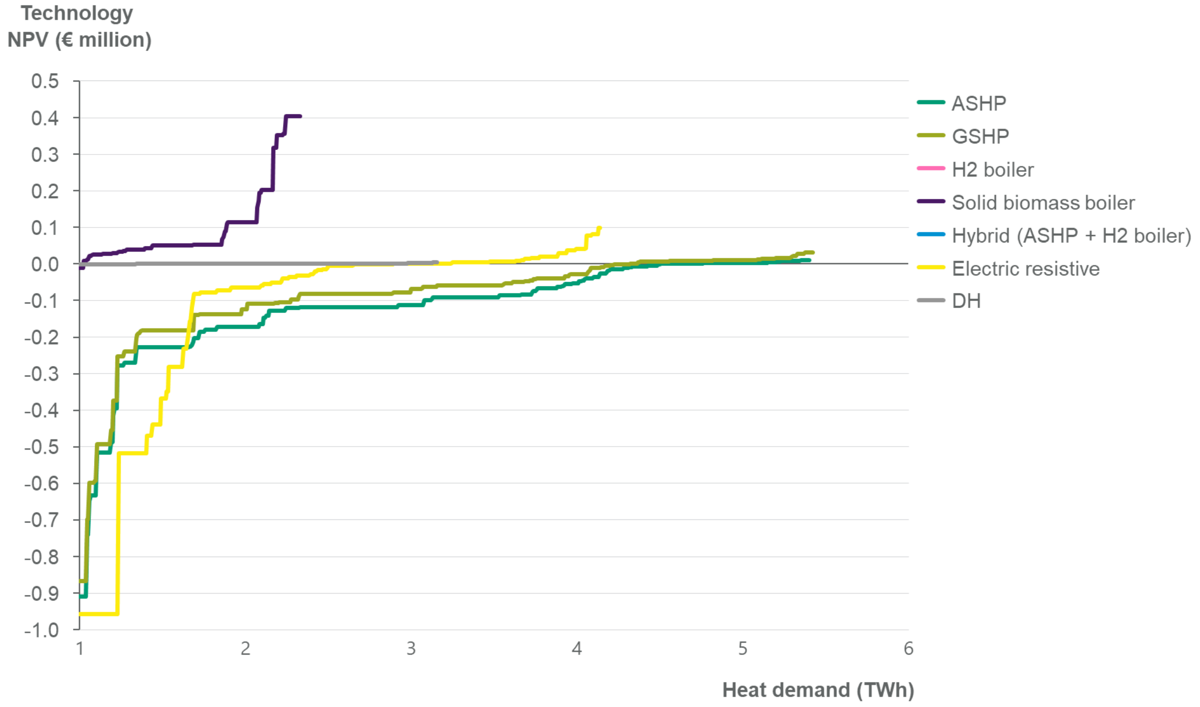


Figure 29 Net present value (NPV) of the economic potential for the take up of heating systems in the commercial and public sectors, in 2050 under the decarbonised scenario, using the economic cost-benefit analysis

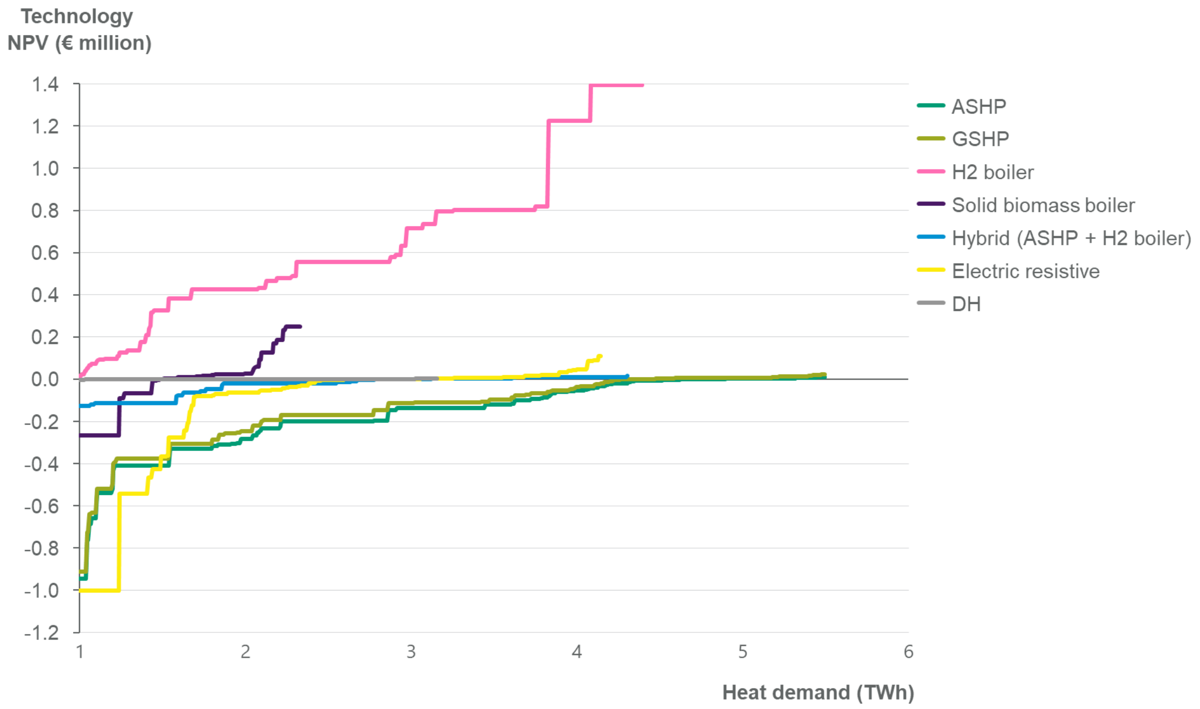


Figure 30 Net present value (NPV) of the economic potential for the take up of heating systems in industry, in 2030 under the decarbonised scenario, using the economic cost-benefit analysis

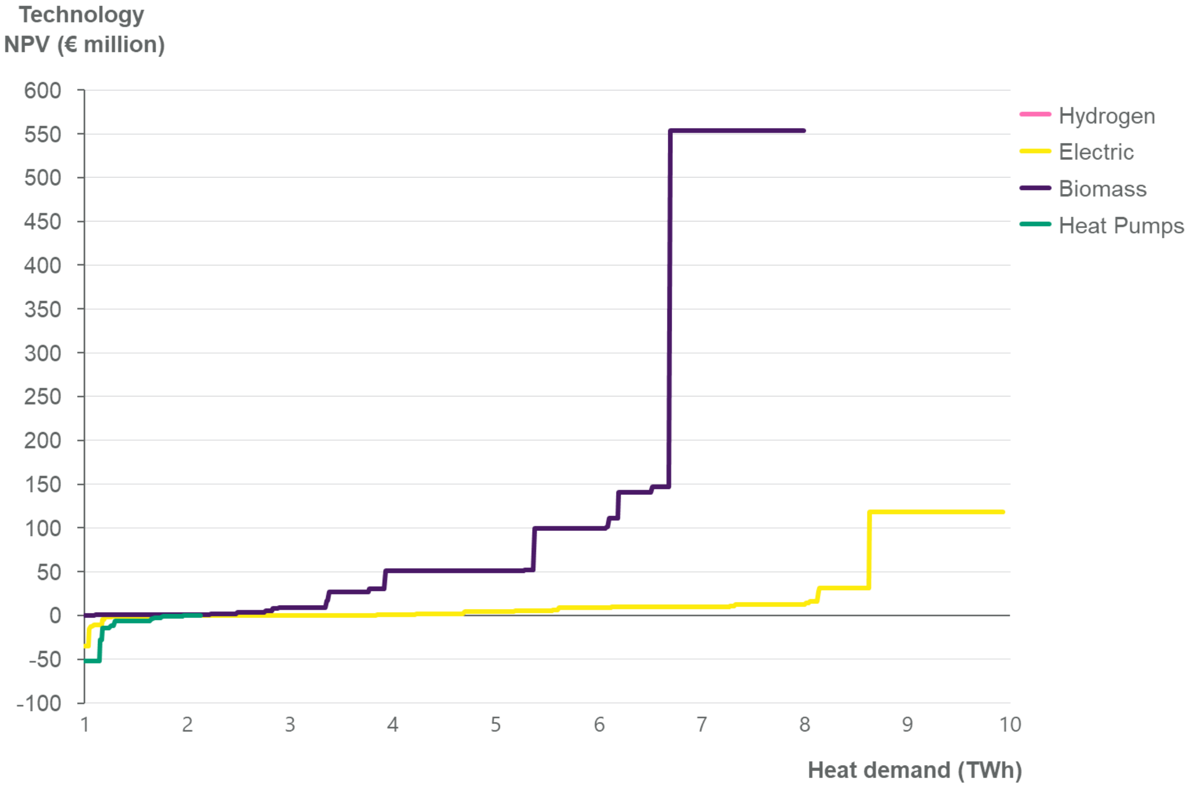
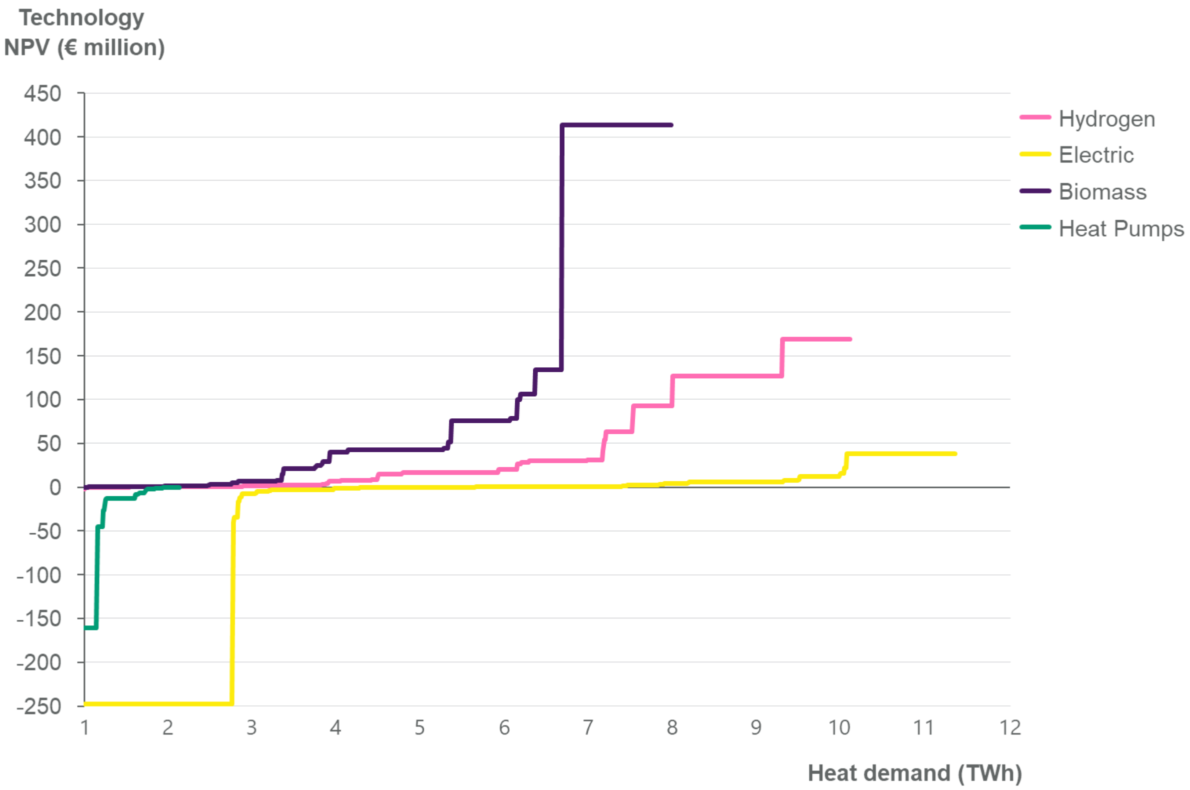


Figure 31 Net present value (NPV) of the economic potential for the take up of heating systems in industry, in 2050 under the decarbonised scenario, using the economic cost-benefit analysis



Financial – decarbonised scenario

Figure 32 Net present value (NPV) of the economic potential for the take up of heating systems in the residential sector, in 2030 under the decarbonised scenario, using the financial cost-benefit analysis

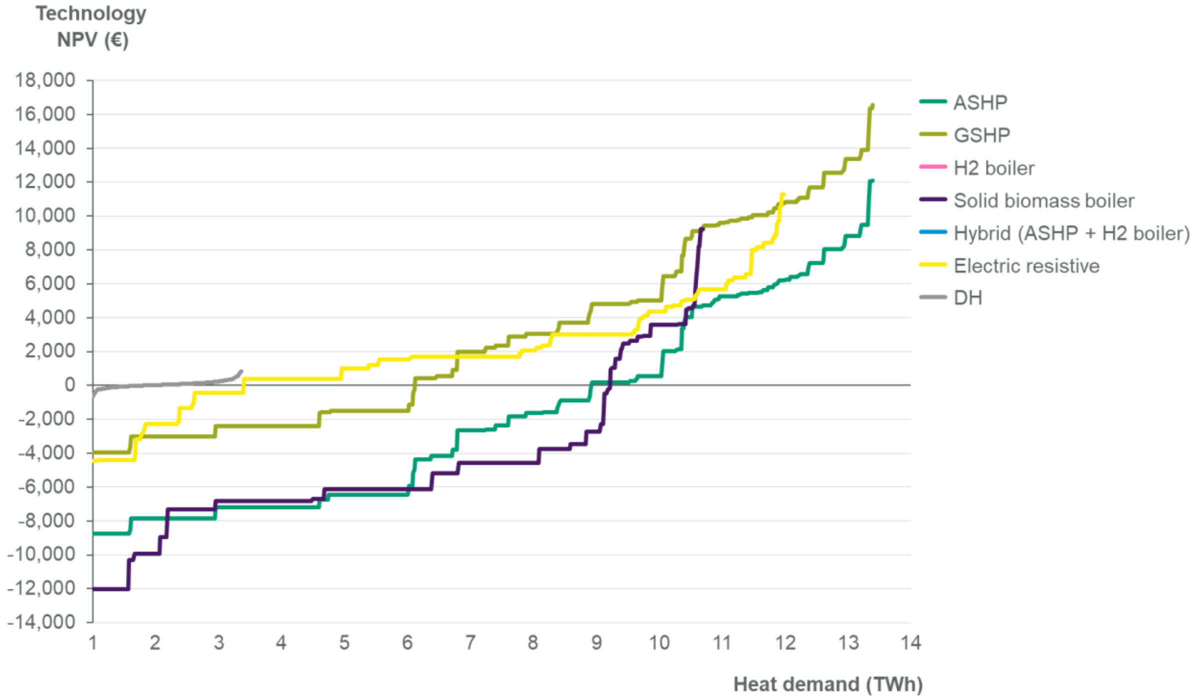


Figure 33 Net present value (NPV) of the economic potential for the take up of heating systems in the residential sector, in 2050 under the decarbonised scenario, using the financial cost-benefit analysis

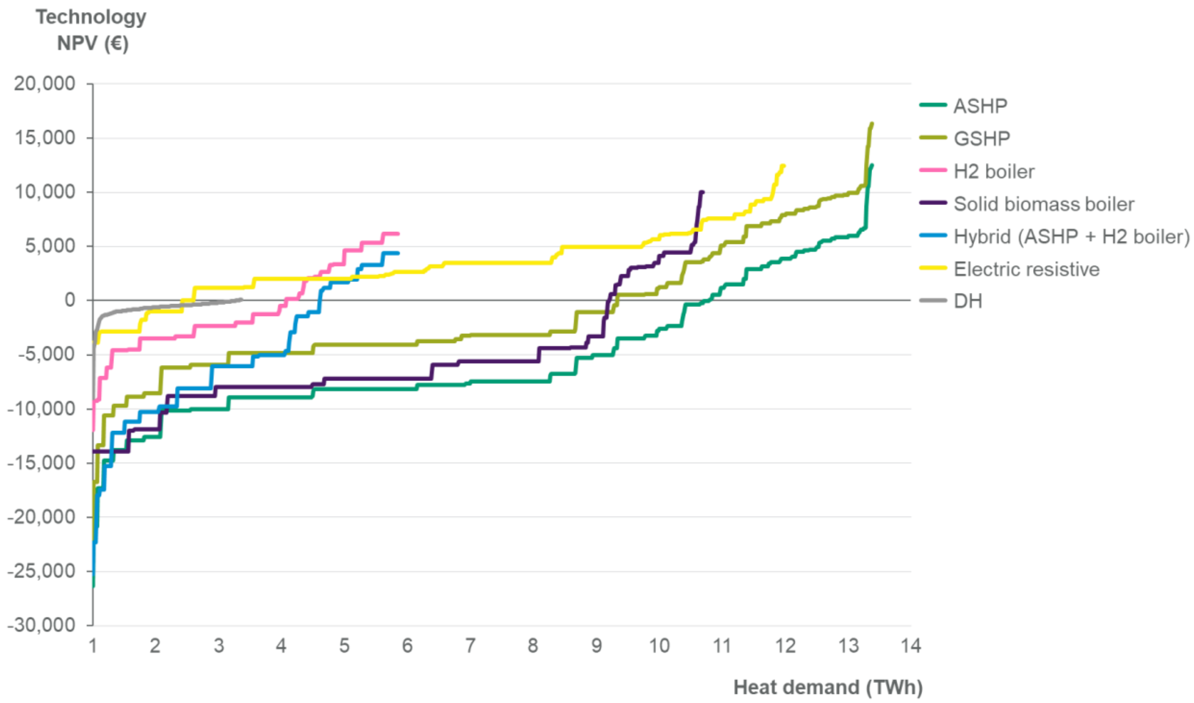


Figure 34 Net present value (NPV) of the economic potential for the take up of heating systems in the commercial and public sector, in 2030 under the decarbonised scenario, using the financial cost-benefit analysis

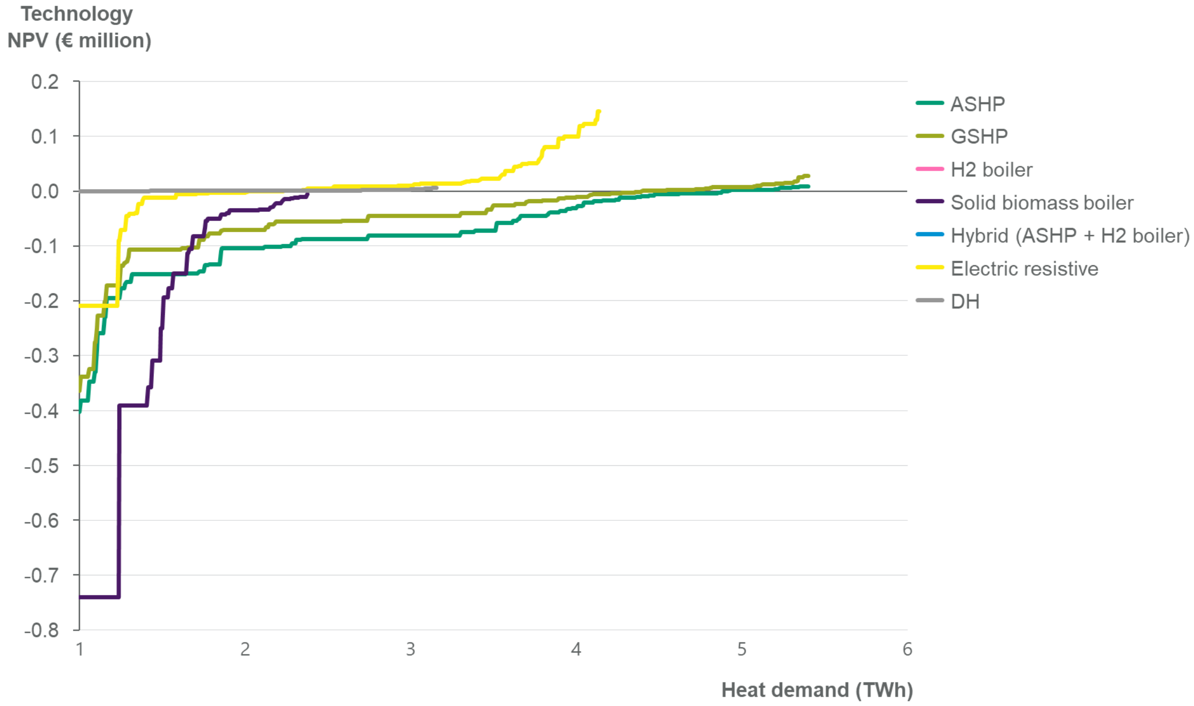


Figure 35 Net present value (NPV) of the economic potential for the take up of heating systems in the commercial and public sector, in 2050 under the decarbonised scenario, using the financial cost-benefit analysis

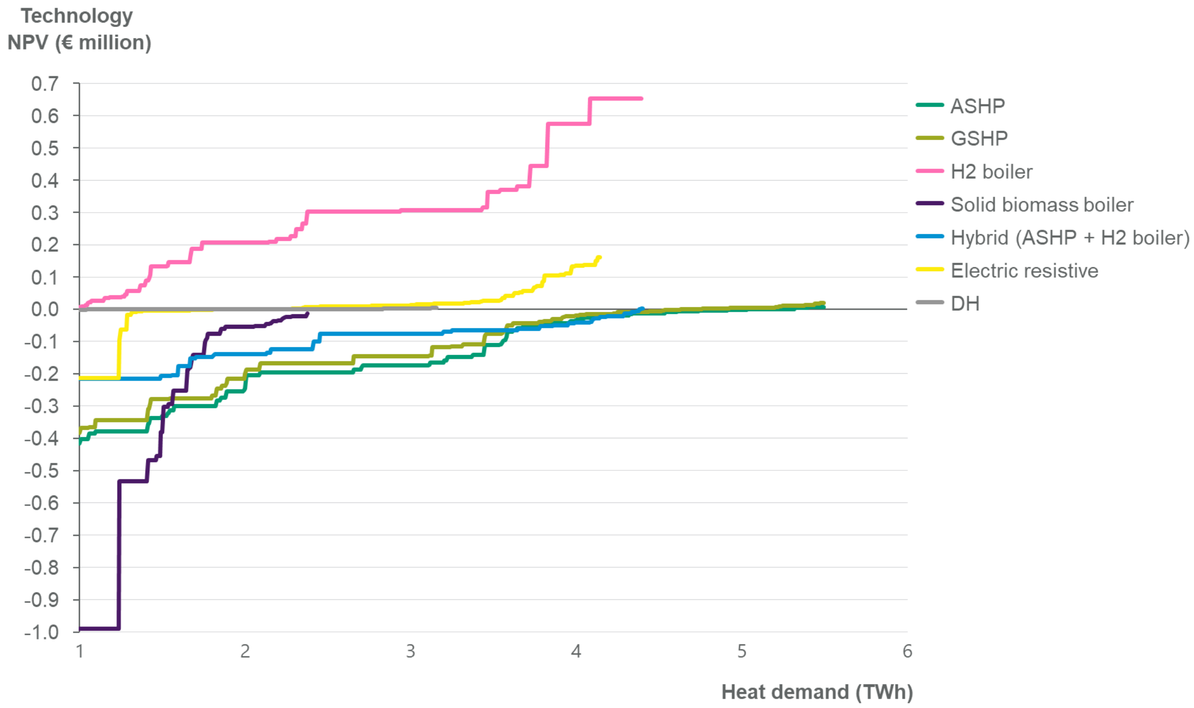


Figure 36 Net present value (NPV) of the economic potential for the take up of heating systems in industry, in 2030 under the decarbonised scenario, using the financial cost-benefit analysis

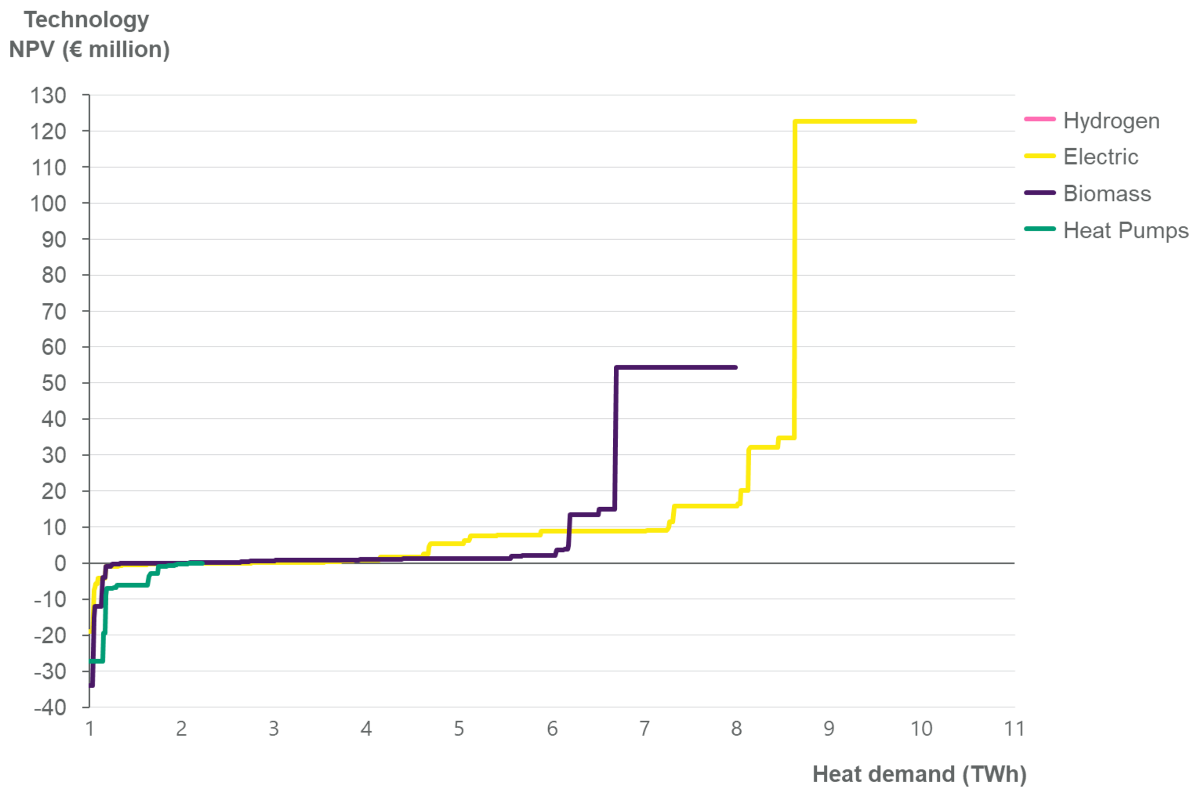
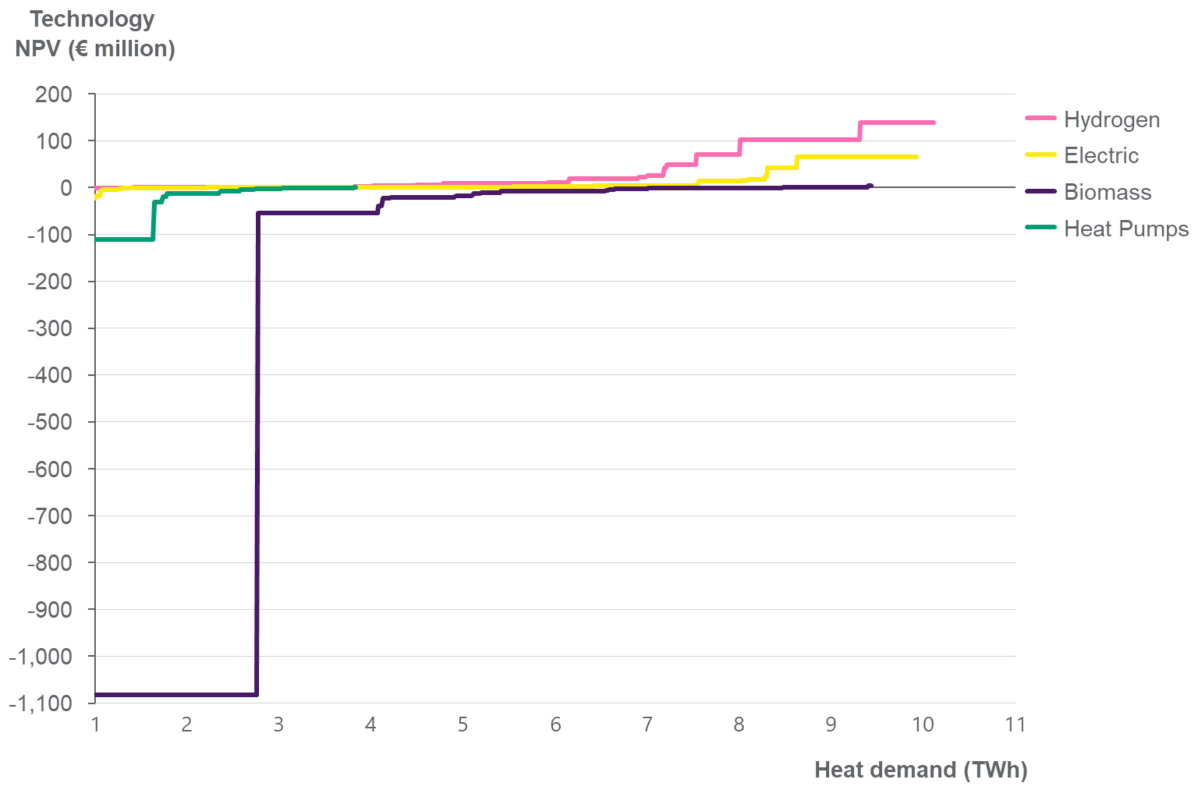


Figure 37 Net present value (NPV) of the economic potential for the take up of heating systems in industry, in 2050 under the decarbonised scenario, using the financial cost-benefit analysis



4.3.2 Present Costs

The following charts show the modelled present cost of the heating systems across the heat sector in Ireland, in the decarbonised scenario, for both 2030 and 2050, in the residential, services (commercial and public) and industrial sectors. Each column represents the heating system in a given archetype which has the lowest present cost when compared to all other suitable heating systems; the counterfactual heating system is shown for each archetype if it has a lower present cost than all suitable and available low carbon heating systems. Where a low carbon heating system has the lowest cost but has partial suitability for that archetype (i.e. only some of the stock in that archetype is suitable for the given heating system), the archetype stock is split, with the stock unsuitable for the first heating system assigned to the heating system with the next-lowest present cost.

The set of charts that follow depict present cost under a (i) economic cost-benefit analysis, and (ii) financial cost-benefit analysis. They are determined based the methodology described in Section 4.2 (Cost-benefit analysis (CBA)).

Effectively these graphs present potential scenarios for most cost-effective technology uptake (i.e. economic potential in competition), for each of the modelled archetypes, across the total heating demand in Ireland for the residential, services, and industry sectors, using present value (in this case cost) as the metric.

Economic – decarbonised scenario

In the residential sector in the decarbonised scenario, there is a significant increase in heating demand met by low carbon heating systems under competition in 2050 (1.65 TWh across the building stock), with a notable increase in heating demand met by ASHP systems. This increase in heating demand met by low carbon heating systems in 2050 mainly displaces heating demand met by CF gas boilers (which reduce in heating demand met from 3.9 TWh in 2030 to 2.1 TWh in 2050 in the residential sector), alongside some displacement of heating demand met by electric resistive heating technologies.

In the services (commercial and public) sectors, the heating demand met by heat pumps (including both ASHP & GSHPs) under competition increases from 3.5 TWh in 2030 to 4.0 TWh in 2050. There is also an increase in heating demand met by hybrids (ASHP + hydrogen boilers) in 2050 by 0.9 TWh, although there are no standalone hydrogen boilers in the services sectors under competition by 2050.

The majority of heating demand met by low carbon technologies in the industrial sector is met by electric heating technologies and heat pumps, although these is a small amount of heating demand met by hydrogen in 2050 (0.25 TWh). More than half of industrial heating demand remains on counterfactual heating systems (with various fuels) under competition in both 2030 and 2050, based on present costs under economic analysis.

Figure 38 Economic present cost (€ thousands) of heating systems in the residential sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the decarbonised scenario. CF represents counterfactual heating systems.

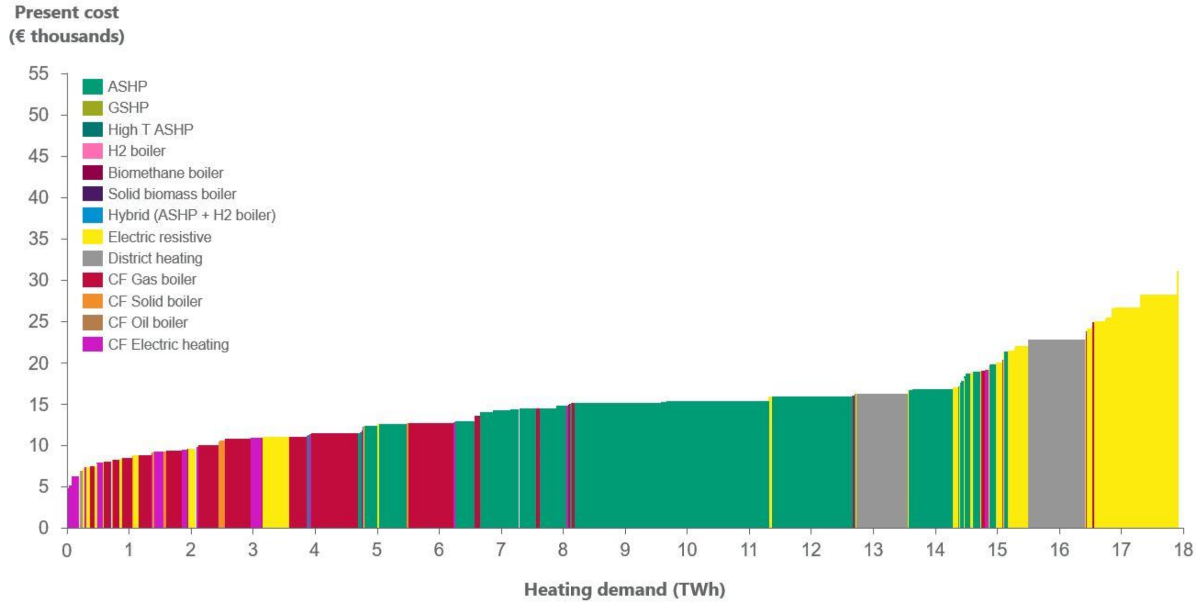


Figure 39 Economic present cost (€ thousands) of heating systems in the residential sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the decarbonised scenario. CF represents counterfactual heating systems.

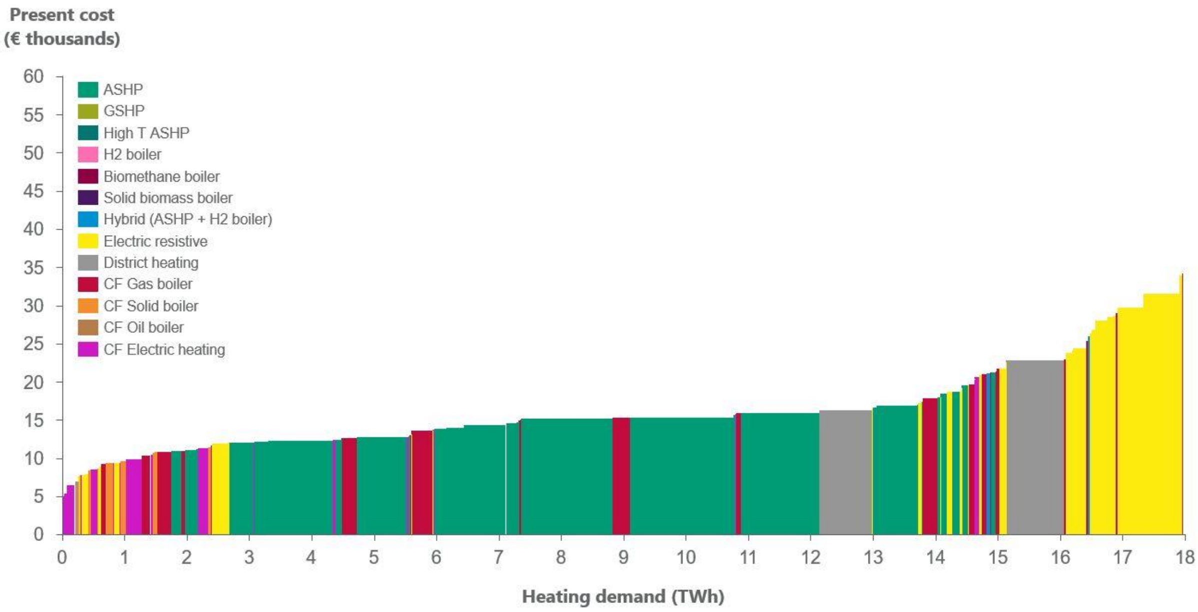


Figure 40 Economic present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the decarbonised scenario. CF represents counterfactual heating systems.

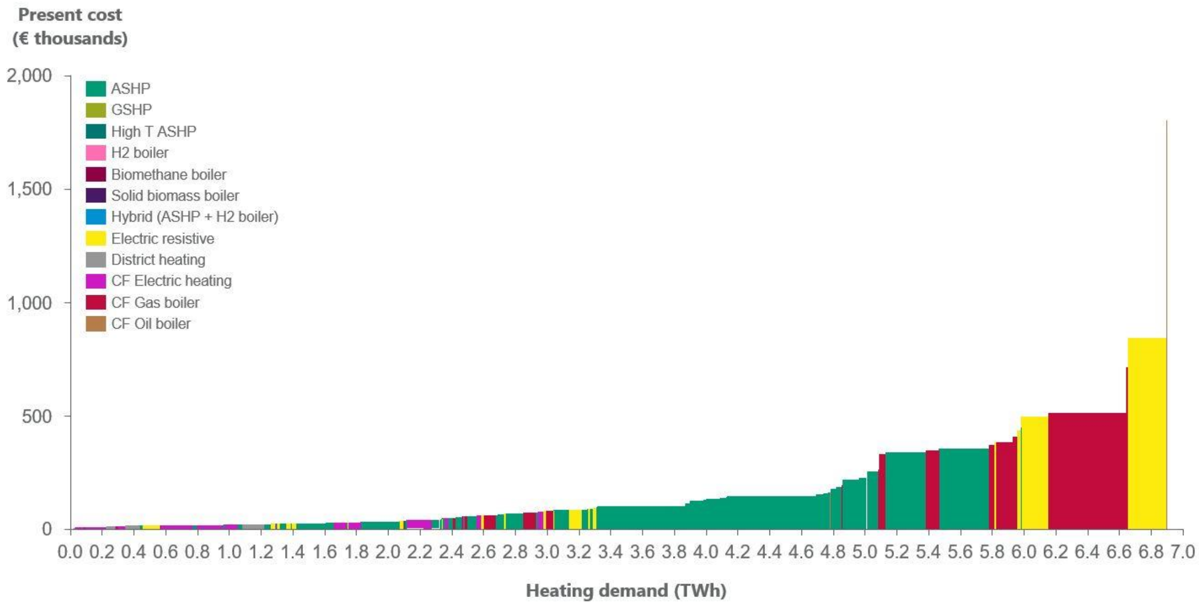


Figure 41 Economic present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the decarbonised scenario. CF represents counterfactual heating systems.

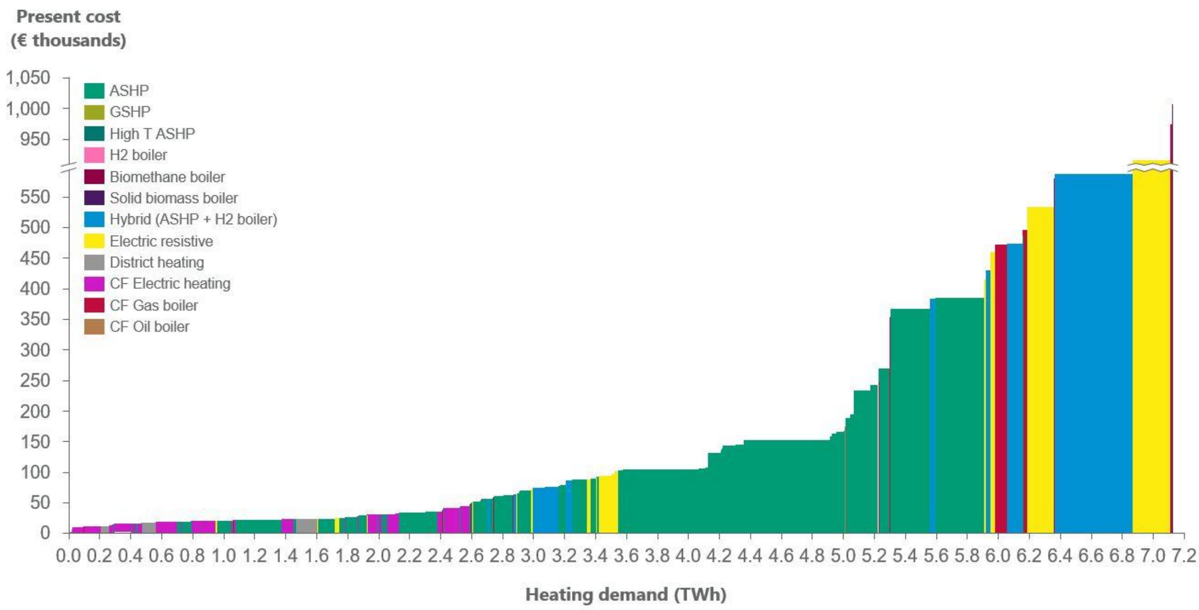


Figure 42 Economic present cost (€ million) of heating systems in the industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the decarbonised scenario. CF represents counterfactual heating systems.

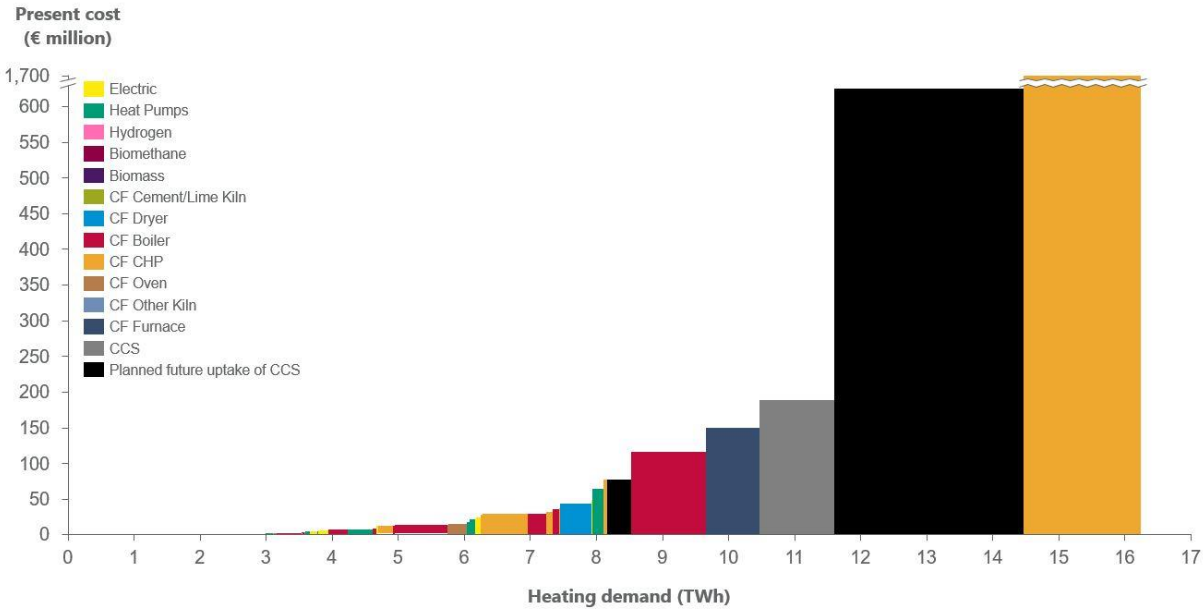
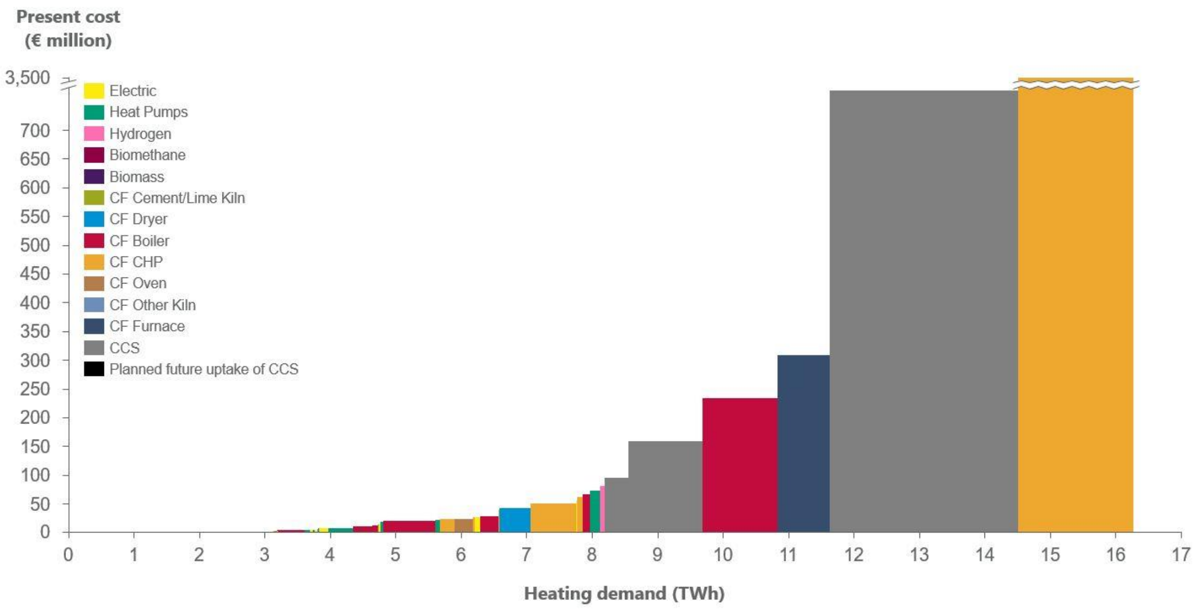


Figure 43 Economic present cost (€ million) of heating systems in the industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the decarbonised scenario. CF represents counterfactual heating systems.



Financial – decarbonised scenario

In the residential sector in the decarbonised scenario under financial analysis, there is an overall increase of 2.4 TWh of heating demand met by low carbon heating systems under competition from 2030 to 2050, mainly caused by an increase of 1.9 TWh in heating demand met by ASHPs, and uptake of 0.5 TWh worth of heating demand across hydrogen boilers and hybrid (ASHP + hydrogen boiler) systems.

In the services (commercial and public) sectors, 1 TWh of heating demand is met by hybrid (ASHP + hydrogen boilers) in 2050, which displaces heating demand that would otherwise be met by CF gas boiler systems. There is also a large increase in heating demand met by solid biomass boilers under competition, from 0.6 TWh in 2030 to 1.4 TWh in 2050.

In the industrial sector, there is a large increase in the heating demand met by heat pump technologies between 2030 and 2050 under competition in the financial analysis, from 1.3 TWh in 2030 to 2.8 TWh in 2050. There is also a large increase in the heating demand met by biomass fuel burning technologies between 2030 and 2050, from 0.8 TWh in 2030 to 5.5 TWh in 2050. Both of these increases in heading demand met by low carbon heating systems displaces heating demand met by CF heating systems (burning various fuels).

Figure 44 Financial present cost (€ thousands) of heating systems in the residential sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the decarbonised scenario. CF represents counterfactual heating systems.

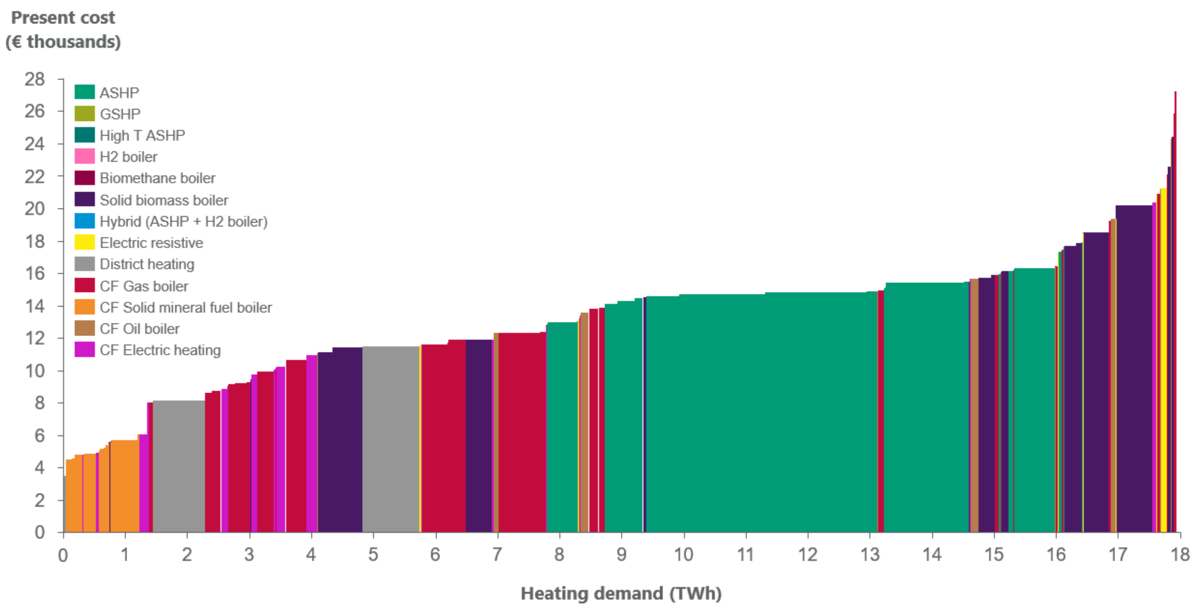


Figure 45 Financial present cost (€ thousands) of heating systems in the residential sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the decarbonised scenario. CF represents counterfactual heating systems.

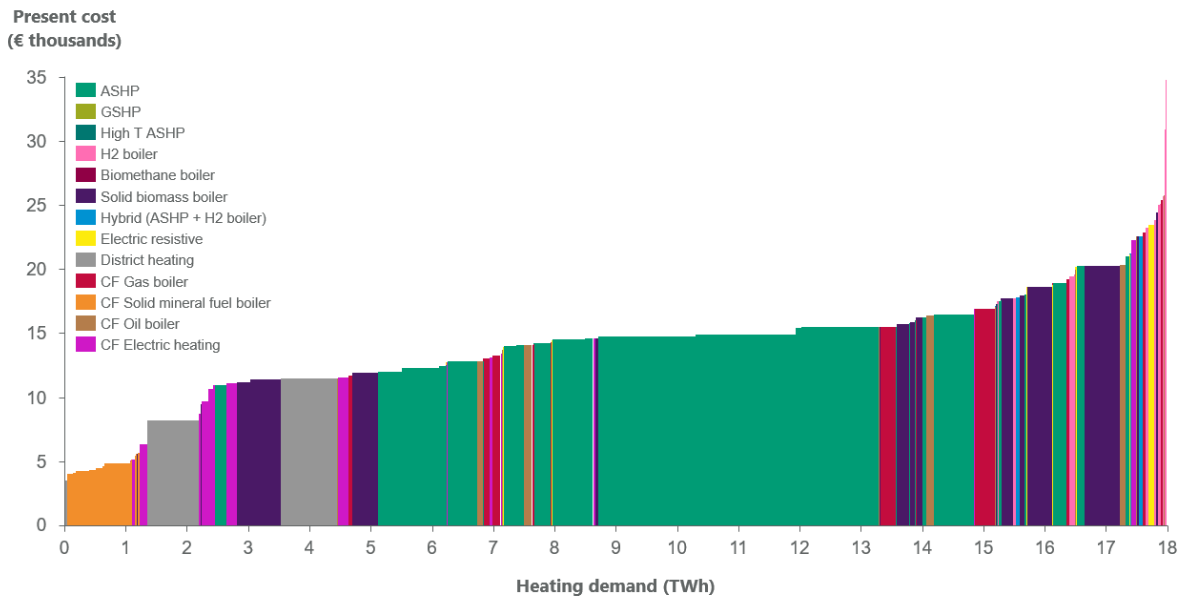


Figure 46 Financial present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the decarbonised scenario. CF represents counterfactual heating systems.

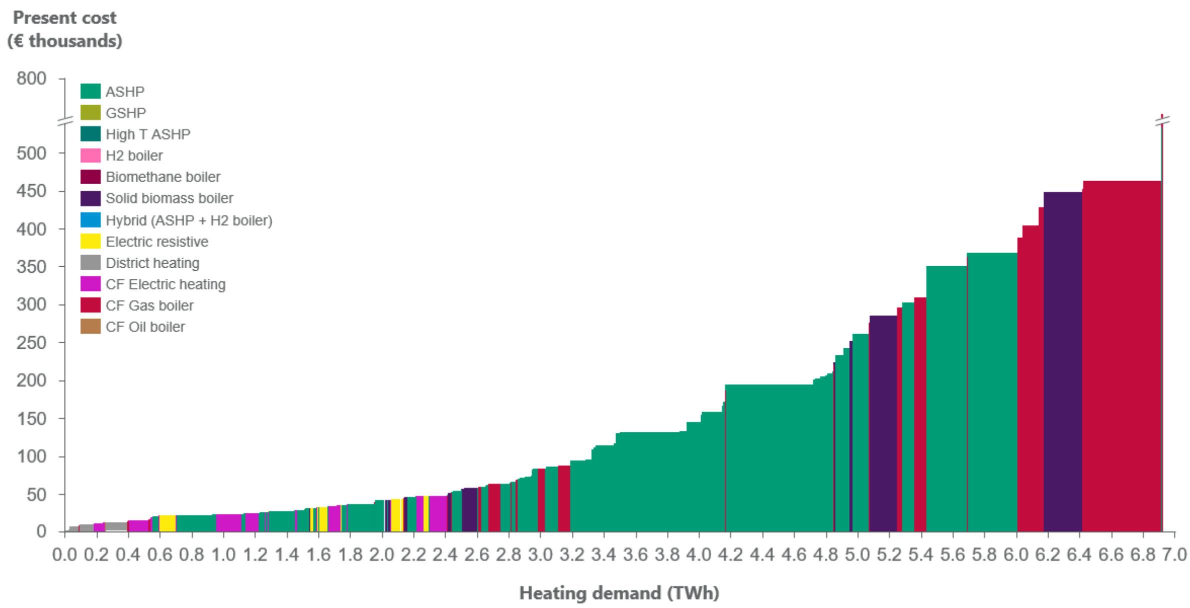


Figure 47 Financial present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the decarbonised scenario. CF represents counterfactual heating systems.

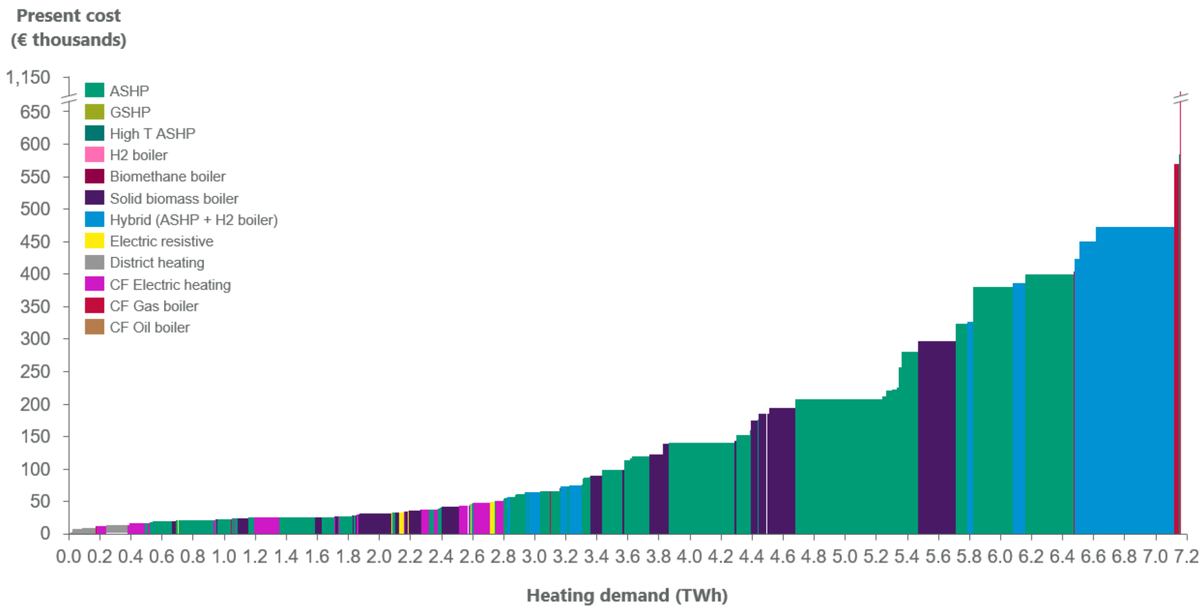


Figure 48 Financial present cost (€ million) of heating systems in the industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the decarbonised scenario. CF represents counterfactual heating systems.

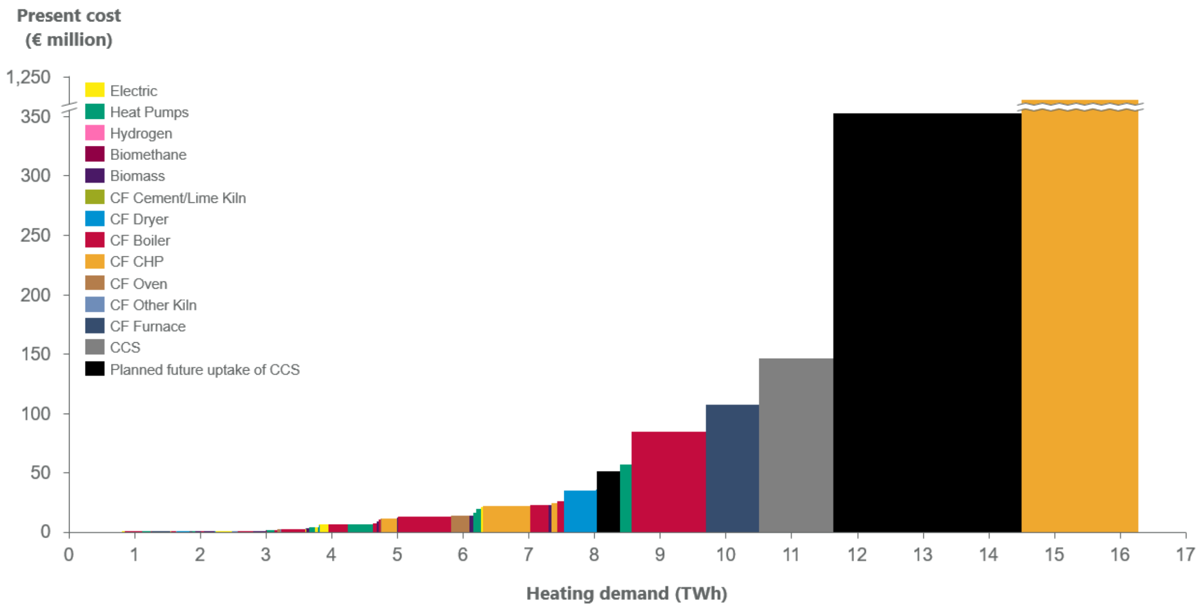
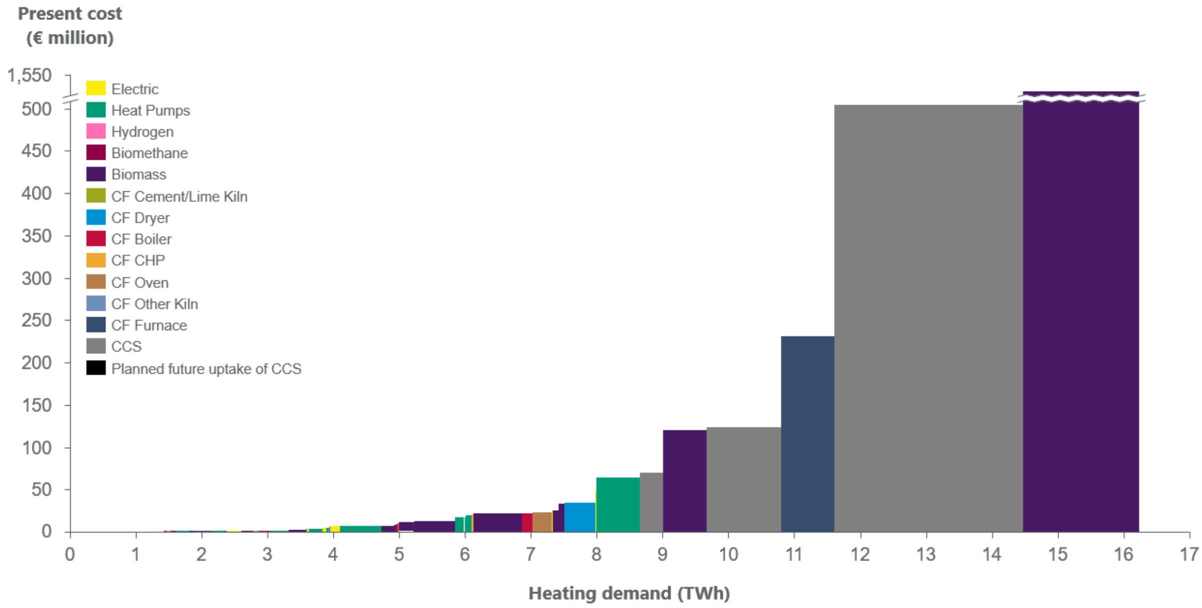


Figure 49 Financial present cost (€ million) of heating systems in the industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the decarbonised scenario. CF represents counterfactual heating systems.



4.3.3 CBA Summary

Table 15 below shows the economic potential in competition and total economic potential (both GWh) of each heating system, in summary of the 24 charts above (Figure 26 to Figure 49). The 'economic potential in competition (GWh)' represents the total heating demand met by this heating system where that heating system has the lowest present cost compared to both the counterfactual heating system and all other low carbon heating systems. The 'Total economic potential (GWh)' shows the total heating demand of stock that could be met by that low carbon heating technology if there was only competition with the counterfactual technology (and no competition with other low carbon heating technologies). Note that this table does not include the heating demand of each counterfactual heating system; these are given in Table 16 below.

Table 15 The economic potential in competition (GWh) and total economic potential (GWh) of each low carbon heating system for both the baseline and decarbonised scenarios, in 2030 and 2050, and under both economic and financial analysis.

Scenario	Sector	Technology	Economic potential in competition (GWh)				Total economic potential (GWh)			
			Economic		Financial		Economic		Financial	
			2030	2050	2030	2050	2030	2050	2030	2050
Baseline	Residential	ASHP	8,805	8,805	7,653	8,859	10,480	10,420	9,904	11,222
		GSHP	-	-	-	-	8,293	8,407	6,349	7,310
		Solid biomass boiler	-	-	3,363	3,362	-	-	9,224	9,223
		Electric resistive	3,317	3,169	197	187	10,739	10,641	4,871	4,428
		District heating	540	540	540	540	540	540	540	540
	Services	ASHP	3,851	4,072	4,197	4,430	4,125	4,352	4,570	4,726
		GSHP	-	-	-	-	3,824	3,930	3,900	4,447
		Solid biomass boiler	-	-	677	723	31	-	1,534	1,518
		Electric resistive	948	929	318	191	2,004	2,089	1,383	1,578
		District heating	188	188	188	188	188	188	188	188
Balanced	Residential	ASHP	8,026	9,896	7,040	8,901	9,603	11,376	9,027	11,178
		GSHP	-	-	-	-	7,521	9,452	5,819	9,480
		H2 boiler	-	-	-	327	-	-	-	3,085

	Solid biomass boiler	-	-	3,012	3,014	-	-	8,350	8,347
	Hybrid (ASHP + H2 boiler)	-	89	-	162	-	1,906	-	3,635
	Electric resistive	3,037	2,733	165	168	9,777	9,671	2,421	1,455
	District heating	1,811	1,811	1,811	1,811	1,811	1,811	1,811	1,811
Services	ASHP	3,528	3,951	3,873	3,609	3,782	4,138	4,247	4,557
	GSHP	-	-	-	-	3,506	3,715	3,634	3,988
	Solid biomass boiler	-	1	619	1,384	31	500	1,408	1,426
	Hybrid (ASHP + H2 boiler)	-	913	-	1,004	-	1,798	-	3,359
	Electric resistive	861	652	316	83	1,858	1,878	1,246	1,155
	District heating	317	317	317	317	317	317	317	317

Table 16 below shows the Net Present Value (NPV) (€) of each low carbon heating system where the present cost of the low carbon heating system is lower than the present cost of the counterfactual heating system (i.e. with a negative present value, so only where value is added), weighted by heating demand supplied. Note that the total heating demand (GWh) columns do not show heating demand under competition, and instead shows the heating demand that could be met by each technology in archetypes where value is added compared to the counterfactual heating system. This is equivalent to showing the heating demand under competition of only each individual low carbon heating system and the counterfactual heating system.

Table 16 The Net Present Value (NPV) (€) of each low carbon heating system compared to the counterfactual heating system (only where value is added), for the baseline and decarbonised scenario, for the residential and services (commercial and public) sectors, in 2030 and 2050, and broken down by counterfactual heating system.

Scenario	Sector	Counterfactual	Technology	NPV weighted by heating demand (€)				Total heating demand (GWh)			
				Economic		Financial		Economic		Financial	
				2030	2050	2030	2050	2030	2050	2030	2050
Baseline	Residential	Electric heating	ASHP	3,319	- 3,413	- 2,553	- 4,166	77	196	140	203
			GSHP	-	- 1,160	- 431	- 2,313	-	114	28	114
			Electric resistive	- 3,018	- 3,068	- 3,194	- 3,266	239	271	239	271
		Gas boiler	ASHP	- 1,138	- 1,596	- 1,882	- 2,291	1,404	1,404	1,977	3,204
			GSHP	- 1,053	- 2,109	- 1,710	- 2,891	47	47	146	266
		Oil boiler	ASHP	- 23,697	- 25,515	- 6,630	- 7,880	8,343	8,343	7,787	7,815
			GSHP	- 19,128	- 21,610	- 2,687	- 4,307	8,246	8,246	6,175	6,930
			Solid biomass boiler	-	-	- 6,463	- 7,463	-	-	9,180	9,183
			Electric resistive	- 19,668	- 19,735	- 2,405	- 2,123	9,651	9,651	4,632	4,157
		Solid mineral fuel boiler	ASHP	- 1,583	- 1,253	-	-	656	476	-	-
			Solid biomass boiler	-	-	- 459	- 85	-	-	43	39
			Electric resistive	- 2,652	- 1,240	-	-	849	719	-	-
		All CFs	District heating	- 19,208	- 11,027	- 11,924	- 12,814	540	540	540	540
	Services	Electric heating	ASHP	- 46,212	- 28,060	- 32,452	- 27,311	516	784	997	1,183

			GSHP	- 61,481	- 38,527	- 54,288	- 24,494	256	386	385	906
			Electric resistive	- 10,765	- 7,440	- 9,971	- 6,570	490	588	739	939
		Gas boiler	ASHP	- 133,688	- 118,723	- 101,497	- 98,417	2,628	2,650	2,609	2,632
			GSHP	- 93,400	- 85,029	- 61,515	- 64,606	2,604	2,630	2,579	2,630
		Oil boiler	ASHP	- 193,870	- 210,727	- 117,733	- 134,121	921	911	965	911
			GSHP	- 181,828	- 201,626	- 101,414	- 118,413	921	911	936	911
			Solid biomass boiler	-	-	- 231,821	- 249,751	-	-	1,534	1,518
			Electric resistive	- 245,195	- 220,460	- 117,765	- 106,032	284	254	644	639
		All CFs	District heating	- 441,992	- 435,933	- 311,221	- 318,584	188	188	188	188
Decarbonised	**Residential**	Electric heating	ASHP	- 2,429	- 4,230	- 3,377	- 5,401	171	201	171	201
			GSHP	- 347	- 2,275	- 913	- 3,800	39	112	88	112
			Electric resistive	- 2,921	- 2,835	- 3,109	- 3,017	248	269	248	269
		Gas boiler	ASHP	- 1,344	- 5,475	- 2,123	- 8,786	1,269	3,184	1,818	3,916
			GSHP	- 1,046	- 3,324	- 1,900	- 6,768	39	1,818	123	3,080
			H2 boiler	-	-	-	- 3,304	-	-	-	3,085
			Hybrid (ASHP + H2 boiler)	-	- 2,010	-	- 7,991	-	1,906	-	3,635
		Oil boiler	ASHP	- 23,665	- 25,395	- 6,559	- 7,563	7,530	7,530	7,038	7,062
			GSHP	- 19,108	- 21,290	- 2,573	- 3,979	7,443	7,522	5,608	6,288
			Solid biomass boiler	-	-	- 6,412	- 7,568	-	-	8,309	8,310

		Electric resistive	- 18,438	- 17,869	- 2,125	- 1,972	8,712	8,712	2,173	1,186
	Solid mineral fuel boiler	ASHP	- 1,849	- 1,444	-	-	634	462	-	-
		Solid biomass boiler	-	-	- 453	- 80	-	-	41	37
		Electric resistive	- 2,262	- 612	-	-	818	689	-	-
	All CFs	District heating	- 13,765	- 16,258	- 9,564	- 12,476	1,811	1,811	1,811	1,811
Services	Electric heating	ASHP	- 49,336	- 26,412	- 35,200	- 26,987	514	901	998	1,337
		GSHP	- 65,026	- 31,876	- 52,021	- 31,952	262	506	440	795
		Electric resistive	- 11,409	- 7,856	- 10,176	- 7,999	471	498	738	668
	Gas boiler	ASHP	- 130,080	- 220,970	- 96,388	- 222,209	2,374	2,364	2,357	2,364
		GSHP	- 90,145	- 189,943	- 56,866	- 192,263	2,353	2,337	2,330	2,337
		Hybrid (ASHP + H2 boiler)	-	- 55,774	-	- 107,112	-	1,798	-	3,359
	Oil boiler	ASHP	- 266,781	- 286,093	- 114,827	- 127,098	894	873	892	856
		GSHP	- 248,802	- 270,497	- 98,727	- 111,954	890	871	863	856
		Solid biomass boiler	- 10,322	- 160,682	- 235,506	- 326,960	31	500	1,408	1,426
		Electric resistive	- 325,817	- 340,020	- 108,336	- 110,771	1,387	1,380	508	487
	All CFs	District heating	- 370,750	- 458,977	- 312,266	- 425,794	317	317	317	317

Table 17 below shows the total heating demand met by each heating system (including both low carbon heating systems and counterfactual heating systems) under competition. It is a summary of the 24 present cost uptake curves shown above (Figures 25 to 48, showing the sum of the heating demand met by each technology in each sector and scenario, in 2030 and 2050, and in both the economic and financial cases. Note that rows for certain technologies have been removed where there is no heating demand met by the technology in any case.

Table 17 The total heating demand met by each heating system under competition, in both the baseline and decarbonised scenario, in 2030 and 2050, using both economic and financial analysis, for each sector.

Scenario	Sector	Technology	Total heating demand (useful energy) met under competition (GWh/a)			
			Economic		Financial	
			2030	2050	2030	2050
Baseline	Residential	ASHP	8,805	8,805	7,653	8,859
		Solid biomass boiler	-	-	3,363	3,362
		Electric resistive	3,317	3,169	197	187
		District heating	540	540	540	540
		CF Gas boiler	4,091	4,091	3,605	2,465
		CF Solid mineral fuel boiler	232	430	1,105	1,110
		CF Oil boiler	0	0	538	535
		CF Electric heating	975	956	976	951
	Services	ASHP	3,851	4,072	4,197	4,430
		Solid biomass boiler	-	-	677	723
		Electric resistive	948	929	318	191
		District heating	188	188	188	188
		CF Electric heating	1,122	1,030	715	736
		CF Gas boiler	1,181	1,182	1,199	1,201
		CF Oil boiler	-	-	0	0
	Industry	Electric	1,703	1,689	805	799
		Heat Pumps	1,275	1,263	1,275	1,263
		Biomass	2,916	3,059	3,122	3,576
		CF Cement/Lime Kiln	-	-	572	572
		CF Dryer	496	557	779	839
		CF Boiler	3,927	3,927	4,045	3,927
		CF CHP	3,184	3,181	2,970	2,720

		CF Oven	337	339	346	405
		CF Other Kiln	124	124	124	133
		CF Furnace	2,032	2,010	2,032	2,131
Balanced	Residential	ASHP	8,026	9,896	7,040	8,901
		H2 boiler	-	-	-	327
		Solid biomass boiler	-	-	3,012	3,014
		Hybrid (ASHP + H2 boiler)	-	89	-	162
		Electric resistive	3,037	2,733	165	168
		District heating	1,811	1,811	1,811	1,811
		CF Gas boiler	3,880	2,052	3,413	1,087
		CF Solid mineral fuel boiler	216	409	1,057	1,061
		CF Oil boiler	0	1	482	482
		CF Electric heating	959	969	959	969
	Services	ASHP	3,528	3,951	3,873	3,609
		Solid biomass boiler	-	1	619	1,384
		Hybrid (ASHP + H2 boiler)	-	913	-	1,004
		Electric resistive	861	652	316	83
		District heating	317	317	317	317
		CF Electric heating	1,123	1,140	718	707
		CF Gas boiler	1,067	147	1,083	60
		CF Oil boiler	4	1	0	0
	Industry	Electric	1,636	1,630	794	788
		Heat Pumps	1,259	1,248	1,259	2,817
		Hydrogen	-	249	-	129
		Biomass	20	-	762	5,492
		CF Dryer	479	485	705	691
		CF Boiler	3,824	3,824	3,942	428
		CF CHP	3,052	2,941	2,838	38
		CF Oven	337	337	346	300
		CF Other Kiln	108	75	108	73

		CF Furnace	1,167	1,126	1,167	1,126
		CCS	1,133	4,364	1,133	4,364
		Planned future uptake of CCS	3,231	-	3,231	-

4.3.4 Baseline scenario – summary results

Table 18 summarises the total heating and cooling demand met by efficient and renewable heating and cooling technologies, in total and divided by sector, for the baseline scenario.

Table 18 Reporting 2050 economic potential of efficient and renewable heating and cooling technologies identified during the CBA for the baseline scenario. "Other" category comprises the agriculture sector

	Total (TWh/a)	Residential (TWh/a)	Services (TWh/a)	Industry (TWh/a)	Other (TWh/a)
District heating	1.15	0.65	0.50	0.00	0.00
Heat pumps	6.09	2.04	4.05	0.00	0.00
Other electricity	12.33	1.72	21.03	9.52	0.16
Hydrogen	0.00	0.00	0.00	0.00	0.00
Non-waste Biofuels	7.45	1.74	1.04	4.19	0.48
Geothermal*	Not applicable				
Waste	0.57	0.00	0.00	0.57	0.00

*Lack of suitable data below depth of 400 metres. Up to 400 metres potential included in heat pump potential.

Figure 50 shows the trajectory of carbon dioxide emissions between 2020 and 2050, for the baseline scenario, disaggregated by sector. Reductions in emissions are seen in all sectors, with total emissions projected to fall from ~13 MtCO_2 in 2020 to ~6 MtCO_2 in 2050. Reductions in emissions are due both to the decarbonisation of the electricity system and to replacement of fossil heating systems with renewable options. The industry sector, which sees significant emissions reductions, see a widespread switch from fossil boilers to electric boilers, which are more cost-effective overall.

Figure 50 Carbon dioxide emissions from heating by sector under the baseline scenario. Cumulative emissions 2020 to 2050 are 289 Mt CO_2.

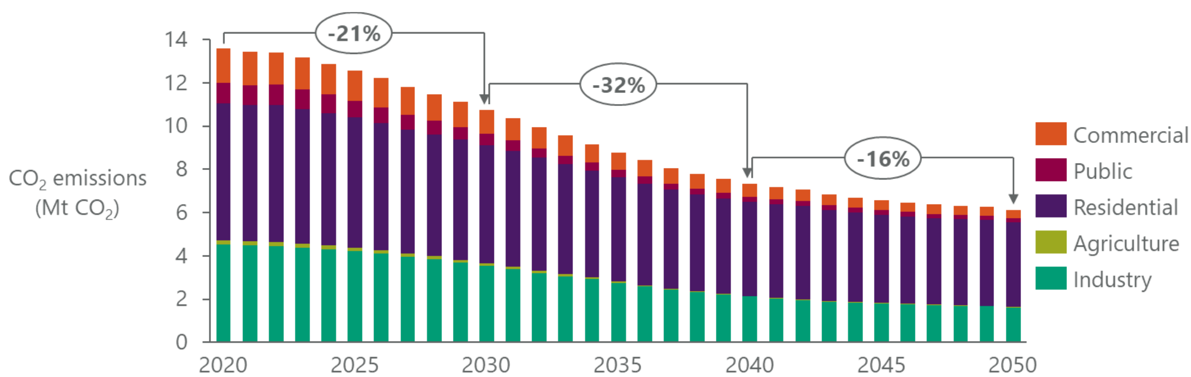


Figure 51 shows the trajectory of energy savings achieved through installation of energy efficiency measures between 2020 and 2050, for the baseline scenario, disaggregated by sector. Projected energy savings by 2050 are expected to be ~4 TWh. The relatively high savings seen in the commercial sector are partly due to the high technical potential for savings in that sector compared to other sectors. Previous analysis has shown that up to 25% reductions in heating demand in the commercial sector are possible through installing energy efficiency measures. This compares with 9% for industry and 17% for residential. Further, grant support for installing energy efficiency measures in the commercial sector is relatively high compared to the residential sector.

Figure 51 Energy savings from efficiency measures, baseline scenario

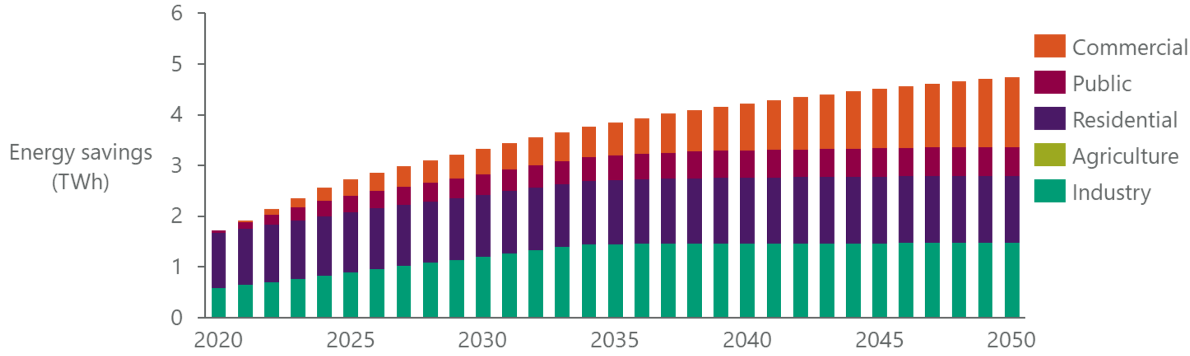


Figure 52 shows the change in the energy mix used for heating between 2020 and 2050, for the baseline scenario, disaggregated by fuel type. The share of heating provided by electricity is projected to increase significantly over time, from ~10% in 2020 to ~50% by 2050, with an accompanying in reduction in the use of oil and gas for heating.

Figure 52 Energy mix by fuel in the baseline scenario. Non-waste biofuels are predominantly solid biomass, but also include liquid biofuels (B100) and gaseous biofuels (biomethane).

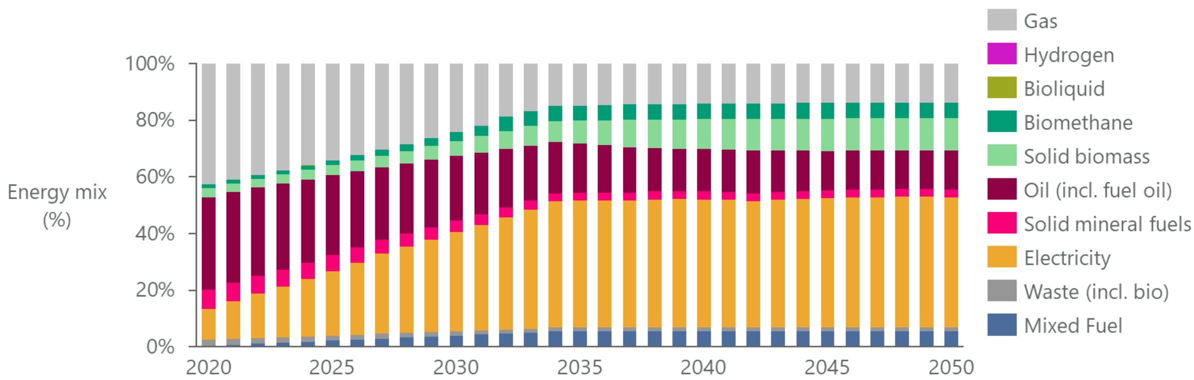


Figure 53 shows the projected capital costs associated with installing renewable heating technology and energy efficiency measures between 2020 and 2050, for the baseline scenario, disaggregated by sector and cost type (heating technology or energy efficiency). Total capex is projected to stay roughly constant between 2020 and 2050, at just under €1 billion per year, with the largest share attributable to the residential sector.

Figure 53 Total capex by sector, baseline scenario. 'HS' refers to heating system costs, and 'EE' to energy efficiency measure costs

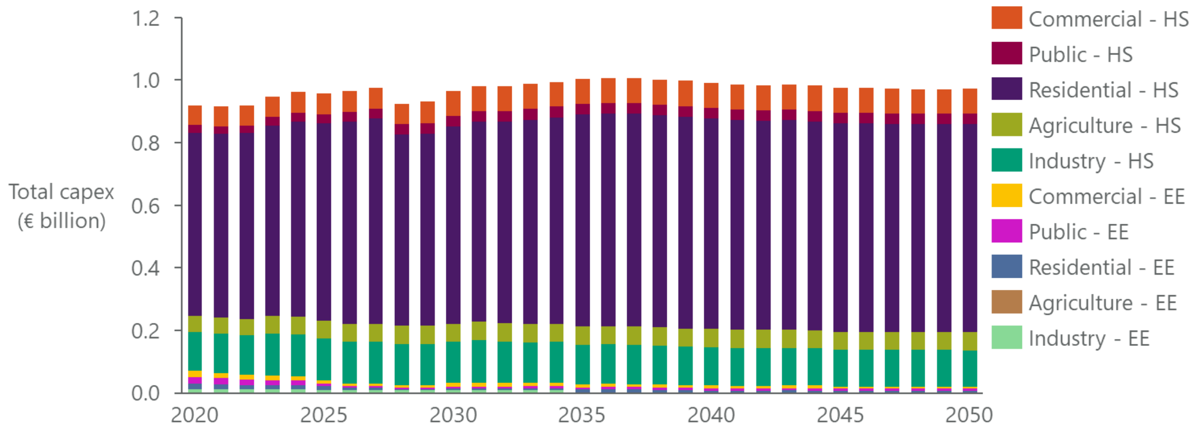
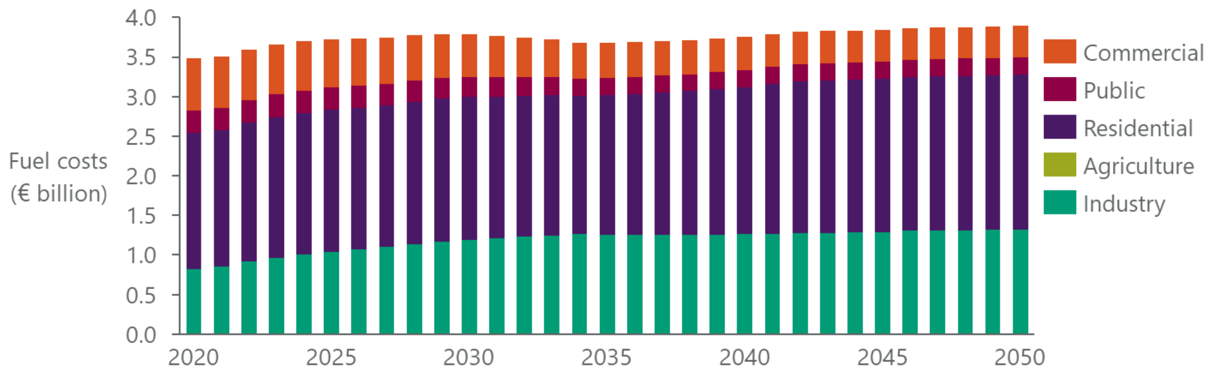


Figure 54 shows the projected fuel costs for heating between 2020 and 2050, for the baseline scenario, disaggregated by sector. Annual fuel costs are projected to increase slightly over time, from ~€3.5 billion in 2020 to ~€4 million in 2050.

Figure 54 Total fuel costs for heating, baseline scenario



4.3.5 Decarbonisation scenario – summary results

Table 19 summarises the total heating and cooling demand met by efficient and renewable heating and cooling technologies, in total and divided by sector.

Table 19 Reporting economic potential of efficient and renewable heating and cooling technologies identified during the CBA for the decarbonisation scenario. "Other" category comprises the agriculture sector

	Total (GWh/a)	Residential (GWh/a)	Services (GWh/a)	Industry (GWh/a)	Other (GWh/a)
District heating	3.06	1.97	1.10	0.00	0.00
Heat pumps	17.00	11.58	5.42	0.00	0.00
Other electricity	6.36	1.36	20.12	4.81	0.16
Hydrogen	6.76	1.41	1.57	3.78	0.00
Non-waste Biofuels	6.97	3.02	0.89	2.52	0.55
Geothermal	-	-	-	-	-
Waste	0.00	0.00	0.00	0.00	0.00

Figure 55 shows the evolution of carbon dioxide emissions from all sectors in Ireland, from 2020 to 2050, in the decarbonisation scenario. Total emissions are projected to fall from ~16 $MtCO_2$ in 2020 to ~2 $MtCO_2$ in 2050.

Figure 55 Carbon dioxide emissions from heating by sector in the decarbonisation scenario. Cumulative emissions 2020 to 2050 are 219 Mt CO_2.

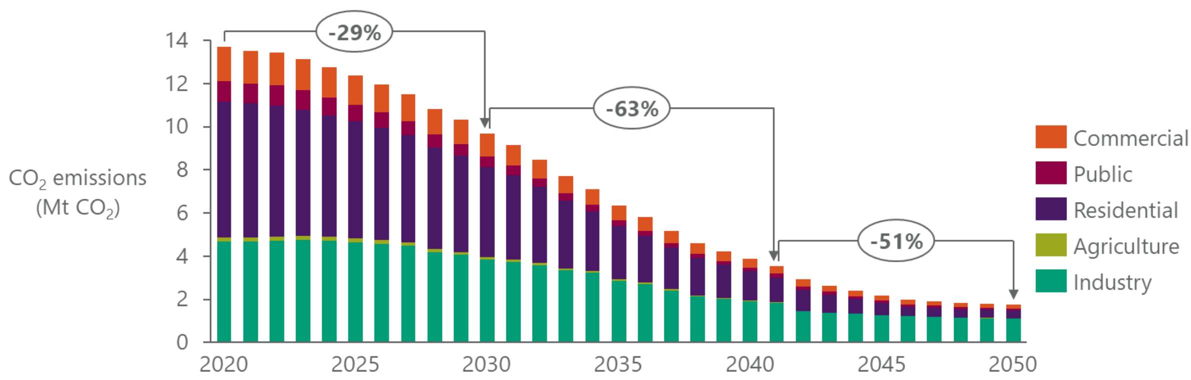


Figure 56 shows the projected energy savings due to installation of energy efficiency measures up to 2050, for the decarbonisation scenario. Total savings are projected to reach ~5 TWh by 2050.

Figure 56 Energy savings from efficiency measures, decarbonisation scenario

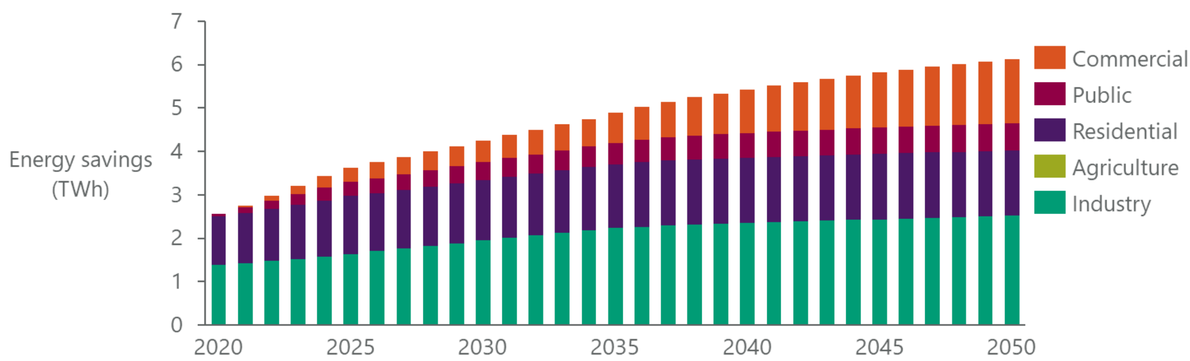


Figure 57 shows the energy mix by fuel type between 2020 and 2050, for the decarbonisation scenario. Electricity, which contributes less than 20% of all energy used for heating in Ireland today, is projected to become the largest energy contributor, accounting for nearly 60% of the total by 2050.

Figure 57 Energy mix by fuel in the decarbonisation scenario

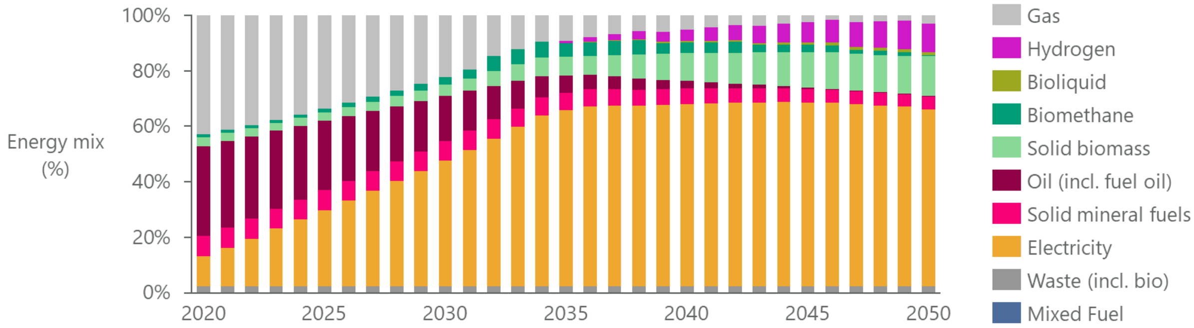


Figure 58 shows the projected capital costs (capex) associated with the installation of energy efficiency measures and renewable heating technologies between 2020 and 2050, for the decarbonisation scenario. The majority of the capex is incurred in the residential sector. A significant increase in capex in the sector is seen from 2032; this is the year when non-renewable heating technologies are no longer allowed (the modelling has shown non-renewable technologies cannot be allowed past this data if Net Zero is to be achieved by 2050), leading to higher uptake of renewable heating technologies, which have higher capex. Capex peaks in the industry sector are associated with some sites installing carbon capture and storage (CCS) technology.

Figure 58 Total capex by sector, decarbonisation scenario. 'HS' refers to heating system costs, and 'EE' to energy efficiency measure costs

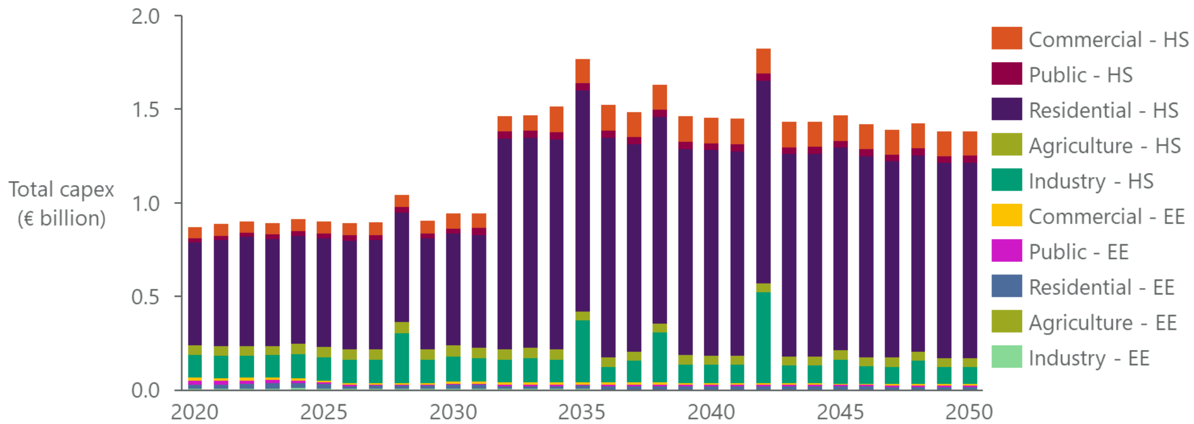


Figure 59 shows the evolution of fuel costs by building sector, between 2020 and 2050, for the decarbonisation scenario. As more efficient technologies such as heat pumps are installed, total fuel costs are projected to remain roughly constant over time, at €3.5 billion. However, the share of costs associated with the residential sector is projected to decrease, while that associated with the industry sector is projected to increase.

Figure 59 Total fuel costs for heating, decarbonisation scenario

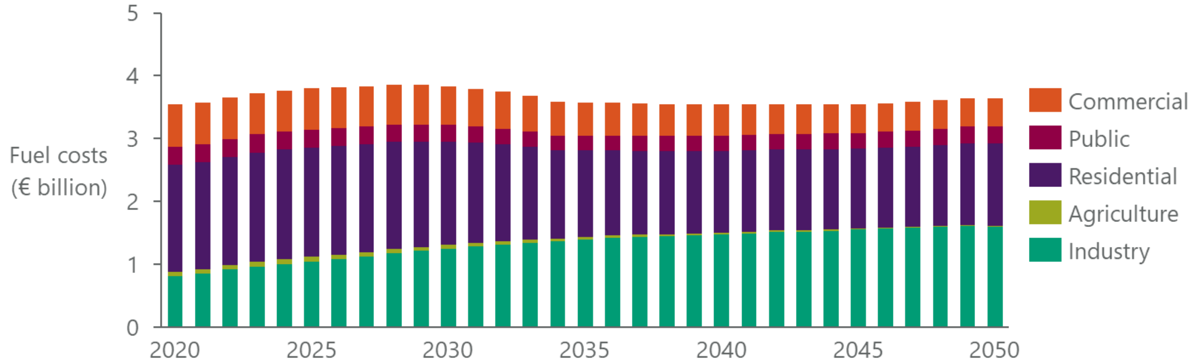


Table 20 shows the projected technology mix in 2030 and 2050, for the baseline scenario, disaggregated by technology group.

Table 20 Technology mix in 2030 and 2050 for the baseline scenario, showing stock and heating demand (useful energy for heating) met.

Sector	Technology group	2030 stock	2030 Heating demand met (GWh/a)	2050 stock	2050 Heating demand met (GWh/a)
Commercial	Bioenergy boiler	3,265	0.07	8,296	0.47
	Electric resistive	91,567	2.02	81,357	1.52
	Heat pumps	9,965	0.84	856	0.03
	Hybrid heat pumps	14,599	0.52	33,702	2.16
	District heating	1,951	0.10	2,660	0.25
	Hydrogen boiler	10,783	1.93	7,527	0.94
Residential	Bioenergy boiler	18,365	0.04	117,537	1.74
	Electric resistive	193,503	1.32	215,235	1.72
	Oil boiler	590,028	9.51	424,416	5.71
	Heat pumps	95,200	0.62	133,762	2.03
	Hybrid heat pumps	1,875	0.03	417	0.01
	District heating	40,021	0.26	54,574	0.65
	Gas boiler	609,249	5.36	604,134	5.21
	Solid boiler	225,318	1.17	223,641	1.15
Public	Bioenergy boiler	1,873	0.12	3,602	0.57
	Electric resistive	6,917	0.20	7,479	0.30
	Heat pumps	3,096	0.71	344	0.03
	Hybrid heat pumps	5,629	0.63	8,761	1.89

	District heating	948	0.10	1,293	0.25
	Hydrogen boiler	4,911	1.54	2,962	0.37
Agriculture	Bioenergy boiler	1,092	0.07	2,504	0.48
	Electric resistive	16,146	0.07	16,146	0.07
	Oil boiler	2,508	0.47	1,096	0.07
Industry	Industrial boiler	5,093	6.82	5,043	6.77
	Industrial oven	2,802	0.61	2,802	0.61
	Industrial furnace	2,715	2.11	2,715	2.11
	Industrial kiln	348	3.17	348	3.17
	Industrial CHP	1,503	2.38	1,411	1.61
	Industrial dryer	3,388	1.47	3,388	1.47
	Industrial heat pump	483	0.29	625	0.69

Table 21 Technology mix in 2030 and 2050 for the decarbonisation scenario, showing stock and heating demand (useful energy for heating) met.

Sector	Technology group	2030 stock	2030 Heating demand met (TWh/a)	2050 stock	2050 Heating demand met (TWh/a)
Commercial	Bioenergy boiler	2,499	0.04	7,469	0.42
	Electric resistive	87,617	2.01	26,030	0.62
	Heat pumps	18,522	0.50	89,370	2.75
	Hybrid heat pumps	2,079	0.08	3,679	0.67
	District heating	4,575	0.23	6,238	0.58
	Hydrogen boiler	-	0.00	1,591	0.34
Residential	Bioenergy boiler	7,236	0.02	234,054	3.02
	Electric resistive	187,950	1.30	153,721	1.36
	Heat pumps	347,645	1.86	1,027,975	9.95
	Hybrid heat pumps	22,014	0.25	167,496	1.63
	District heating	123,643	0.79	168,604	1.97
	Hydrogen boiler	-	0.00	21,856	0.24
Public	Bioenergy boiler	1,455	0.08	3,156	0.47
	Electric resistive	6,716	0.20	5,940	0.29
	Heat pumps	5,723	0.59	9,482	1.57
	Hybrid heat pumps	1,318	0.18	2,178	0.43

	District heating	1,973	0.21	2,691	0.52
	Hydrogen boiler	-	0.00	977	0.13
Agriculture	Bioenergy boiler	979	0.05	3,600	0.55
	Electric resistive	16,146	0.07	16,146	0.07
Industry	Industrial boiler	5,183	6.81	3,937	5.06
	Industrial oven	2,802	0.61	2,802	0.55
	Industrial furnace	2,702	1.20	2,702	1.18
	Industrial kiln	338	0.11	338	0.11
	Industrial CHP	1,409	2.18	1,693	2.11
	Industrial dryer	3,384	1.38	3,384	1.30
	Industrial heat pump	483	0.28	1,445	1.64

4.3.6 Energy efficiency results – BER ratings

Figure 60 to Figure 65 in this section show the projected Building Energy Rating (BER) breakdown of the residential, commercial and public stock in 2020, 2030, and 2050, for the baseline and decarbonised scenarios.

In the residential sector, the number of buildings with higher BER ratings (more energy efficient) increases over time, as expected. This effect is more pronounced in the Decarbonisation scenario, where new or additional measures are brought to bear to increase uptake of home energy upgrades.

In the commercial and public sectors, BER ratings are based on notional buildings. Therefore, a numerical scale of total primary energy consumption is shown. A breakdown of the energy efficiency packages taken up is also shown. These range from initial (no additional measures) to deep (highest level of energy efficiency measures installed). As in the residential sector, the number of buildings with lower primary energy consumption increases over time.

Figure 60 Residential stock BER ratings in 2020, 2030 and 2050, under the baseline scenario

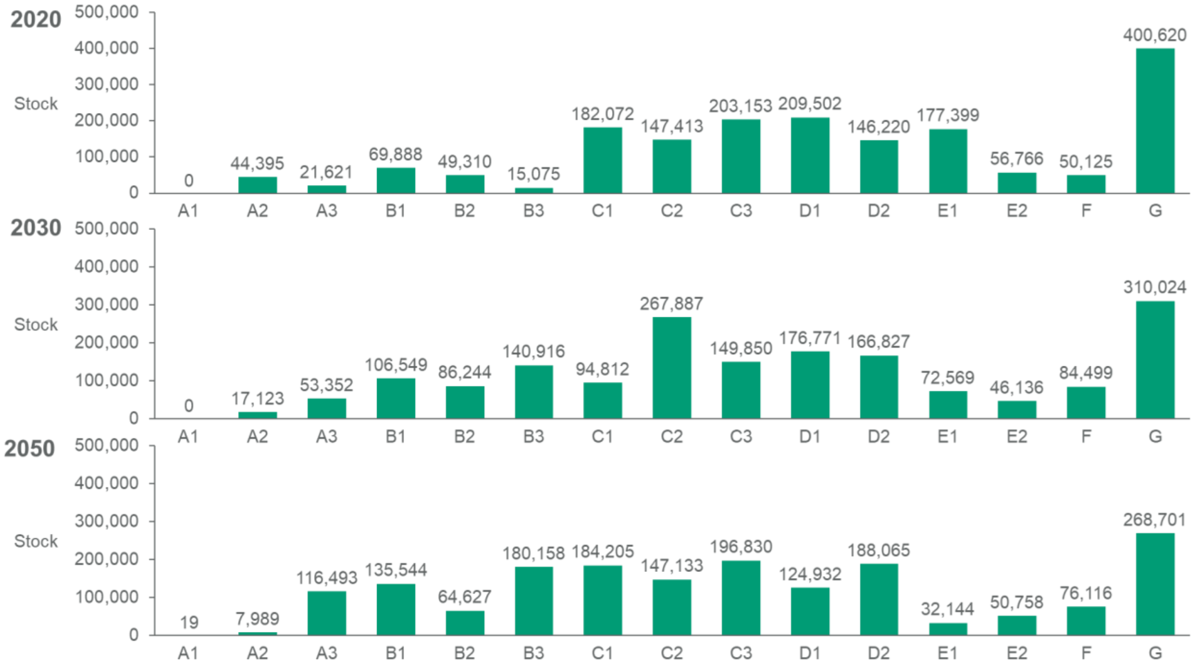


Figure 61 Commercial building stock total primary energy consumption distribution, 2020, 2030 and 2050, under the baseline scenario

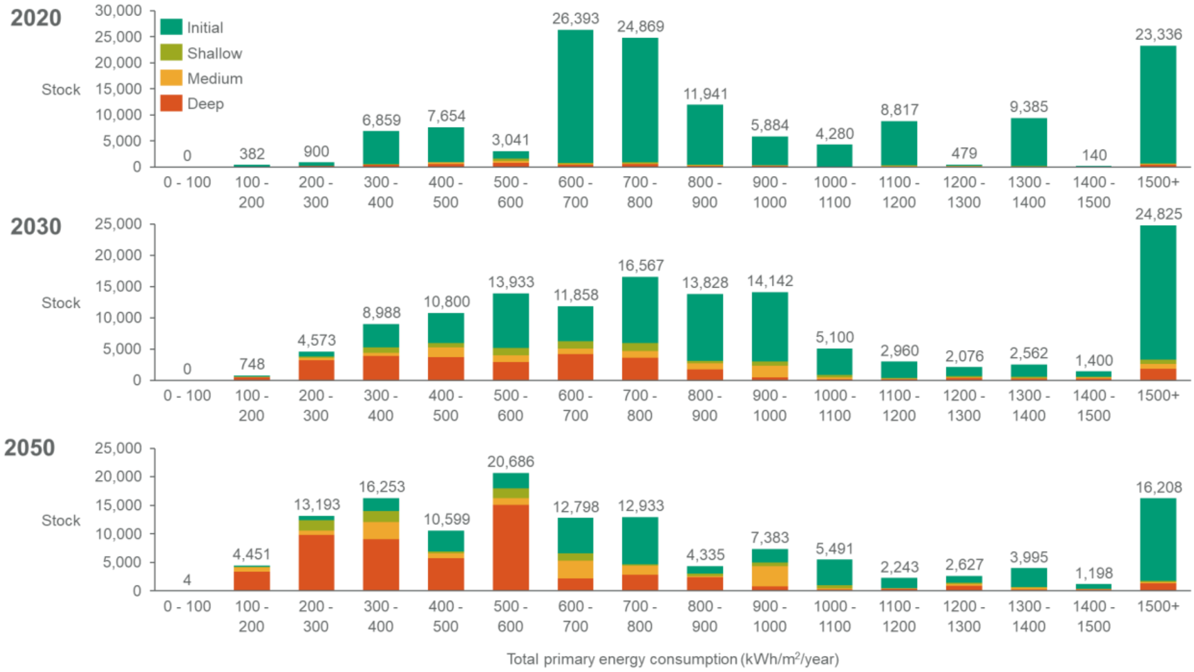


Figure 62 Public building stock total primary energy consumption distribution, 2020, 2030 and 2050, under the baseline scenario

Figure 63 Residential stock BER ratings in 2020, 2030 and 2050, under the decarbonisation scenario

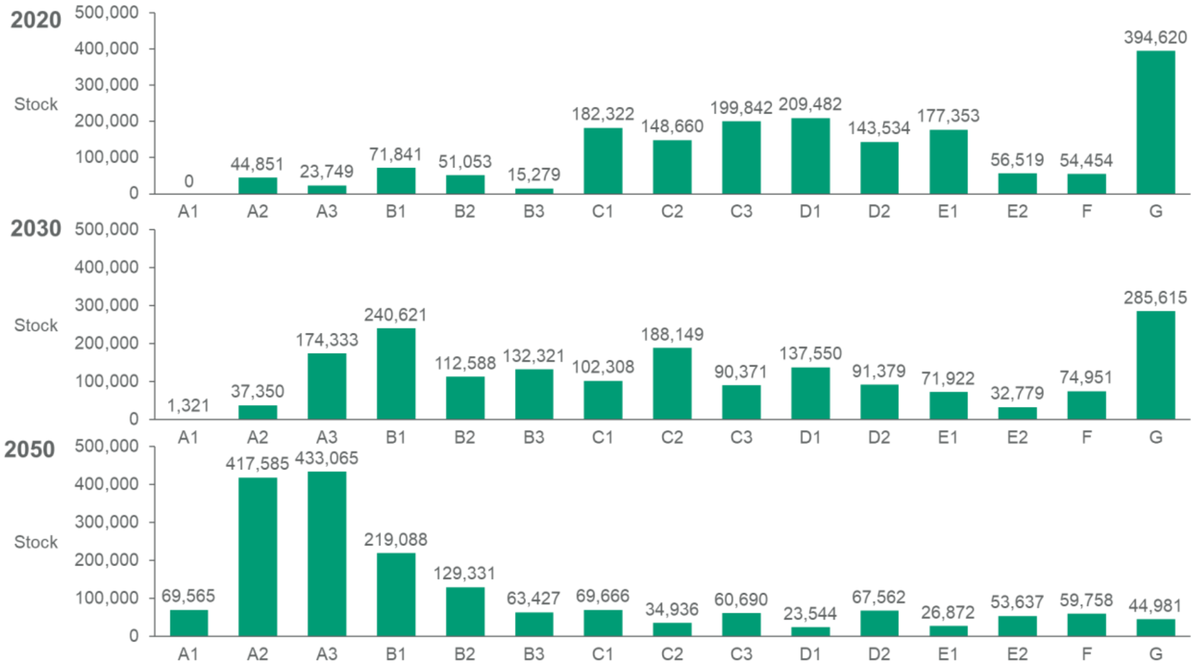


Figure 64 Commercial building stock total primary energy consumption distribution, 2020, 2030 and 2050, under the decarbonisation scenario

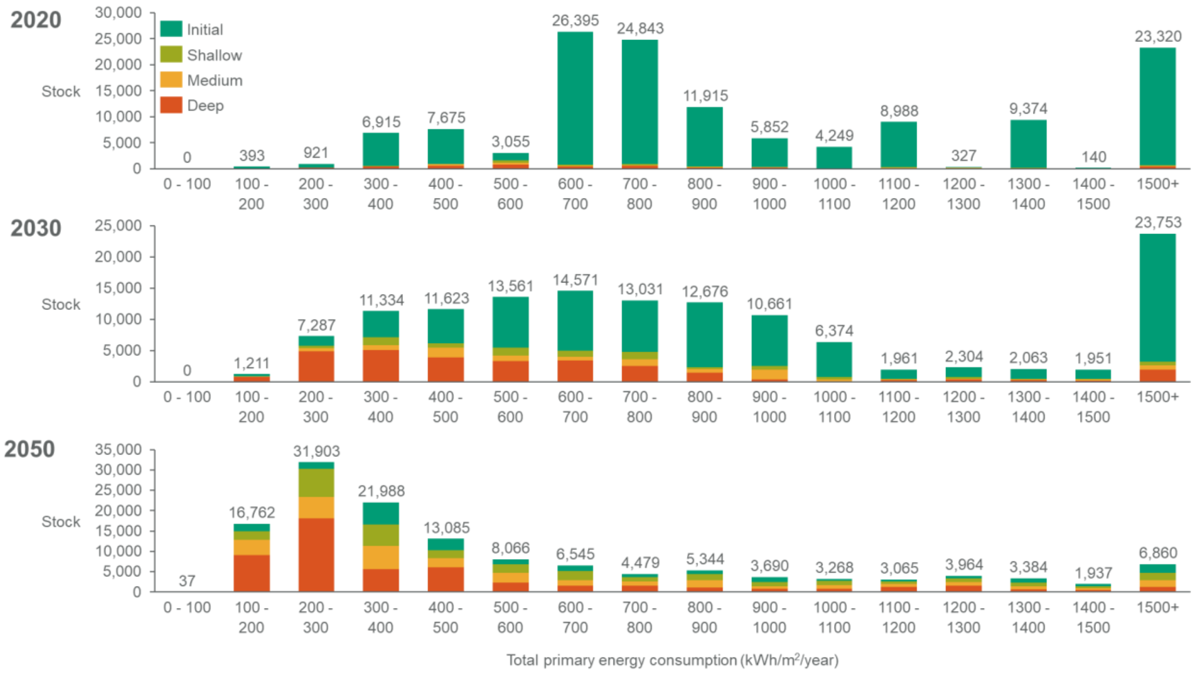


Figure 65 Public building stock total primary energy consumption distribution, 2020, 2030 and 2050, under the decarbonisation scenario

4.3.7 Sensitivities

This section outlines the main results for the five sensitivities tested on the Balanced scenario. The sensitivities are outlined in Table 22 below.

Table 22 Sensitivity analysis

Sensitivity	Description
Higher hydrogen price	Hydrogen price increased by 15% relative to base price
Lower hydrogen price	Hydrogen price decreased by 15% relative to base price
Higher electricity price	Electricity price increased by 15% relative to base price
Lower electricity price	Electricity price decreased by 15% relative to base price
District heating network costs	District heating networks costs varied from 50% of base costs to 150%

Table 23 shows the total heating demand (useful energy) by building sector, in 2030 and 2050, for the four hydrogen and electricity price sensitivities.

Table 23 Total heating demand (useful energy) by building sector, in 2030 and 2050

Scenario	Sector	2030 Heating demand met (useful energy) (TWh/a)	2050 Heating demand (useful energy) met (TWh/a)
Higher hydrogen price	Residential	20.2	19.7
	Services	8.9	8.8
	Industry	12.3	11.9
	Other	0.6	0.6
Lower hydrogen price	Residential	20.2	19.7
	Services	8.9	8.8
	Industry	12.3	11.9
	Other	0.6	0.6
Higher electricity price	Residential	20.2	19.7
	Services	8.9	8.8
	Industry	12.4	11.9
	Other	0.6	0.6
Lower electricity price	Residential	20.2	19.7
	Services	9.0	8.8
	Industry	12.3	11.9
	Other	0.6	0.6

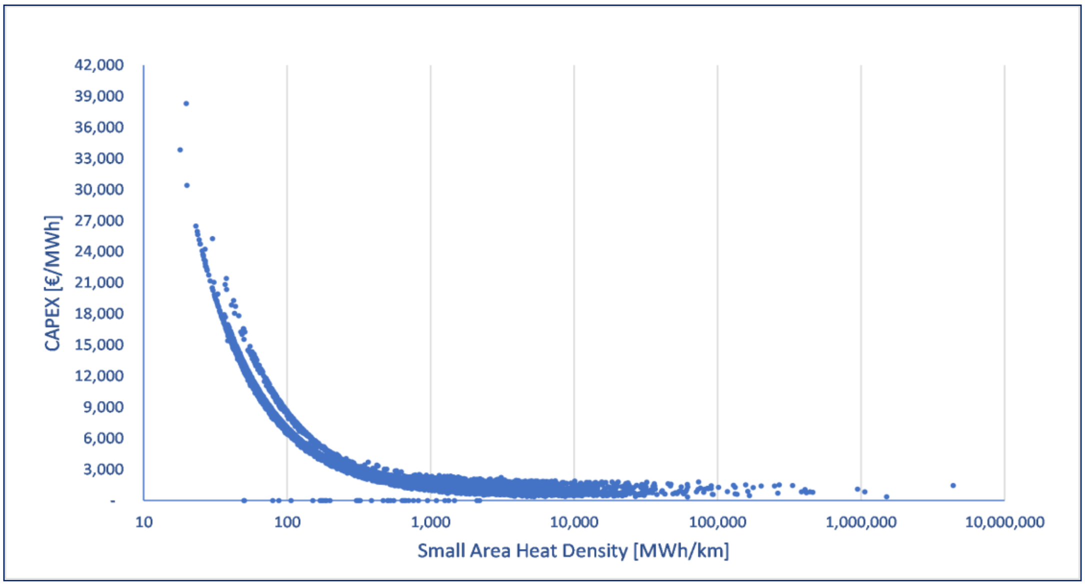
Regarding the district heating network costs, spatial mapping of thermal demand across all 18,641 small areas in Ireland was undertaken. Analysis based on capital expenditure of district heating (comprising generation plant, pipeline, thermal storage, connection capital costs) shows that the vast majority of small areas have a heat density below 10,000 MWh/km. However, 1.5% of small areas showed a heat density between 10,000 and 100,000 MWh/km, whilst 0.1% small areas demonstrated greater than 100,000 MWh/km. These represent the most economically viable district heating locations in Ireland. This analysis also shows that 2.5% of the total heat demand for the domestic, commercial and public sectors (28.6 TWh/y) is within small areas with a high economical potential for district heating (311 small areas with >10,000 MWh/km).

It is also noted that based on capital expenditure analysis, of the total 18,641 small areas, only 23% exist within a city area, whereas, 66% of small areas with a heat density greater than 10,000 MWh/km are within a city. This indicates that cities within Ireland tend to be more suitable for district heating.

Figure 66 shows that the capital cost begins to plateau once the heat density exceeds 1,000 MWh/km, indicating that the critical density threshold is 1,000 MWh/km. This is important because 51% of all small areas in Ireland have a heat density between 1,000 and 10,000 MWh/km. Given this cut-off, there are 9,783 small areas with economic potential for district heating in Ireland. This equates to 54% of the total heat demand.

The analysis above only considered capital expenditure. These preliminary findings are important but more comprehensive economic analysis, including fuel costs as well as other operational costs related to district heating, was undertaken.

Figure 66 Capital expenditure for district heating vs linear heat density (MWh/km)



The following graphs show how the energy mix changes and the emissions trajectories by fuel and by sector respectively in each of the other sensitivities.

Figure 67 Energy mix by fuel in the higher hydrogen price scenario

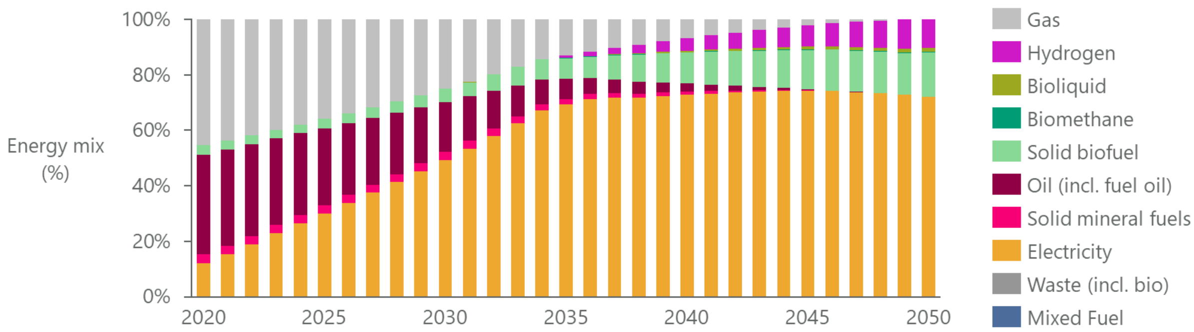


Figure 68 Energy mix by fuel in the lower hydrogen price scenario

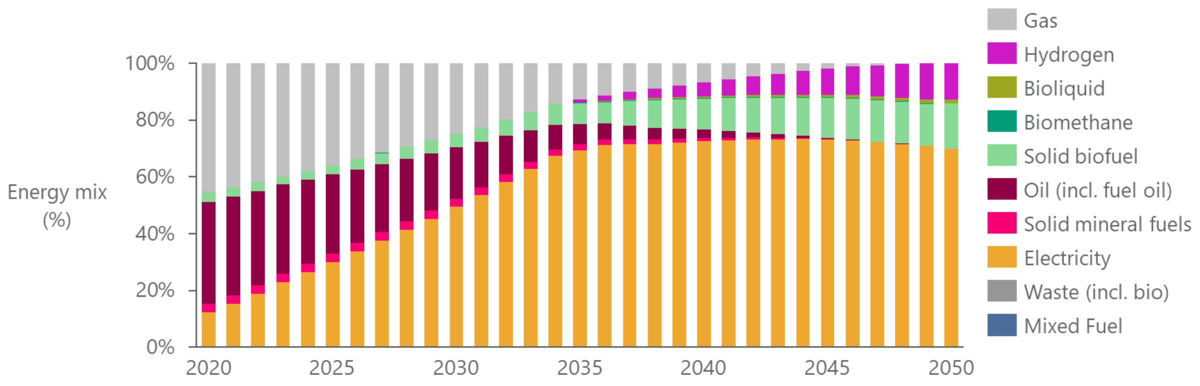


Figure 69 Energy mix by fuel in the higher electricity price scenario

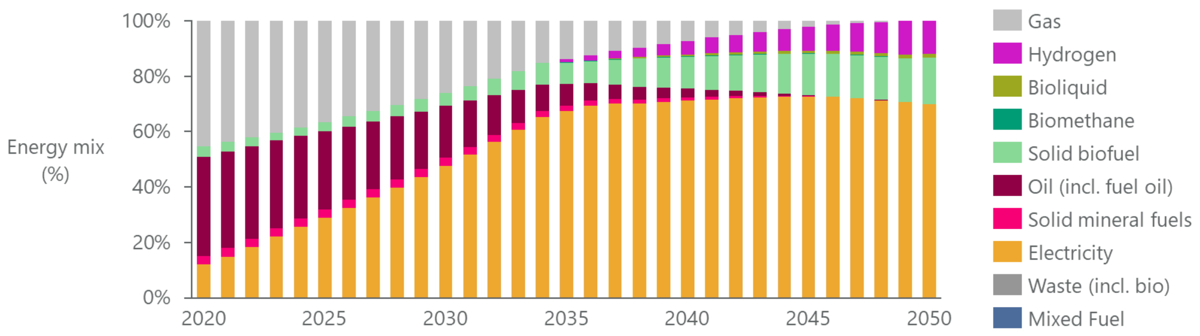


Figure 70 Energy mix by fuel in the lower electricity price scenario

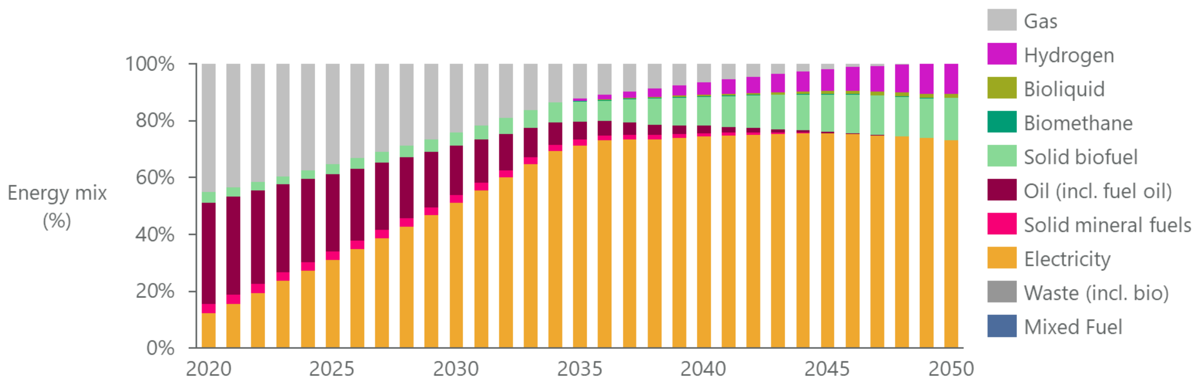


Figure 71 Carbon dioxide emissions from heating by sector in the higher hydrogen price sensitivity. Cumulative emissions 2020 to 2050 are 259 Mt CO_2.

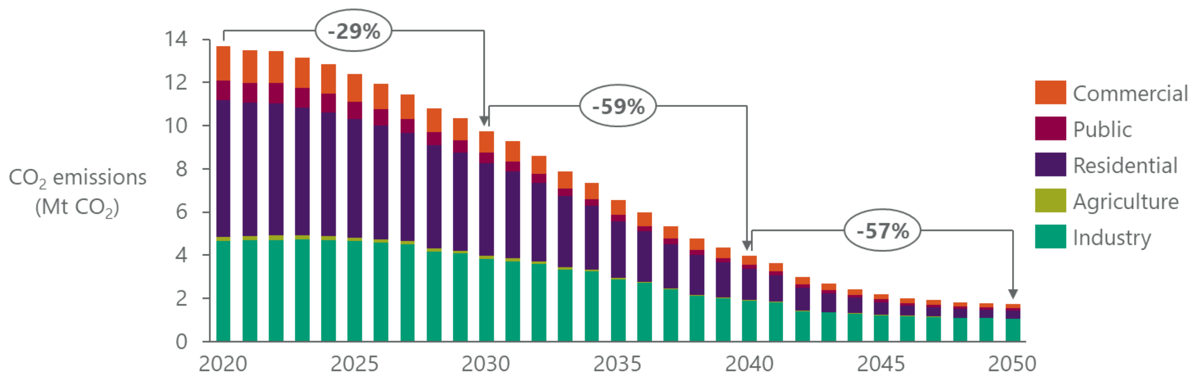


Figure 72 Carbon dioxide emissions from heating by sector in the lower hydrogen price sensitivity. Cumulative emissions 2020 to 2050 are 260 Mt CO_2.

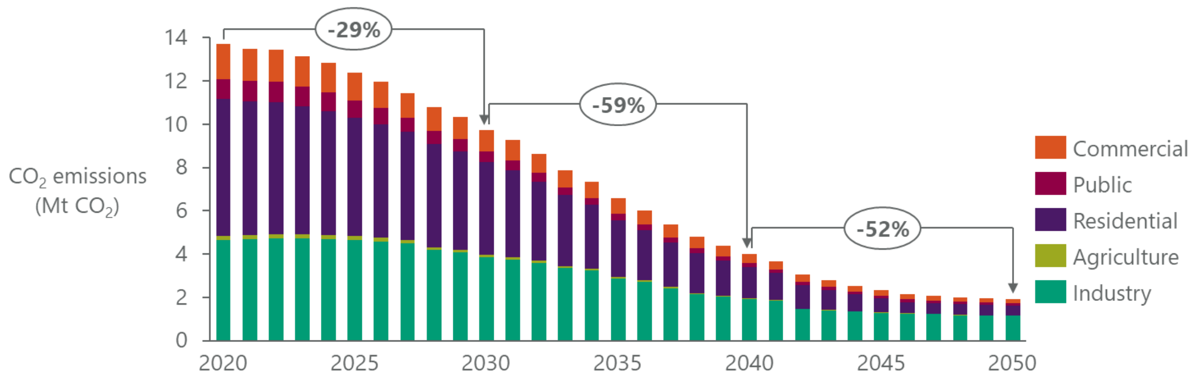


Figure 73 Carbon dioxide emissions from heating by sector in the higher electricity price sensitivity. Cumulative emissions 2020 to 2050 are 269 Mt CO_2.

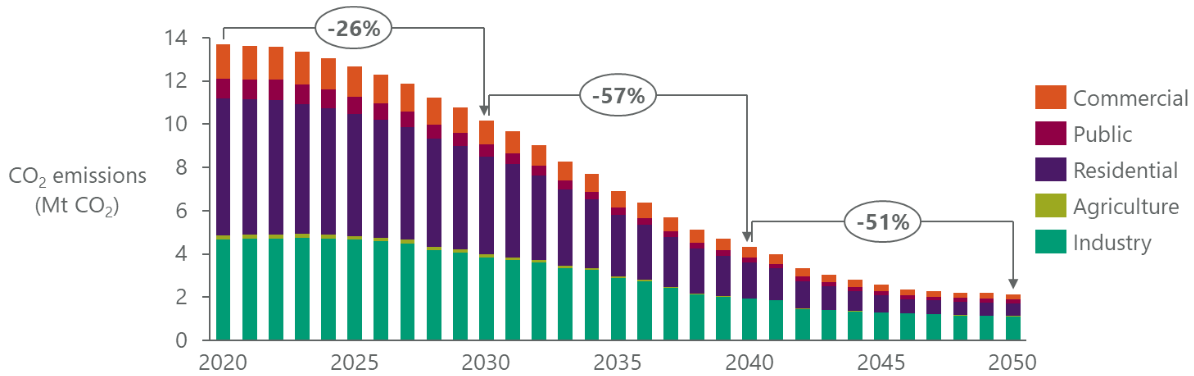


Figure 74 Carbon dioxide emissions from heating by sector in the lower electricity price sensitivity. Cumulative emissions 2020 to 2050 are 267 Mt CO_2.

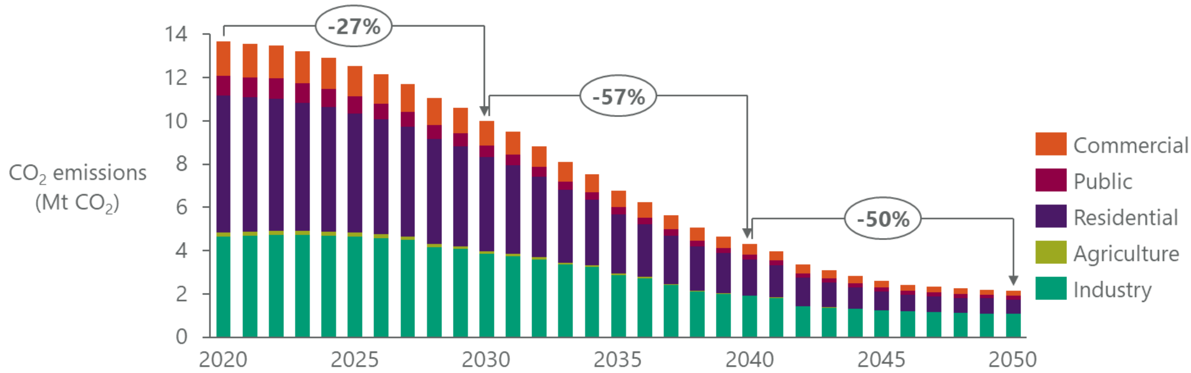


Figure shows the effect of varying district heating network costs on the overall cost of heat of district heating. Costs are varied from 50% of the original assumption to 150%. Whilst the effect is small, the cost of heat increases slightly as network costs decrease. This is due to the fact that with lower costs, more areas become suitable for district heating. Therefore, the most suitable areas (which tend to have access to low-cost waste heat) make up a smaller proportion of areas suitable for district heating, which drives the overall cost up.

Figure 75 Effect of changing network costs for district heating on cost of heat. Scaling factor of unity represents base assumptions.

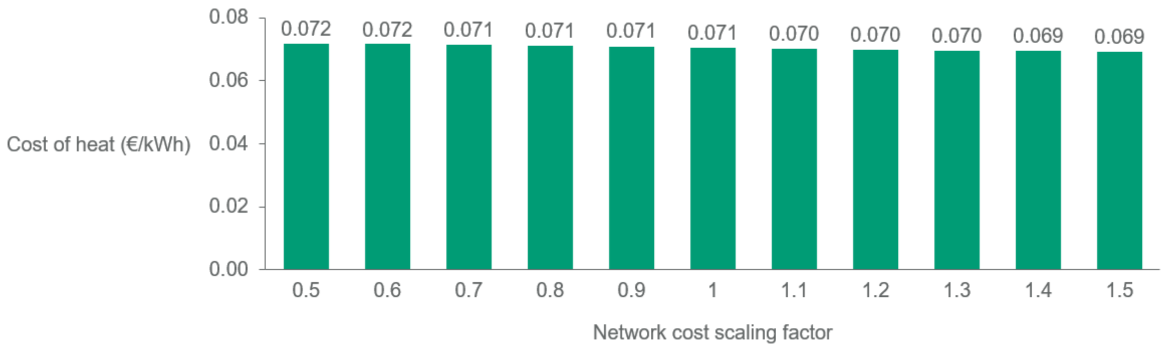
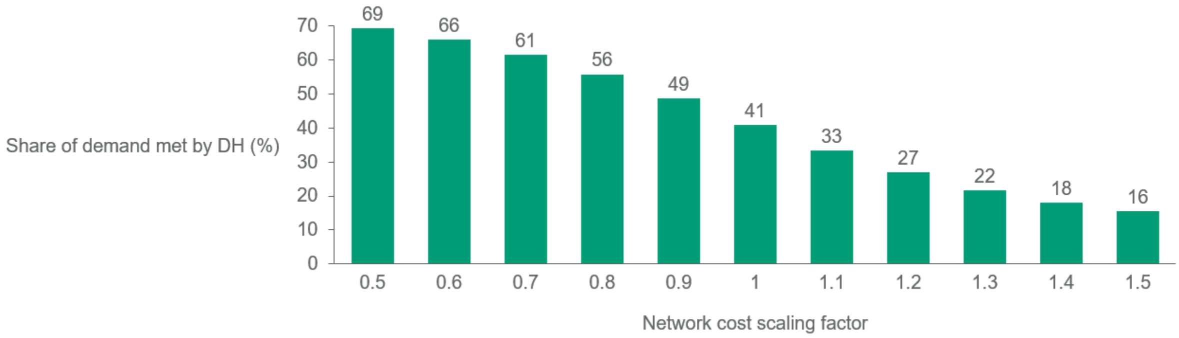


Figure 76 shows the effect of varying district heating network costs on the share of heating demand suitable for district heating. As expected, the lower the network costs, the higher the share of demand which can be cost-effectively met by district heating. With network costs at 50% of the base assumption, nearly 70% of all heating demand can feasibly be met by district heating. Whilst the graph shows that 41% of all heating demand can be met by district heating in the base case, this has not been reflected in the modelling. Instead, the baseline scenario incorporates district heating meeting 10% of overall heating demand, while the figure for the decarbonisation scenario is 20%. These values reflect more realistic outcomes, based on previous modelling work for the UK.

Figure 76 Effect of changing network costs for district heating on share of total heat demand (including industry) met by district heating. Scaling factor of unity represents base assumptions.



5 Potential New Strategies and Policy Measures

5.1 The status of climate policy in Ireland

The Climate Action and Low Carbon Development (Amendment) Bill 2021 is focused on reducing economy wide GHG emissions by 51% by 2030 and reaching economy wide carbon neutrality by 2050. The legislation sets out key objectives as outlined below:

- Places on a statutory basis a 'national climate objective', which commits to pursue and achieve no later than 2050, the transition to a climate resilient, biodiversity-rich, environmentally-sustainable and climate-neutral economy
- Embeds the process of carbon budgeting into law, Government are required to adopt a series of economy-wide five-year carbon budgets, including sectoral targets for each relevant sector, on a rolling 15-year basis, starting in 2021
- Actions for each sector will be detailed in the Climate Action Plan, updated annually
- A National Long-Term Climate Action Strategy will be prepared every five years
- Government Ministers will be responsible for achieving the legally-binding targets for their own sectoral area with each Minister accounting for their performance towards sectoral targets and actions before an Oireachtas Committee each year
- Strengthens the role of the Climate Change Advisory Council, tasking it with proposing carbon budgets to the Minister
- Provides that the first two five-year carbon budgets proposed by the Climate Change Advisory Council should equate to a total reduction of 51% emissions over the period to 2030, in line with the Programme for Government commitment
- Expands the Climate Change Advisory Council from eleven to fourteen members, and provides that future appointments to the Council provide for a greater range of relevant expertise and gender balanced
- Introduces a requirement for each local authority to prepare a Climate Action Plan, which will include both mitigation and adaptation measures and be updated every five years. Local authority Development Plans will also align with their Climate Action Plan
- Public Bodies will be obliged to perform their functions in a manner consistent with national climate plans and strategies, and furthering the achievement of the national climate objective

Additional policy targets and supporting measures are being developed as part of the Climate Action Plan 2021 discussions. This plan will set out the detail of sectoral level objectives and strategies to achieve these. In this context, the discussion on potential new strategies and policy measures is limited, however the insights and findings from this work are available to support the development of these. Hence no estimates of the costs of public support measures, annual budgeting impacts and identification of the aid element are included here.

5.2 Simulation of current policy objectives and measures

The objectives and supporting PaMs set out in Section 3 are examined in this section to understand the progress current levels of effort can deliver as well as the additional effort that may be required to reach the targets set out in Table 7. The approach taken to deliver this assessment is:

- Simulation of the current configuration of PaMs to 2030 is carried out in the ‘Baseline’ scenario, and the outcome is compared to several existing headline policy targets. The current configuration includes current levels of incentivisation and eligibility.

- Where current policy measures do not reach policy targets in the Baseline scenario, the ‘Decarbonisation’ scenario increases policy effort to meet these headline targets. This is carried out by iteration, extending current policy where possible and, if necessary, adding further policies to the mix to achieve targets.

- The level of additional effort required is graded across three categories:

1) An extension of existing policy. These involve actions such as the extension of timelines or budgets. They also include actions that increase consumer awareness of the options available and other measures that simplify and reduce the hassle involved in making a technology switch. Examples include communication campaigns, demonstration events and pilots; simplifying administration, design, installation and financing processes; training programmes and awareness raising for heat technology supply chains. Technology and installation standards also have an important role to support quality and market development.

2) Additional policy effort. These polices include actions that improve the payback of energy efficiency and renewable energy technologies. This category may also include some light regulation that requires consumers to consider the sustainable energy options available at key decision points such as when replacing a boiler. Renewable and low-carbon heat obligations may also have a role as well as measures that allow the value of providing electricity grid flexibility to be captured by end users.

3) Stretch policies. These policies may include regulations and requirements aimed at bringing forward more consumer decisions, sharing the cost of decarbonisation across all CO_2 emitting energy sources and making the cost of installing fossil options less attractive. Examples may include: roadmaps for the phase out of fossil fuels, minimum standards for energy efficiency and carbon intensity and transferring some of the support cost from the electricity sector to oil, gas and coal.

Table 24 below describes the outcome from this analysis.

Table 24 - Key policy targets compared by scenario, and assessment of additional policy effort required to reach policy targets

Objective or Target	Baseline scenario vs target	Decarbonisation[47] scenario vs target	Level of additional policy effort required[48]	Commentary
500,000 homes retrofitted to a B2 Building Energy Rating or cost optimal by 2030	16% of target - residential buildings reaching BER B2 between 2020 & 2030.	76% of target - residential buildings reaching BER B2 between 2020 & 2030.	2-3	An extension of existing policy as well as additional effort are required to come close to existing policy targets.
600,000 heat pumps to be installed over the period 2021-2030	24% of target for heat pumps in existing buildings. Target met for heat pumps in new builds.	92% of target for heat pumps in existing buildings. Target met for heat pumps in new builds.	2-3	An extension of existing policy as well as additional effort are required to meet existing policy targets.
Public sector buildings to have a B Building Energy Rating (or carbon equivalent) by 2030	33% of public sector buildings have performed a deep retrofit by 2030[49].	33% of public sector buildings have performed a deep retrofit by 203049.	2	An extension of existing policy as well as additional effort are required to go beyond what is achieved in these scenarios and meet existing policy targets.
One third of all commercial (including mixed use) buildings to have a B Building Energy Rating (or carbon equivalent gains) by 2030	20% of commercial sector buildings have performed a deep retrofit by 203049.	21% of commercial sector buildings have performed a deep retrofit by 203049.	2	An extension of existing policy as well as additional effort are required to go beyond what is achieved in these scenarios and meet existing policy targets.
Additional 1,600 GWh of renewable heat via SSRH	84% of target	Target achieved	2	Existing policy meets the target in both scenarios.

47 See Section 4.1 for an overview of scenarios modelled as part of this report.

48 See Section 5.2 for a description of policy effort.

49 Due to the complex calculation method for non-domestic building energy ratings which is not currently integrated into SEAI's National Energy Modelling Framework this report instead details the number of deep retrofits completed. A deep retrofit typically reaches a BER of B or better. This metric is being examined for updates in future.

Objective or Target	Baseline scenario vs target	Decarbonisation[47] scenario vs target	Level of additional policy effort required[48]	Commentary
1.6 TWh of indigenous biomethane by 2030[50]	Target achieved	Target achieved	2	An extension of existing policy as well as additional effort are required to go beyond what is achieved in these scenarios and meet existing policy targets, including financial incentives to support the viability gap, sustainability certification, and technology standards.
Additional district heating of 0.12TWh growing linearly from 2023 to 2028	Target achieved	Target achieved	2	An extension of existing policy is required to meet this target.

[50] Indicative target

5.3 Future strategies and measures

The forthcoming Climate Action Plan will inform further detail across these three categories, supported by more in-depth analysis of the policy options. Table 25 below presents the voluntary reporting template that provides an overview of potential new strategies and policy measures, noting as discussed in Section 5.1 that these are currently in development

.

Table 25 – Voluntary reporting template - overview of potential new strategies and policy measures

Short description of potential new strategy or measure	Main objective of new strategy or policy measure	Foreseen greenhouse gas emission reductions	Primary energy savings (GWh/a)	Impact on the share of high efficiency co-generation	Impact on the share of renewables in the national energy mix and in the heating and cooling sector	Links to national financing programming and cost savings for the public budget and market participants	Estimated public support measures, if any, with their annual budget and identification of the potential aid element
Forthcoming Climate Action Plan 2021	Climate-neutral economy by 2050, including a reduction of 51% in the total amount of greenhouse gas emissions by 2030 in comparison with 2018.	A reduction of 51% in the total amount of greenhouse gas emissions by 2030 in comparison with 2018. Additionally, five yearly economy-wide carbon budgets to facilitate reaching economy-wide climate-neutral by 2050.	Unknown, pending outcome of Climate Action Plan 2021	Unknown, pending outcome of Climate Action Plan 2021	Unknown, pending outcome of Climate Action Plan 2021	Unknown, pending outcome of Climate Action Plan 2021	Unknown, pending outcome of Climate Action Plan 2021

Appendix A - Annex VII Voluntary Reporting Templates

Table 26 Part I: Overview of heating and cooling: 1. Reporting current heating and cooling demand; 4. Reporting forecasted heating and cooling demand.

		Unit	2019	2020	2025	2030	2035	2040	2045	2050
Heating demand, **final** energy	Residential sector	TWh/a	26.30	21.68	19.16	16.04	12.07	10.22	9.26	9.42
	Service sector	TWh/a	10.00	3.93	3.17	2.50	1.89	1.85	1.79	1.79
	Industrial sector	TWh/a	22.50	16.74	15.49	14.34	13.42	13.46	13.45	13.47
	Other sectors	TWh/a	0.80	0.75	0.74	0.73	0.68	0.46	0.25	0.07
Cooling demand, **final** energy	Residential sector	TWh/a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Service sector	TWh/a	3.40	3.52	4.09	4.39	4.50	4.62	4.73	4.85
	Industrial sector	TWh/a	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Other sectors	TWh/a	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heating demand, **useful** energy	Residential sector	TWh/a	19.40	18.33	18.24	18.21	18.18	18.17	18.17	18.17
	Service sector	TWh/a	9.20	3.52	3.45	3.43	3.42	3.41	3.41	3.42
	Industrial sector	TWh/a	17.50	12.75	12.57	12.35	12.15	12.06	12.00	11.95
	Other sectors	TWh/a	0.60	0.62	0.62	0.62	0.62	0.62	0.62	0.62
Cooling demand, **useful** energy	Residential sector	TWh/a	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Service sector	TWh/a	8.50	8.53	13.18	15.81	16.66	17.51	18.36	19.21
	Industrial sector	TWh/a	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
	Other sectors	TWh/a	0.10	0.09	0.09	0.09	0.09	0.09	0.09	0.09

Table 27 Part I: Overview of heating and cooling: 2.(a) Reporting current heating and cooling supply

Energy provided on-site (YEAR 2019)			Unit	Value
Residential sector	Fossil fuel sources	Heat only boilers	GWh/a	25,000
		Other technologies	GWh/a	1,000
		HECHP	GWh/a	-
	Renewable energy sources	Heat only boilers	GWh/a	150
		HECHP*	GWh/a	-
		Heat pumps	GWh/a	150
		Other technologies	GWh/a	-
Service sector	Fossil fuel sources	Heat only boilers	GWh/a	7,200
		Other technologies	GWh/a	5,400
		HECHP*	GWh/a	380
	Renewable energy sources	Heat only boilers	GWh/a	400
		HECHP*	GWh/a	25
		Heat pumps	GWh/a	-
		Other technologies	GWh/a	-
Industrial sector	Fossil fuel sources	Heat only boilers	GWh/a	6,200
		Other technologies	GWh/a	7,200
		HECHP*	GWh/a	6,900
	Renewable energy sources	Heat only boilers	GWh/a	900
		HECHP*	GWh/a	100
		Heat pumps	GWh/a	-
		Other technologies	GWh/a	2,000
Other sectors	Fossil fuel sources	Heat only boilers	GWh/a	700
		Other technologies	GWh/a	200
		HECHP*	GWh/a	-
	Renewable energy sources	Heat only boilers	GWh/a	-
		HECHP*	GWh/a	-
		Heat pumps	GWh/a	-
		Other technologies	GWh/a	-

*Numbers quoted against HECHP include all existing CHP units. Sufficiently detailed data to distinguish between HECHP and other CHP unavailable.

Table 28 Part I: Overview of heating and cooling: 2.(a) Reporting current heating and cooling supply

Energy provided off-site (YEAR 2019)	Unit	Value
Residential sector	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
Service sector	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
Industrial sector	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
Other sectors	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data
	GWh/a	No data

*Heating demand met by existing district heating is minimal in comparison to total heat demand.

Table 29 Part I: Overview of heating and cooling: 2.(b) Reporting identified available waste heat

YEAR 2019	Threshold	Unit	Value
Thermal power generation installations	50 MW	GWh/a	8,954
CHP*	20 MW	GWh/a	0
Waste incineration plants	-	GWh/a	390
Renewable energy installations**	20 MW	GWh/a	0
Industrial installations	20 MW	GWh/a	1,546

* CHP systems deemed fully optimised, hence no additional available heat for extraction.
** No solely renewable installations, though some of the power stations and industrial sites do consume a fraction of renewables.

Table 30 Part III: Reporting economic potential of efficient and renewable heating and cooling technologies identified during the CBA. Total cooling demand of 20.7 TWh is assumed to be all electric.

YEAR 2050	TOTAL GWh/a	Residential GWh/a	Services GWh/a	Industry GWh/a	Other GWh/a
Industrial waste heat*	-	-	-	-	-
Industrial waste cold*	-	-	-	-	-
Waste incineration	0.00	0.00	0.00	0.00	0.00
High efficiency CHP	1.50	0.00	0.00	1.50	0.00
Renewable energy sources	11.23	4.24	1.75	4.80	0.44
*Geothermal***	-	-	-	-	-
Biomass	4.91	3.02	0.87	1.02	0.00
Solar thermal	0.54	0.37	0.16	0.00	0.00
Other RES	5.78	0.85	0.71	3.78	0.43
Heat pumps	17.40	10.29	5.47	1.64	0.00
Heat loss reduction in existing DHC networks	-	-	-	-	-

*Projections of economic potential unavailable
** Lack of suitable data below depth of 400 metres. Up to 400 metres potential included in heat pump potential.

Appendix B - Additional economic potential figures

Economic Net Present Value – baseline scenario

Figure 77 Net present value (NPV) of the economic potential for the take up of heating systems in the residential sector, in 2030 under the baseline scenario, using the economic cost-benefit analysis

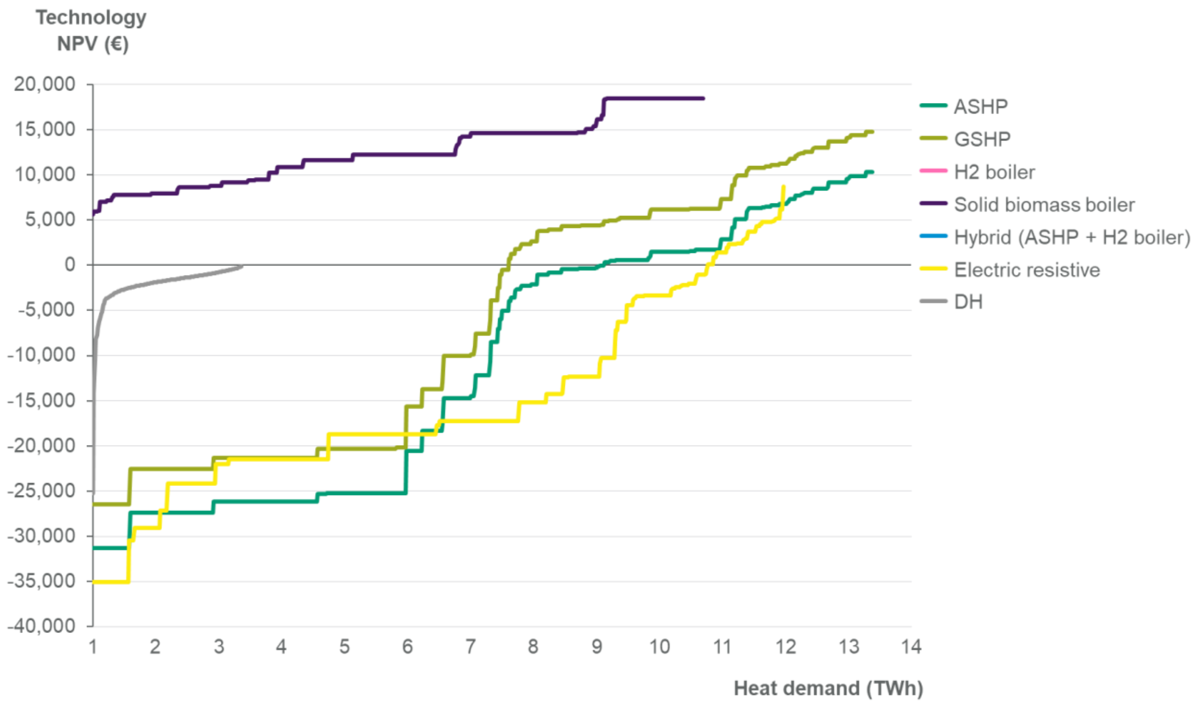


Figure 78 Net present value (NPV) of the economic potential for the take up of heating systems in the residential sector, in 2050 under the baseline scenario, using the economic cost-benefit analysis

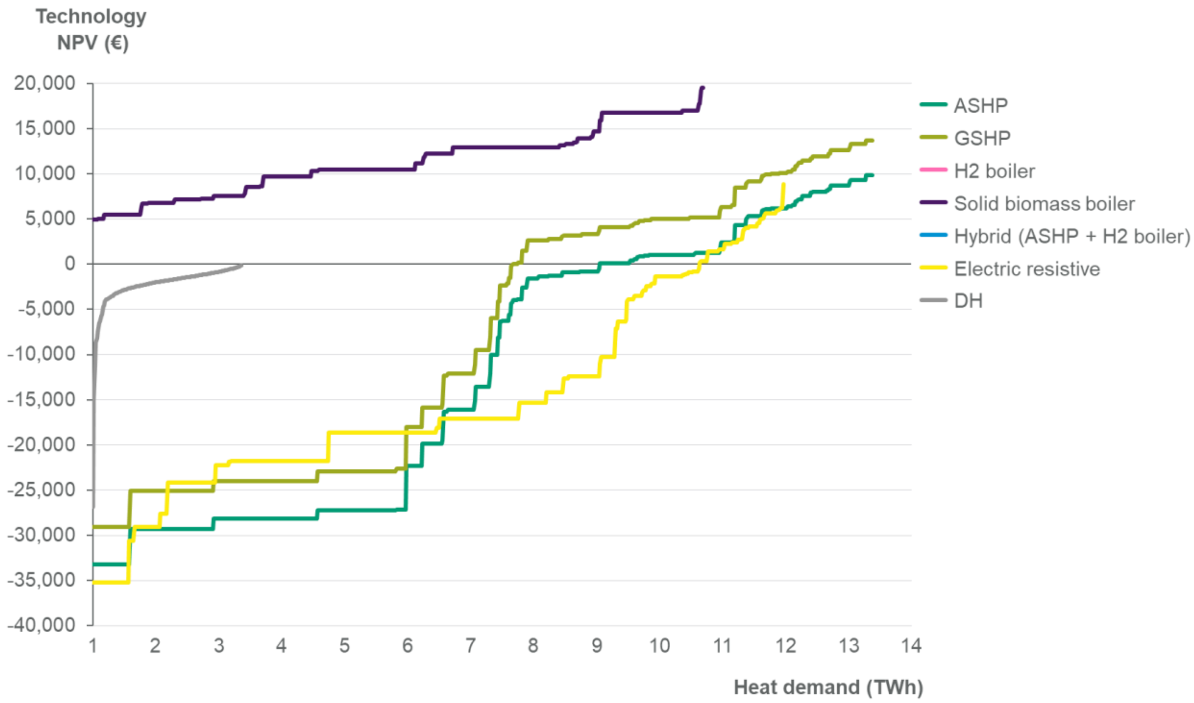


Figure 79 Net present value (NPV) of the economic potential for the take up of heating systems in the commercial and public sectors, in 2030 under the baseline scenario, using the economic cost-benefit analysis

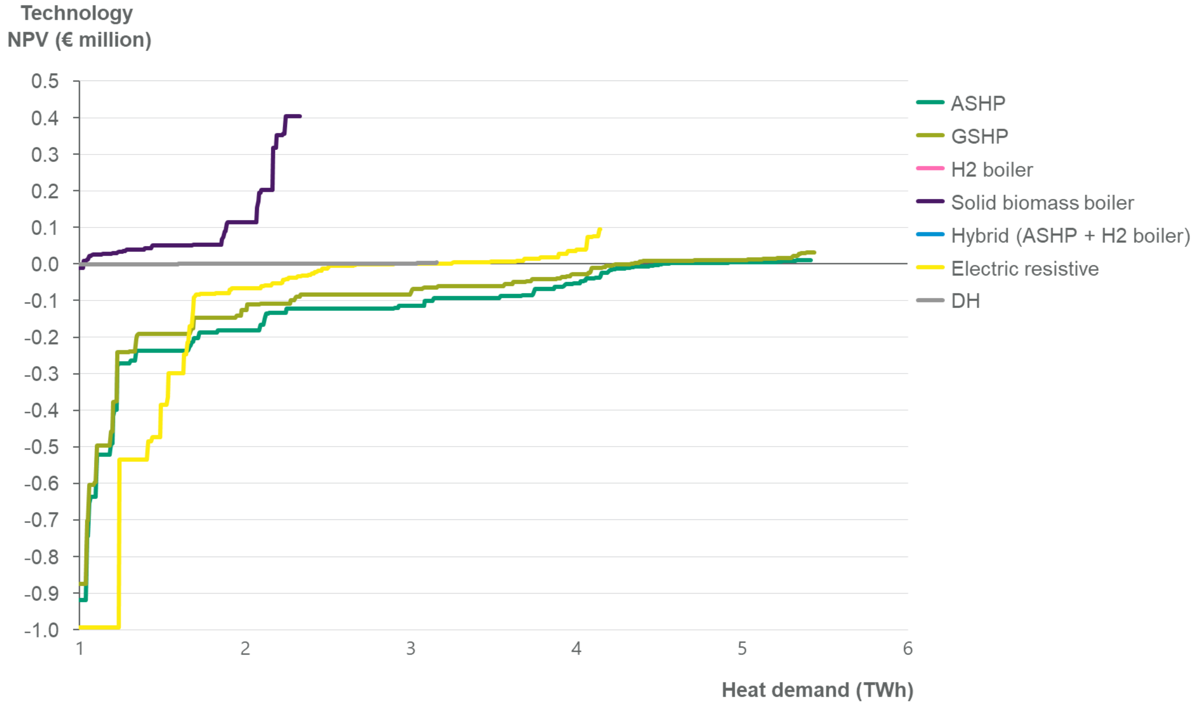


Figure 80 Net present value (NPV) of the economic potential for the take up of heating systems in the commercial and public sectors, in 2050 under the baseline scenario, using the economic cost-benefit analysis

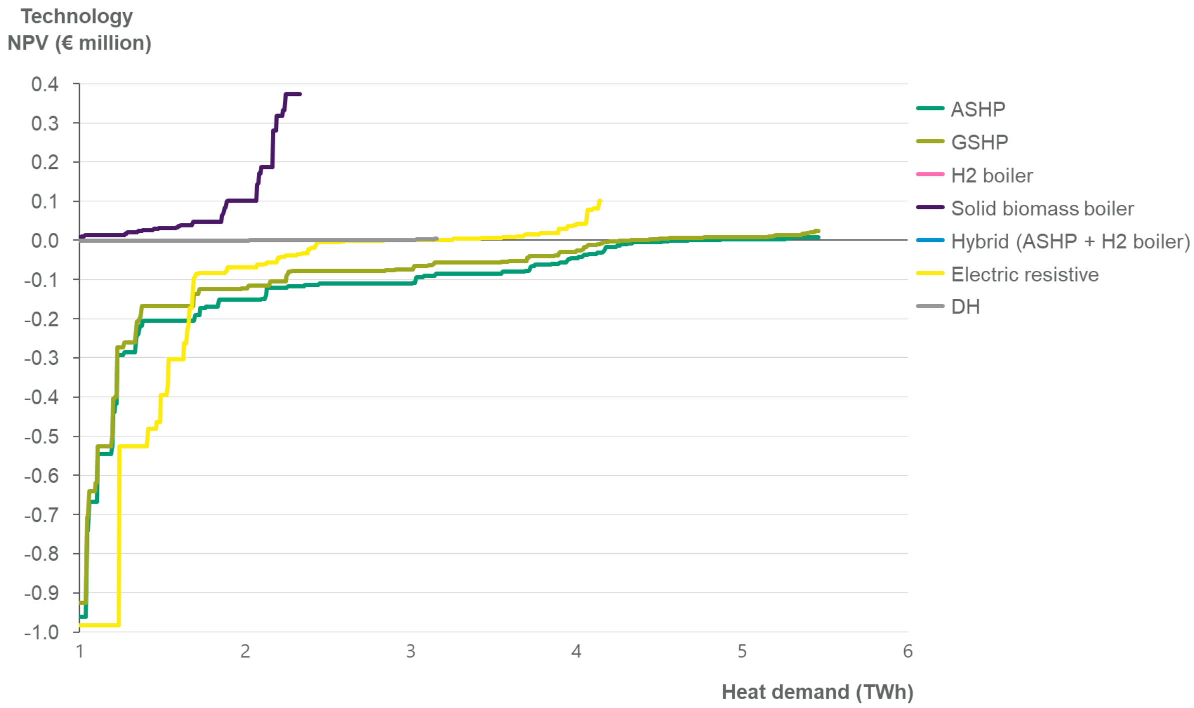


Figure 81 Net present value (NPV) of the economic potential for the take up of heating systems in industry, in 2030 under the baseline scenario, using the economic cost-benefit analysis

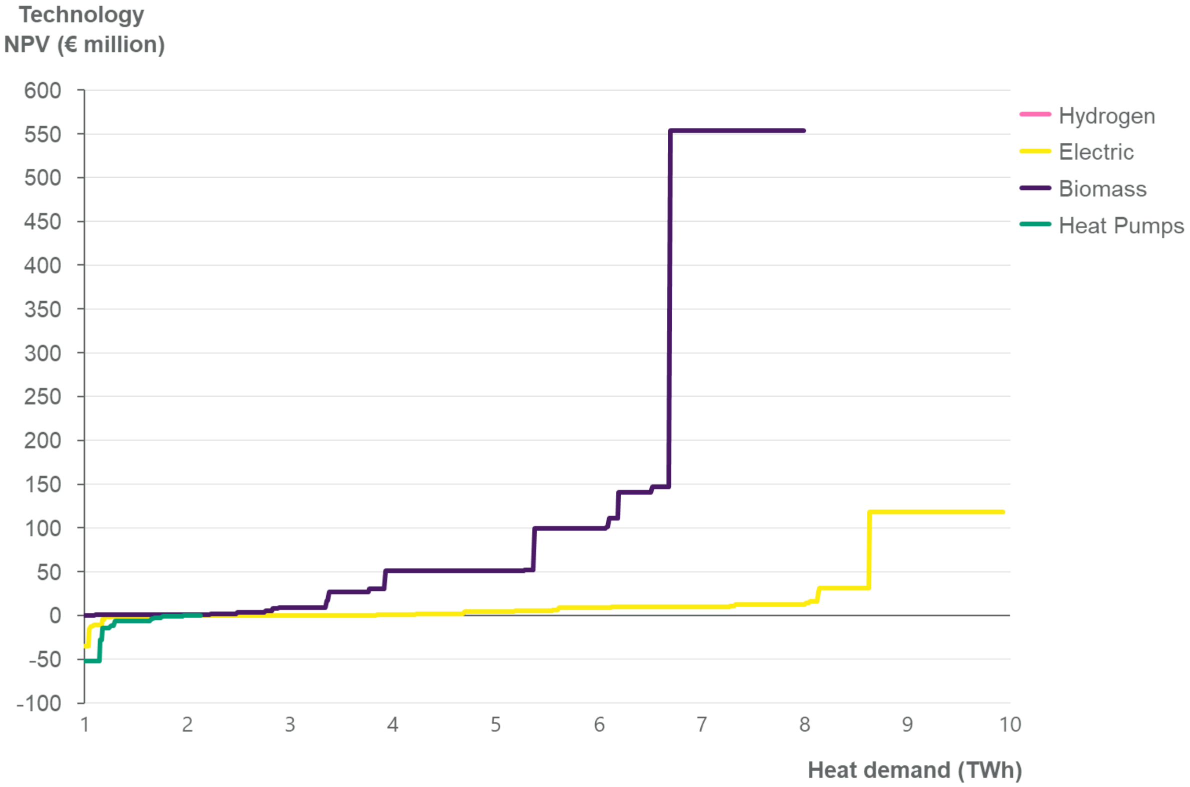
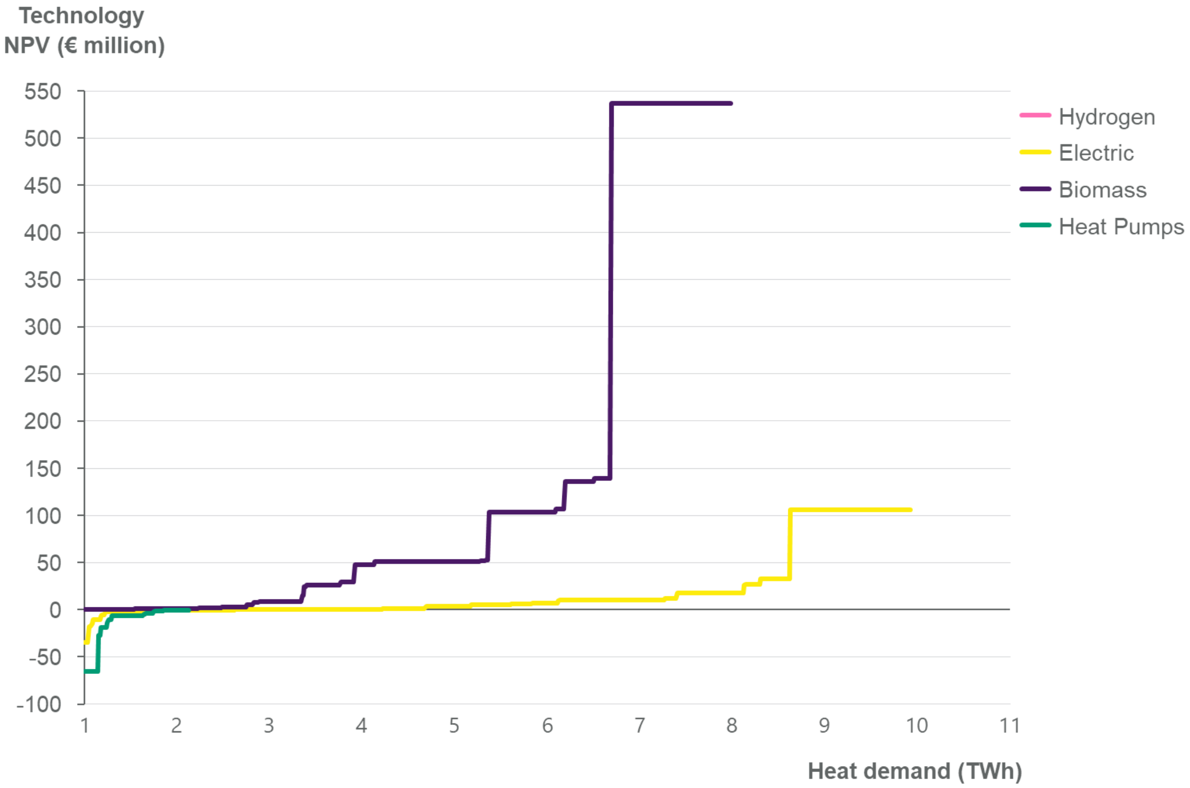


Figure 82 Net present value (NPV) of the economic potential for the take up of heating systems in industry, in 2050 under the baseline scenario, using the economic cost-benefit analysis



Financial Net Present Value– baseline scenario

Figure 83 Net present value (NPV) of the economic potential for the take up of heating systems in the residential sector, in 2030 under the baseline scenario, using the financial cost-benefit analysis

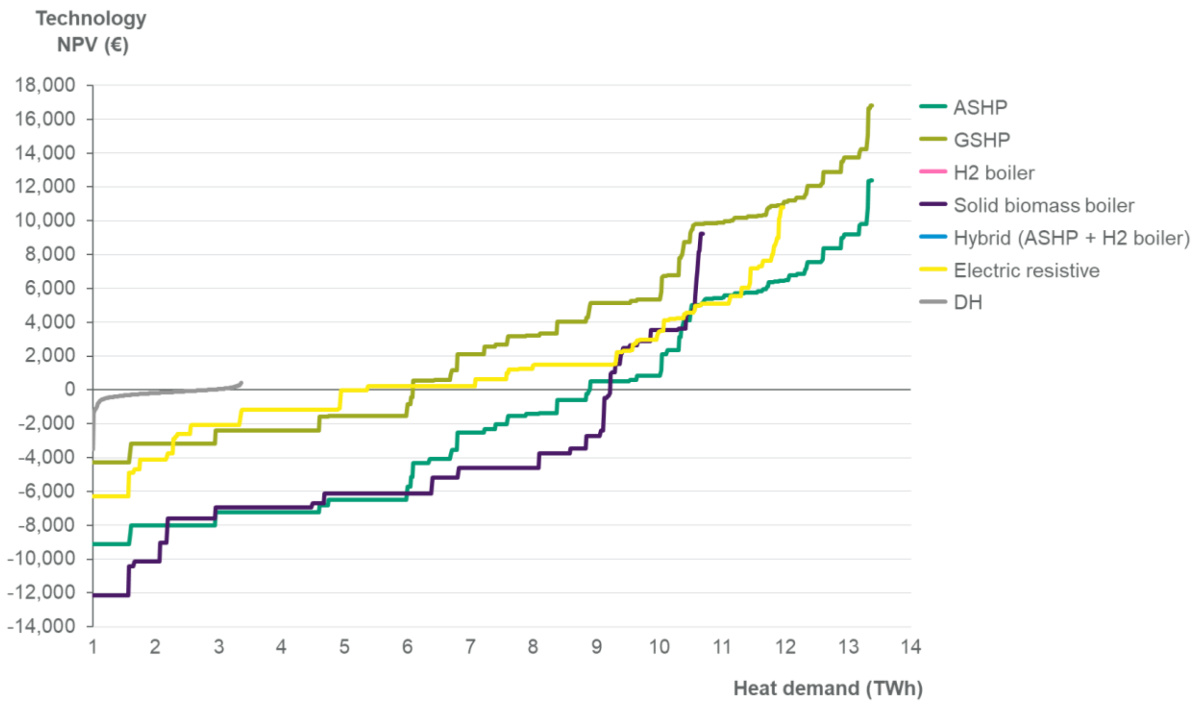


Figure 84 Net present value (NPV) of the economic potential for the take up of heating systems in the residential sector, in 2050 under the baseline scenario, using the financial cost-benefit analysis

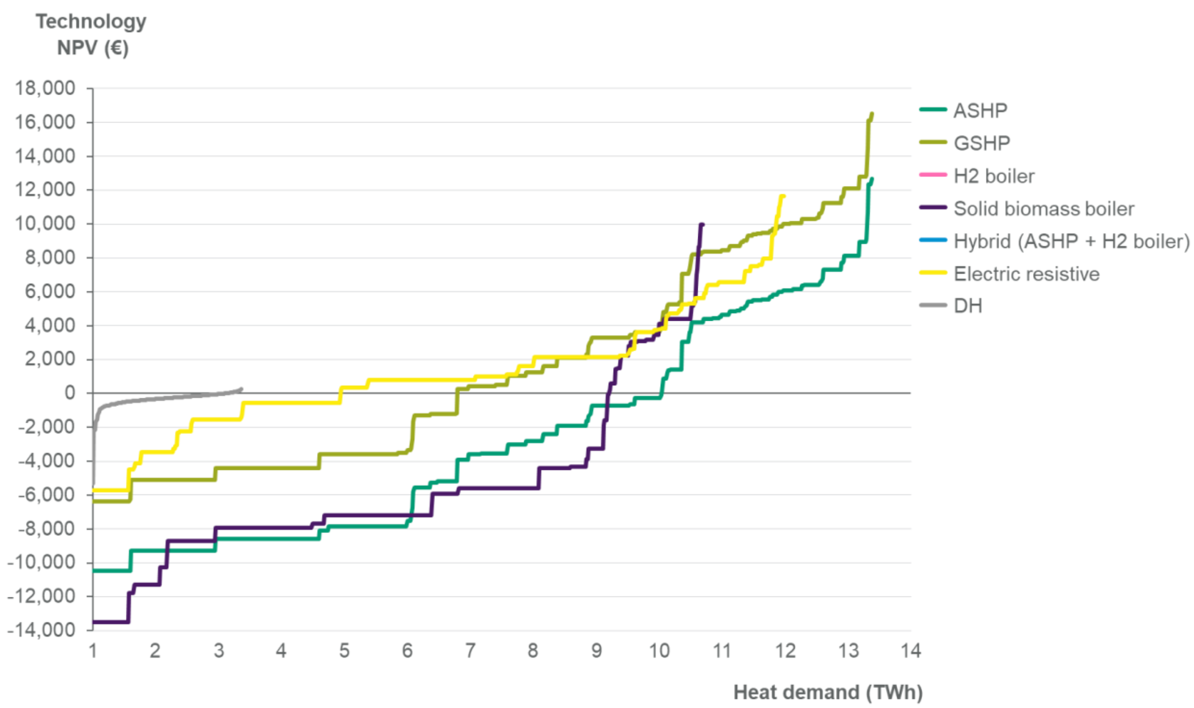


Figure 85 Net present value (NPV) of the economic potential for the take up of heating systems in the commercial and public sectors, in 2030 under the baseline scenario, using the financial cost-benefit analysis

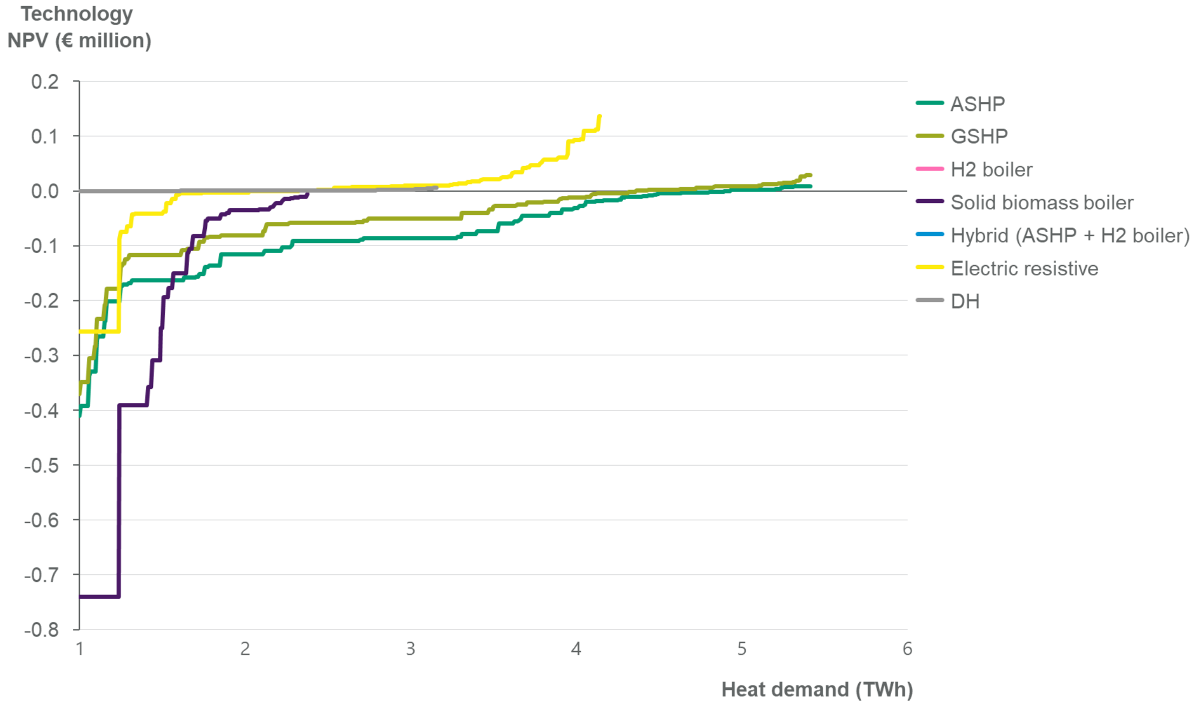


Figure 86 Net present value (NPV) of the economic potential for the take up of heating systems in the commercial and public sectors, in 2050 under the baseline scenario, using the financial cost-benefit analysis

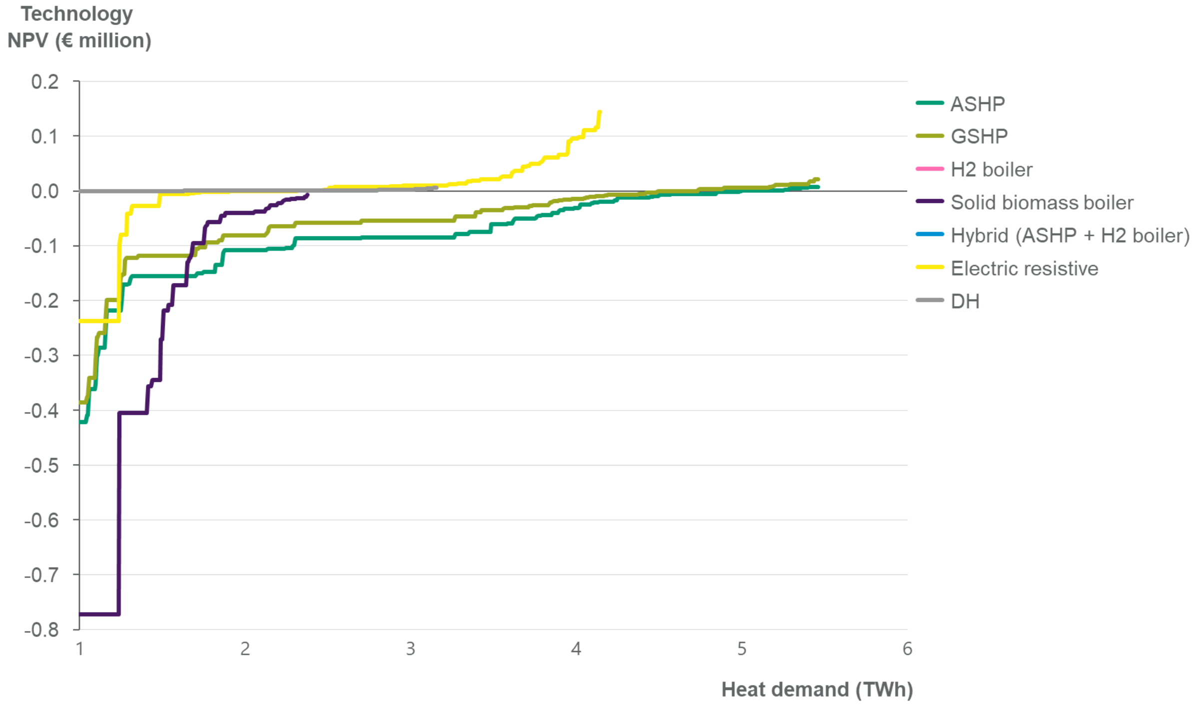


Figure 87 Net present value (NPV) of the economic potential for the take up of heating systems in industry, in 2030 under the baseline scenario, using the financial cost-benefit analysis

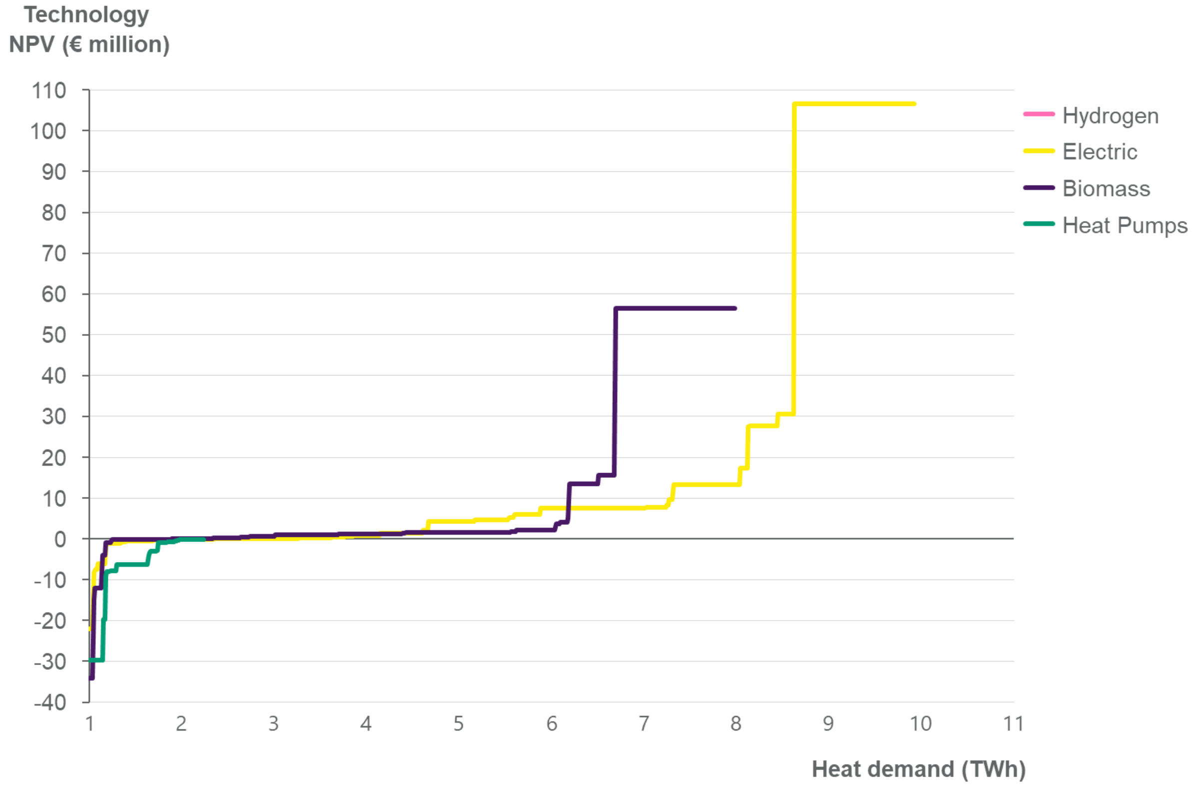
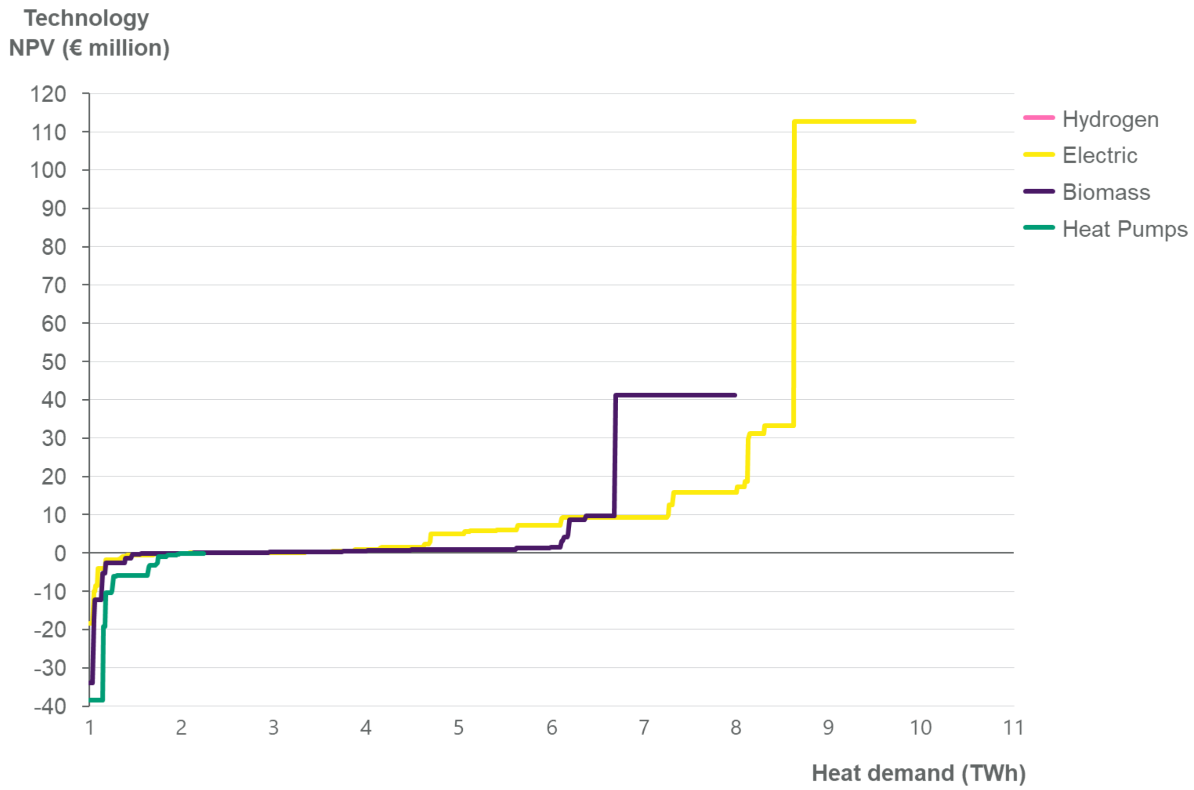


Figure 88 Net present value (NPV) of the economic potential for the take up of heating systems in industry, in 2050 under the baseline scenario, using the financial cost-benefit analysis



Economic Present Cost – baseline scenario

In the baseline scenario in the economic analysis, under competition the heat demand met by ASHPs in the residential sector is approximately equal in 2030 and 2050 (10.7 TWh). The main difference between these two cases

Figure 90 Economic present cost (€ thousands) of heating systems in the residential sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the baseline scenario. CF represents counterfactual heating systems.

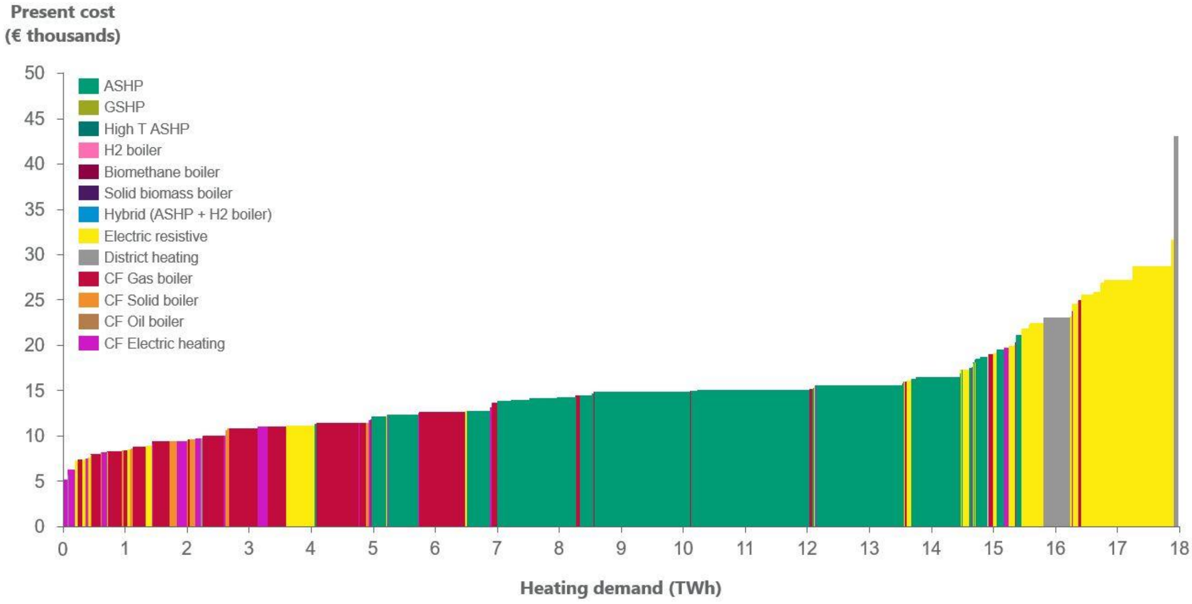


Figure 91 Economic present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the baseline scenario. CF represents counterfactual heating systems.

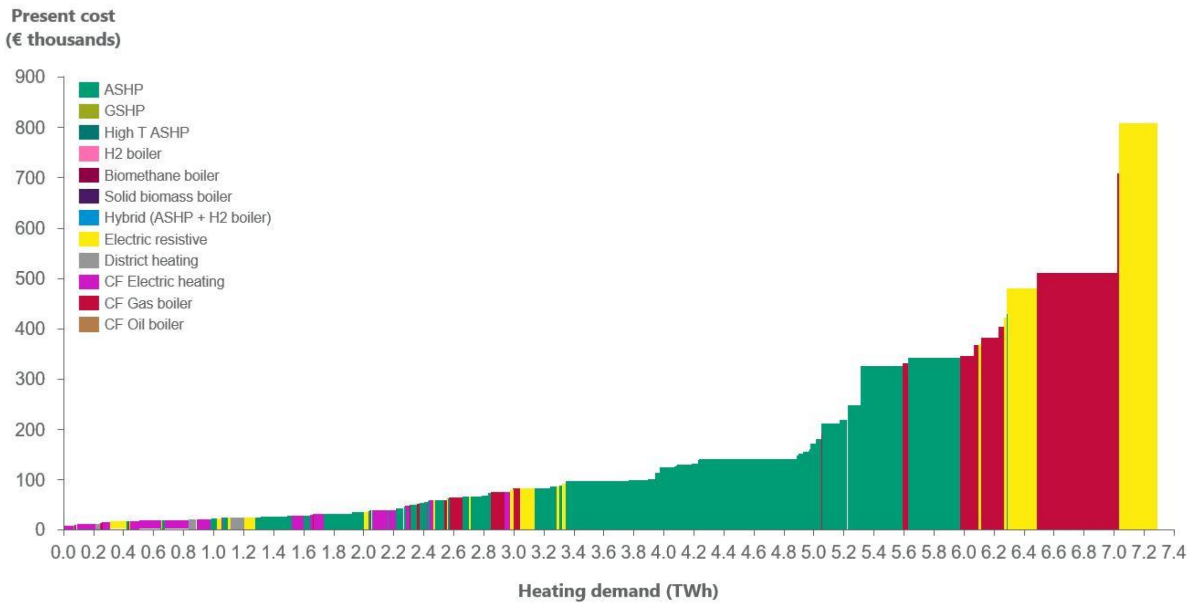


Figure 92 Economic present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the baseline scenario. CF represents counterfactual heating systems.

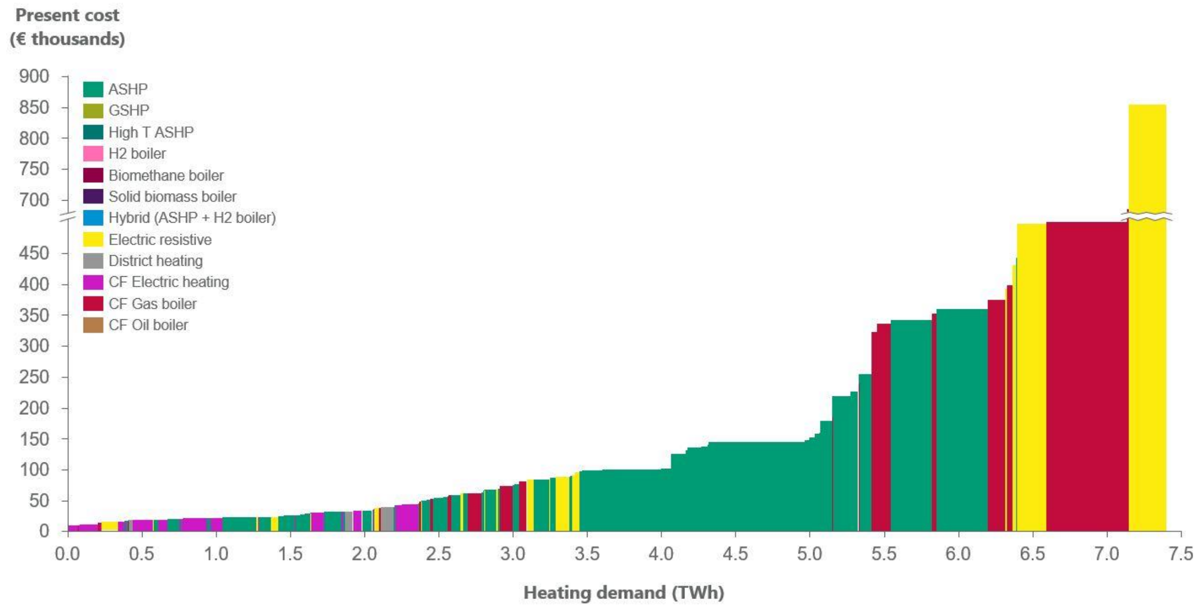


Figure 93 Economic present cost (€ million) of heating systems in industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the baseline scenario. CF represents counterfactual heating systems.

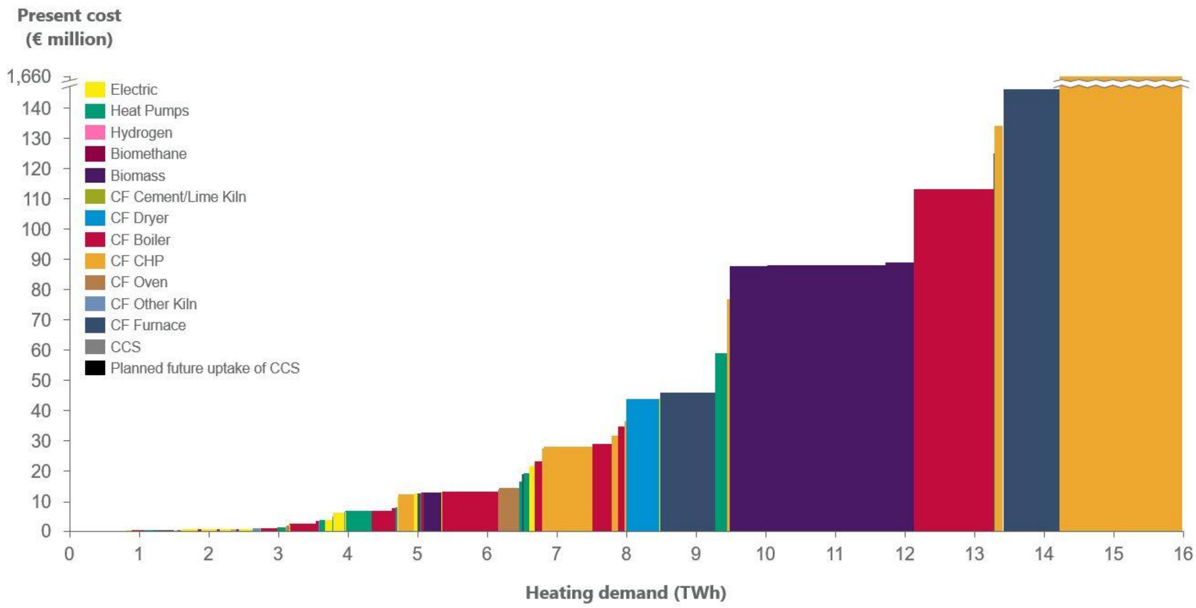


Figure 94 Economic present cost (€ million) of heating systems in industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the baseline scenario. CF represents counterfactual heating systems.

) is the total heating demand met by counterfactual heating systems, with 0.6 TWh less heating demand met by CF electric resistive in 2050 than 2030, and an increase by 0.6 TWh heating demand met by CF oil boiler in 2050 compared to 2030. This is due to the increasing projected electricity prices in later years.

For the services (commercial and public) sectors, there is lower economic potential under competition for heating demand to be met by ASHPs in 2050 than in 2030, with the difference made up by an increase in heating demand met by CF oil boilers. This is caused by the CF oil boiler heating systems comparing more favourably against ASHPs in terms of present cost in 2050 than 2030 for the same reason stated above.

In the industrial sector, there is little variation of economic potential under competition (in GWh) between 2030 and 2050.

Figure 89 Economic present cost (€ thousands) of heating systems in the residential sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the baseline scenario. CF represents counterfactual heating systems.

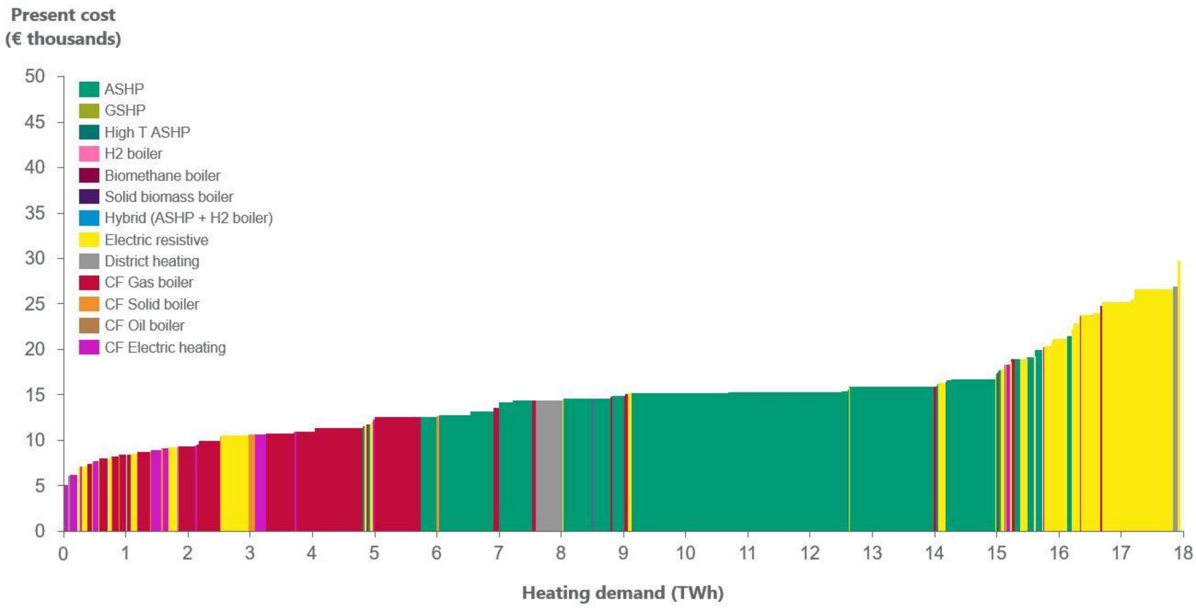


Figure 90 Economic present cost (€ thousands) of heating systems in the residential sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the baseline scenario. CF represents counterfactual heating systems.

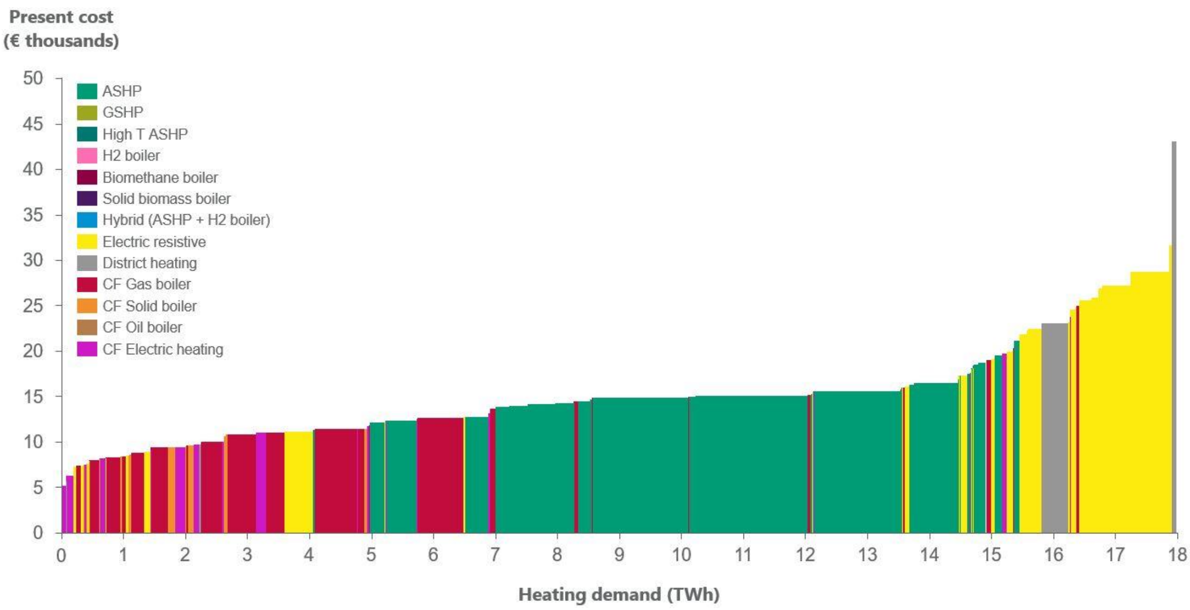


Figure 91 Economic present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the baseline scenario. CF represents counterfactual heating systems.

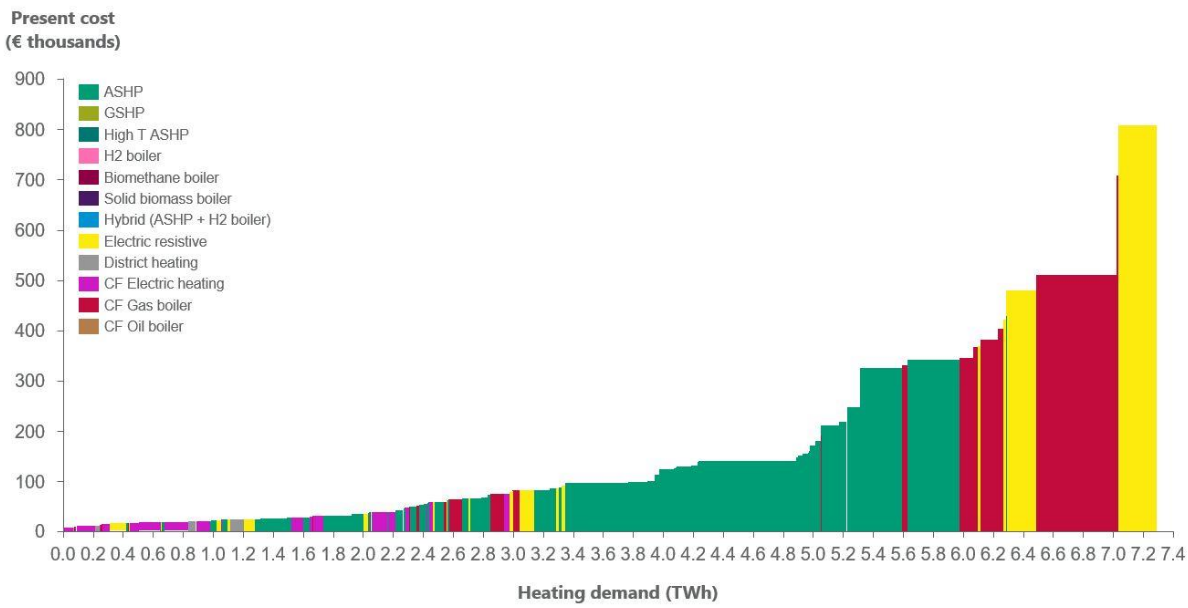


Figure 92 Economic present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the baseline scenario. CF represents counterfactual heating systems.

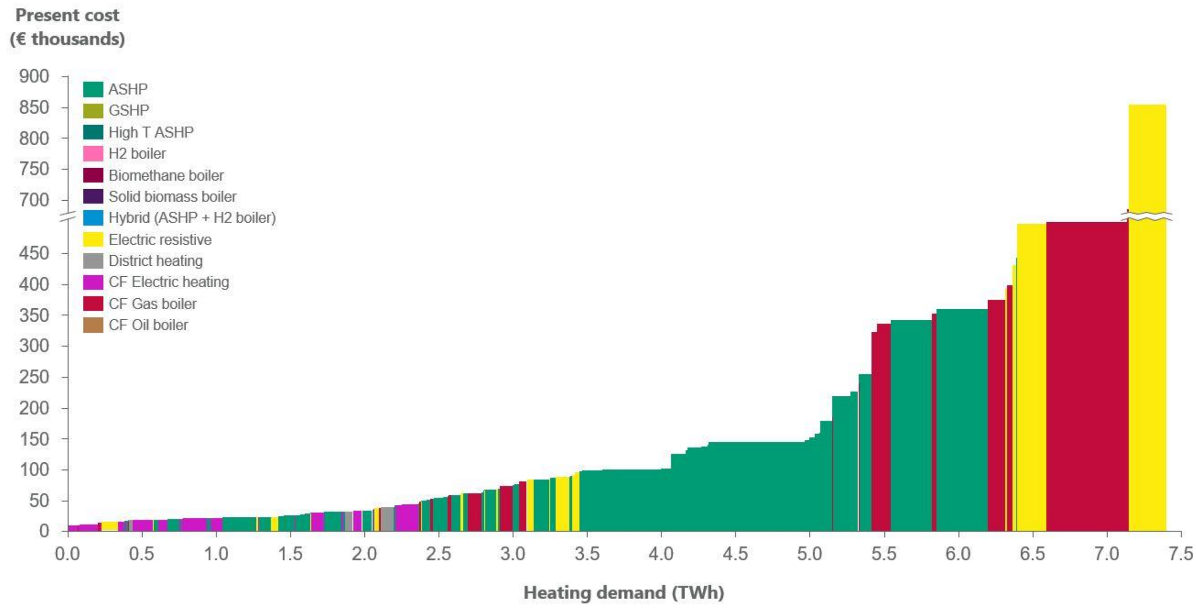


Figure 93 Economic present cost (€ million) of heating systems in industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the baseline scenario. CF represents counterfactual heating systems.

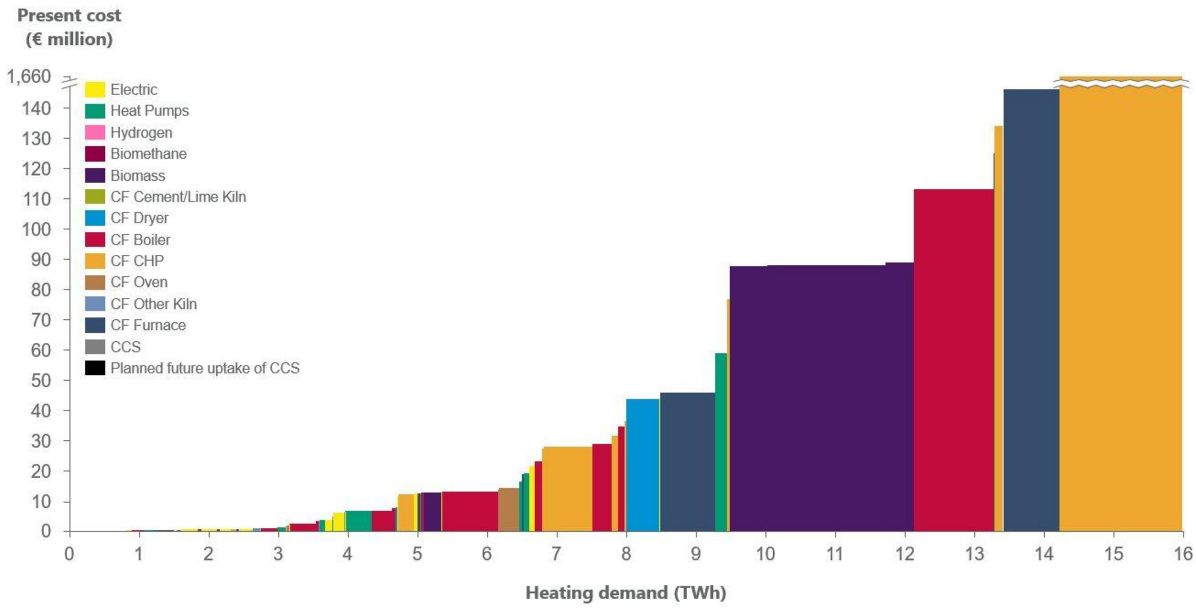
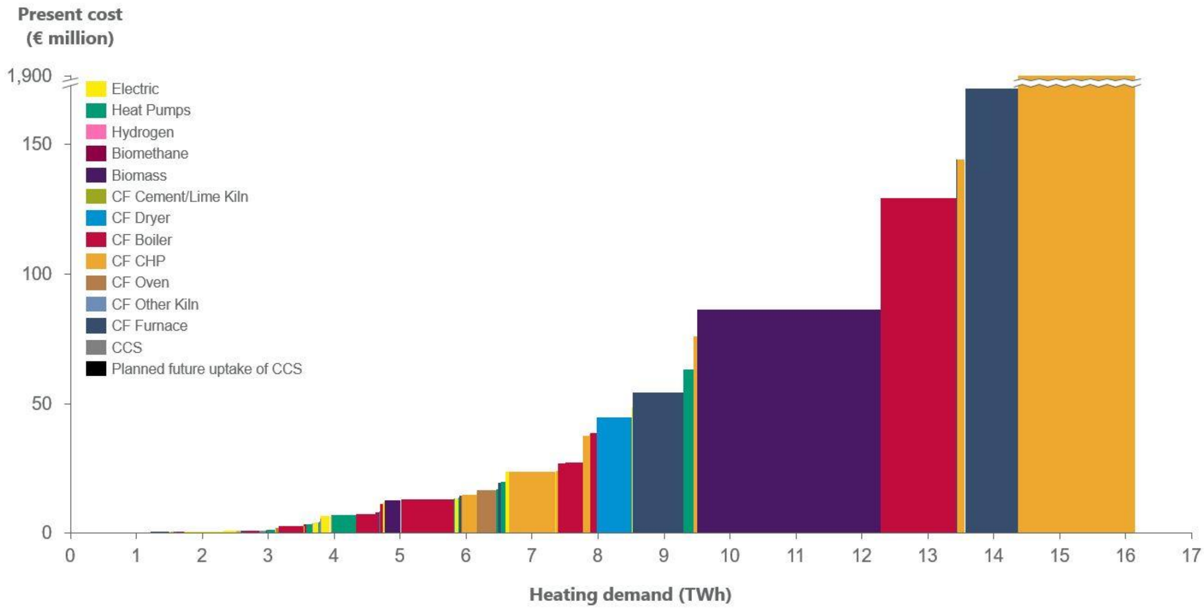


Figure 94 Economic present cost (€ million) of heating systems in industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the baseline scenario. CF represents counterfactual heating systems.



Financial Net Present Cost – baseline scenario

In the financial analysis in the baseline scenario, there is a significant increase in uptake of biomass burning technologies compared to the economic analysis. This is due to the higher discount rates used by sector in the financial analysis in addition to the lack of more significant emissions costing (as explained in Section 4.2 (Cost-benefit analysis (CBA)).

In the residential sector in the baseline scenario, 3.4 TWh of heating demand is met by solid biomass boilers under competition in both 2030 and 2050. There is an increase in heating demand met by ASHPs in residential from 7.7 TWh in 2030 to 8.9 TWh in 2050, which displaces heating demand in mainly CF gas boiler archetypes.

In the services (commercial and public) sectors, over half of the heating demand in the baseline scenario in the financial analysis is met by ASHPs under competition, in both 2030 and 2050 (57% and 59% respectively). There is little change in the split of heating demand met by each technology under competition between 2030 and 2050 in the baseline scenario.

In the industrial sector, the negative present cost column represent an archetype which use a fuel with negative cost (bio waste), and this negative fuel cost outweighs the positive costs (capex, opex etc). This negative bio waste fuel cost is calculated dynamically in the modelling, based on the cost and availability of various biogenic crops and products. 2.1 TWh of heating demand is met under competition by electric systems (both direct electric and heat pumps) in industry in the financial analysis, in both 2030 and 2050.

Figure 95 Financial present cost (€ thousands) of heating systems in the residential sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the baseline scenario. CF represents counterfactual heating systems.

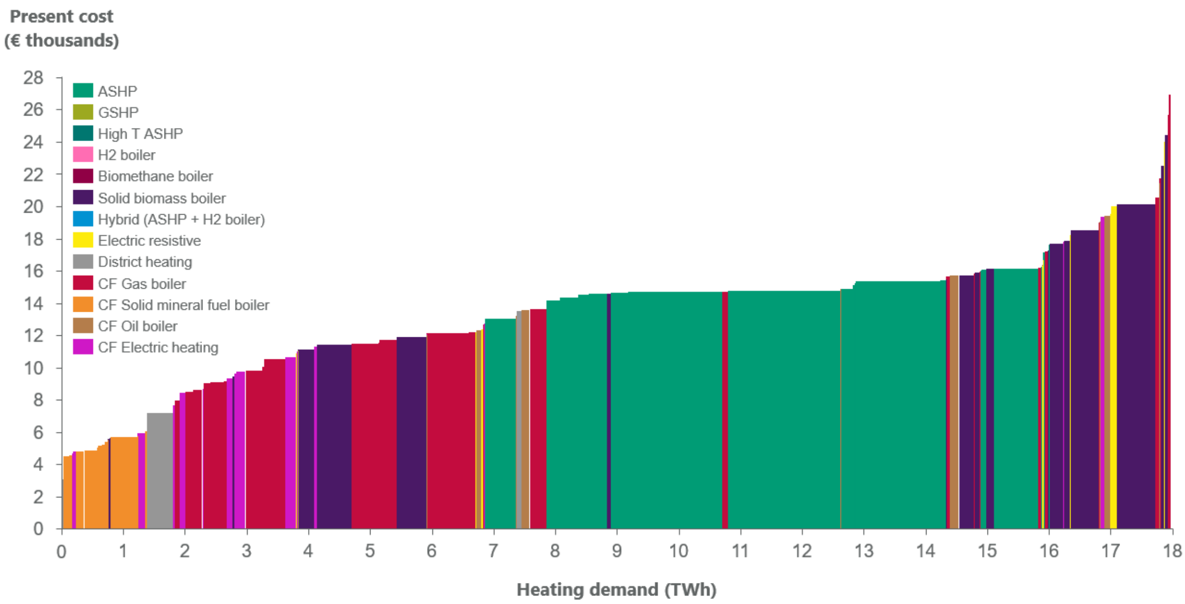


Figure 96 Financial present cost (€ thousands) of heating systems in the residential sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the baseline scenario. CF represents counterfactual heating systems.

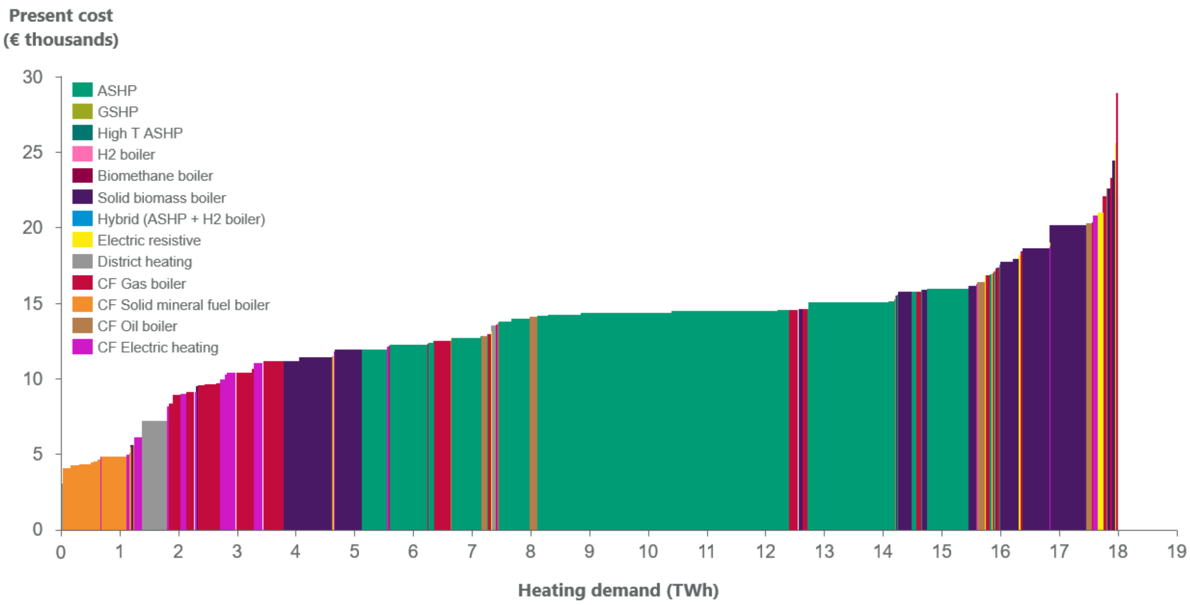


Figure 97 Financial present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the baseline scenario. CF represents counterfactual heating systems.

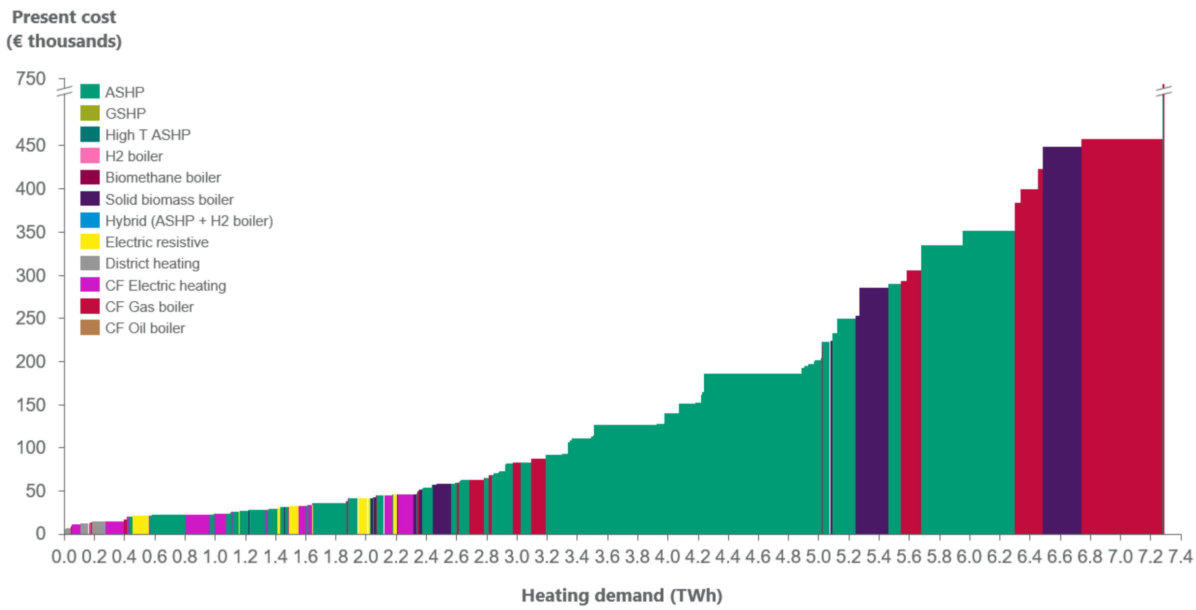


Figure 98 Financial present cost (€ thousands) of heating systems in the commercial and public sectors, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the baseline scenario. CF represents counterfactual heating systems.

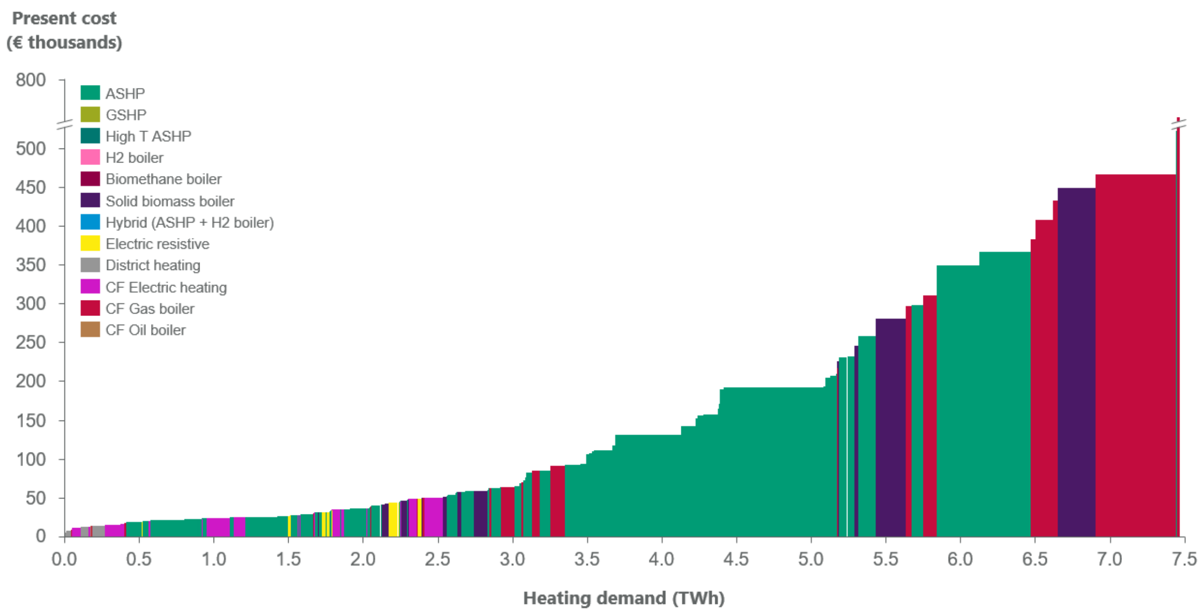


Figure 99 Financial present cost (€ thousands) of heating systems in the industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2030 in the baseline scenario. CF represents counterfactual heating systems.

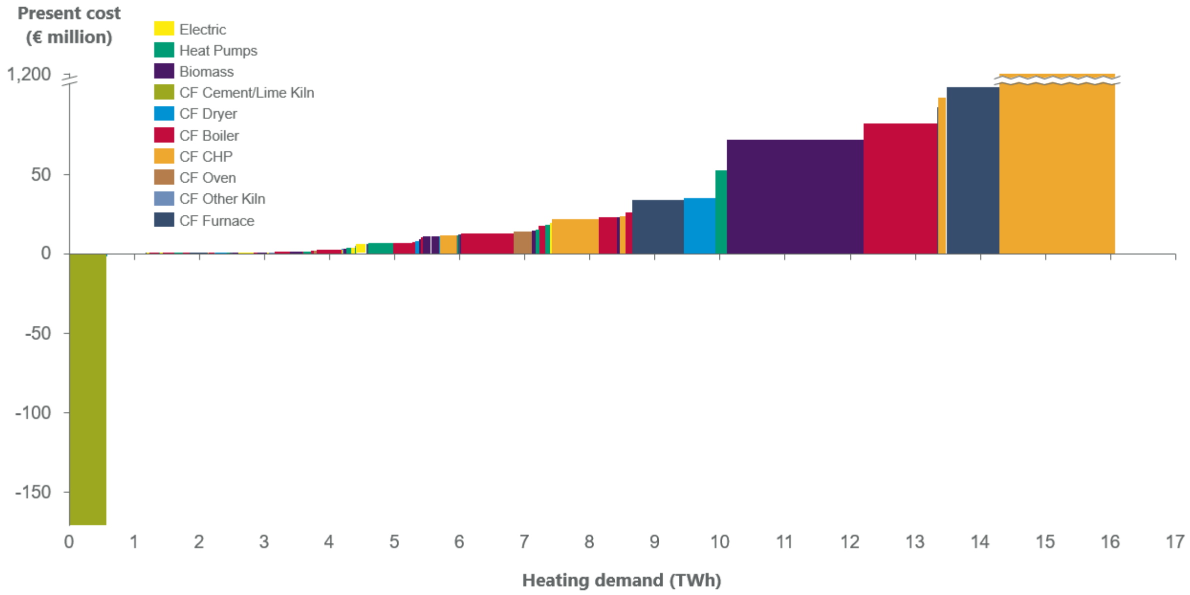
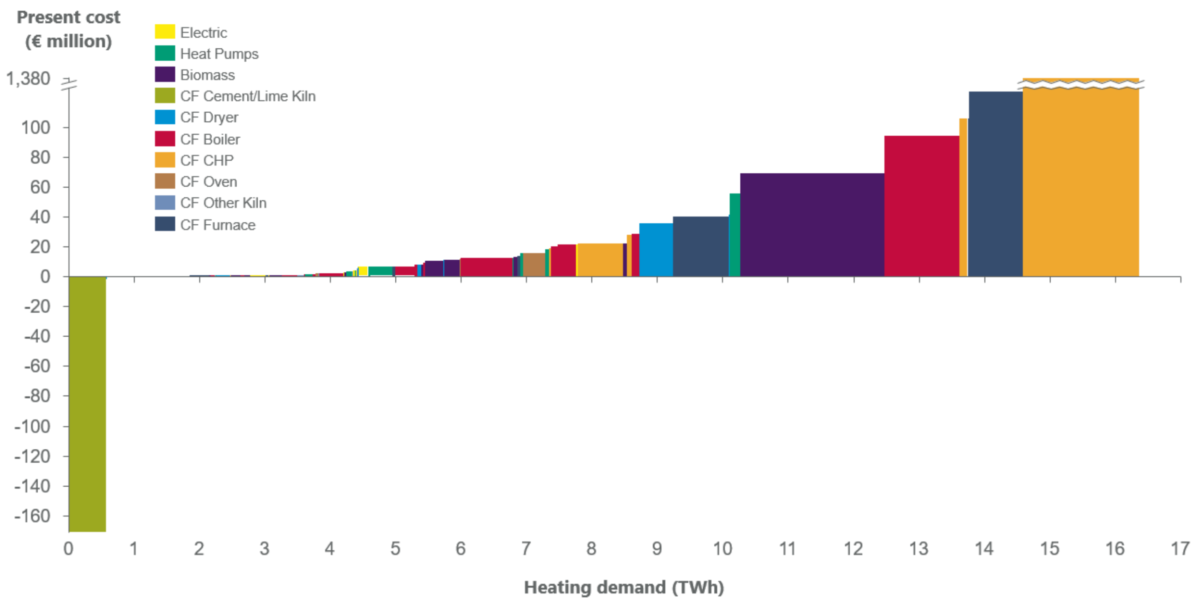


Figure 100 Financial present cost (€ thousands) of heating systems in the industrial sector, showing the share of total heating demand (useful energy) that can be met by each heating system at different present costs, in 2050 in the baseline scenario. CF represents counterfactual heating systems.



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