# EuroHeat

## Low-Carbon Heating Strategy Review of Selected European Countries

*June 2020*

iERC
International Energy Research Centre

Citation: IERC (2020), EuroHeat: Low-Carbon Heating Strategy Review of Selected European Countries, International Energy Research Centre, Ireland.

**About IERC**

The International Energy Research Centre (IERC) is a centre of international excellence in integrated energy systems research funded by Department of Communications, Climate Action and Environment, Government of Ireland and hosted at Tyndall National Institute, Cork, Ireland. IERC is a key element of the Government Energy Research Strategy and conducts sustainable energy research and examine the knowledge gaps through five different research lenses: Technology, Data Analytics, Behaviour, Business Models, and Policy & Regulation. www.ierc.ie

**About Ervia and Gas Networks Ireland**

Ervia is the commercial semi-state multi-utility company responsible for the delivery of Ireland's national gas and water infrastructure and services. Through Gas Networks Ireland, Ervia build and operate the gas networks to provide a secure supply of energy to homes and businesses and are also responsible for the operation and maintenance of Ireland's water and wastewater assets through our regulated business Irish Water. www.ervia.ie ; www.gasnetworks.ie

**Acknowledgements**

This report was authored by Piyush Verma, Senior Energy Policy Analyst with additional contributions and reviews from different team members at International Energy Research Centre. Valuable external review was provided by John Beirne, Philip Connolly, and Henry Smyth at Ervia. IERC would like to thank Ervia and Gas Networks Ireland for their support to carry out this project and acknowledge the Department of Communications, Climate Action and the Environment (DCCAE) for funding this project.

**Disclaimer**

# Contents

# 1. Executive summary and key recommendations

## 1.1 Executive Summary

Ireland has an ambitious vision to be a net zero carbon emissions economy by 2050. There has been significant progress recently in renewable based electricity generation but the heating sector, which has substantial potential to reduce the emissions, has relative to renewable electricity, received few policy instruments[1] to stimulate targeted impactful actions. There is a recognition that low-carbon energy can play a crucial role in decarbonising space heating and reducing emissions especially from the residential sector.

The aim of this report is to analyse the domestic heat sector policy and strategy of countries with a similar temperate climate to Ireland, such as Belgium, France, Netherlands and UK. This report provides policy recommendations to support the decarbonisation of the domestic heating in Ireland along with a comprehensive statistical analysis of similar-climate countries and their housing stocks. This report also looks at the key technologies and the implementation strategies of the countries' leading in domestic heating decarbonisation. Although energy efficiency improvement and deep retrofit will be of great importance, and has been recognised as a priority policy over any other approaches for heat decarbonisation in these countries, it has not been considered as part of this research.

All the countries have considered space heating an area that requires both short-term and long-term policy action. Stringent building regulations and their timely implementation is considered and prioritised for improving the energy efficiency performance of new buildings. A number of policy support actions in the form of incentives, taxation, and subsidies are available to assist the uptake of low carbon technologies as an immediate solution, especially for the new build properties. Providing more significant support for deeper retrofit of existing building stock is one of the key priorities in all these countries. These selected similar-climate countries have also started exploring the potential resources and possibility of developing low carbon heat network infrastructures. These countries have set up a range of investment grant programmes and mechanisms to attract additional institutional and private investment. Governments are already exploring the ways to provide more significant support for heat pumps, micro-CHPs, developing district heating networks, and researching the possibility of incorporating biogas and hydrogen in the existing gas grid.

Key strategies being considered include: local authority engagement; consumer awareness and information campaigns; planning to ban fossil-fuel based boilers; building trust on new technologies through certification schemes; installer and developer training, and creating an enabling environment that is conducive to attracting investments. Longer term strategies are in development to demonstrate policy stability and to attract investors, especially for the deployment of low carbon heat network infrastructures. These countries are also developing technical regulations and standards for these technologies that take account of the local context.

[1] The Support Scheme for Renewable Heat is a significant policy instrument but open to commercial, industrial, agricultural, district heating, public sector and other non-domestic heat users.

## 1.2 Key statistics and findings

- The larger dwelling size and penetration of central heating has been the key driver for the variation in heating consumption per dwelling in the EU during the years 2000-2015.
- In four EU Member States, more than half of the total energy used for heating and cooling came from renewable energy sources in 2017: Sweden (69.1 %), Finland (54.8 %), Latvia (54.6 %) and Estonia (51.6 %). In contrast, the lowest shares were in the Netherlands (5.9 %), Ireland (6.9 %) and the United Kingdom (7.5 %).
- The EU Renewable Energy Directive states a requirement to increase share of renewables in heating and cooling by one percentage point annually. Further, the EU Energy Efficiency Directive also states requiring the measurement of heat use at a building unit level for buildings with a central source of heat or hot water.
- Comparing to the selected countries, Ireland has seen the highest decline in energy consumption per dwelling with more than 38% during the period 2006-2016. Ireland has also reported the largest decline in terms of energy consumption per $m^2$ of space heating during the period 2006-2012.
- France has the highest share of renewable energy with 10.6% (Ireland and UK have 10.4% and 9.8% respectively) in gross inland consumption whereas, in terms of share of renewable energy in the electricity generation, Ireland and UK are leading with 30.1% and 28.1% respectively, which is dominated by wind.
- Ireland has approximately 3% higher share of population who are at the risk of energy poverty compared to the EU28 countries. However, energy poverty risk seems to be improving in recent years in Ireland unlike the Netherlands, which has lowest share of population at the risk of energy poverty but has shown an increasing percentage over the years.
- On average, Ireland has a lower proportion of inhabitants struggling to keep their home warm as compared to EU28 average in any year. However, Ireland has a significantly higher proportional of people struggling to keep their home warm as compared to Netherlands, France and Belgium.
- In 2014, all new construction in France were nearly zero energy buildings (NZEB). According to Ireland's Central Statistics Office, 23% of homes constructed in 2010-2014 were given 'A' BER rating but there was no data available on NZEB.
- With the exception of Ireland, where oil is the main source for heating, natural gas is the dominant fuel for heating purposes. Ireland is the only country where coal meets a significant proportion of the heating demand, 19% in 2015. According to 2016 census, around 13% of Irish residential buildings used solid fuel for central heating.
- In terms of absolute numbers, France's heat demand for space heating is around 325 TWh per annum whereas, Ireland has the lowest with 22.3 TWh per annum.
- Ireland consumes 15,548 kWh/dwelling, which is the second highest among the selected countries. On the other hand, Ireland has the lowest energy demand among these countries when compared against the floor area, which was primarily driven by the increasing number of dwellings; up by 39% between 2000 and 2016, together with the increase in average floor area per dwelling.
- In 2016, the average dwelling was 21% larger than in 1990, and 15% larger than in 2000. Comparing Ireland and UK, the number of new dwellings have significantly increased in Ireland since 1990 which are more energy efficient, and that is reflecting in terms of reduced consumption

per $m^2$ of floor area. Also, Ireland has significantly more detached houses as compared to UK and therefore, it has significantly higher energy consumption per dwelling.

- The availability of hydropower, natural gas or oil reserves have a very important impact on heat policies of these selected countries.
- In Netherlands, as of 1 July 2018, there is no longer a requirement for newly built housing to have a gas connection. To achieve the low carbon heating vision, 170,000 houses would need to disconnected from gas grid every year. In order to achieve the long-term climate targets, the Netherlands Environmental Assessment Agency expects that 20-30% of homes should be connected to district heating by 2050.
- Belgium's aim is to raise the energy performance of residential buildings to the level of 100 kWh/$m^2$ by 2050. Public buildings and offices will be required to become energy neutral by 2040 and 2050 respectively. Brussels Government will examine the issue of mains gas and consider the possibility of a ban on the installation of cooking, heating and domestic hot water appliances that use natural gas or butane/propane from 2030.
- In France, local authorities have been made responsible for the public distribution of heating and cooling. Local authorities are entitled to classify the heating network type in their area and identifying zones in which any new installation must be connected to the grid, providing that at least 50% of the grid supply comes from renewable energy sources.
- UK has developed a community heat network toolkit to support community-led heat network projects and are currently investing significantly to overcome the barriers in leveraging private and other investments to support the design and construction of heat network.

**Key census data:**

- Ireland had 27% population increase between 1998-2018 whereas, Belgium, France, The Netherlands and UK had 11%, 11%, 9% and 13% respectively.
- Ireland has the lowest population density among selected countries, which is approximately half of the EU average population density. Ireland contributes only 1.8% to EU GDP whereas, France and UK each make around 15% contributions.
- Ireland's houses have consistently higher number of occupants as compared to other similar climate-countries. In 2018, Ireland has on average 2.6 persons per household, which is 20% higher than France and Netherlands, and 16% higher than Belgium and UK.
- France has the highest share of apartments with 33.1%, whereas only 8.3% of the population live in apartments in Ireland. In fact, Ireland has the lowest share of apartment dwellers in the EU. Ireland has the second highest share of detached houses among these countries.
- The UK had the highest proportion of people living in cities (59%), whereas Belgium had the lowest share at only 27%. Among the smaller countries of the group, Ireland has the largest rural population at 31%, with another 22% living in potentially low-density towns and suburbs.
- Ireland had significantly more dwellings built in the last 2-3 decades as compared to other similar-climate countries. According to 2016 census records, 9% of all private housing in Ireland are from the construction era prior to 1919 and 7% are dated between 1919-1945. However, comparing with other selected countries, the share of older dwellings (built before 1945 or during the period of 1945-1969) were significantly lower in Ireland.

## 1.3 Key policy recommendations

- **Distinct heat strategies, specific actions and timelines:** Ireland has a very low level of renewable heat deployment and therefore, clear short-term and long-term implementation strategies and drilling-down to detailed actions with timelines need to be developed. This detailed domestic heating decarbonisation action plan and timeline will accompany our National Energy & Climate Plan 2021-2030[2] and recently released Climate Action Plan 2019[3] to further boost confidence and provide direction to the key market players. A range of technological options need to be regularly assessed for the future considerations.
- **Localisation of heating strategies:** The role of local authorities will be crucial in achieving the national heating energy targets. As recommended in the Joint Oireachtas Report on Climate Action[4] and by the European Commission in the EU Strategy on Heating & Cooling[5], city or municipal level targets and strategies for domestic heating should be developed. The local statistics for heating consumption, type of heating, type of housing, resource availability, utilisation of waste heat and other important parameters require detailed examination. Local government has a wider role for effective dissemination and consumer awareness, and for acting as a local exemplar for sustainable energy and low carbon heating practices.
- **Local authorities' role in facilitating district heating:** Considering the variation in population density, degree of urbanisation and types of houses in Ireland, district heating could be an option in urban environments, however it is possibly unlikely to be economically feasible for many lower density housing applications. The role of Local authorities is important in assessing the current resources, analysing the future heating potential, bringing on and encouraging key stakeholders, and developing heat network infrastructure in consultation with the energy provider, pipe operator and the gas network operator. These focused activities are suggested as key actions in the EU district heating study[6], 'Efficient district heating and cooling systems in the EU', and in 'the guide for district heating in Ireland' published by SEAI. The Dublin Energy Agency - Codema's partnership with South Dublin County Council to develop the Tallaght District Heating Scheme[7] for providing low carbon heat in the Tallaght area funded by the Irish Government's Climate Action Fund is already a leading example of a best practice initiative that is for consideration by other local authorities and energy agencies. Ireland's local authorities need to be adequately resourced to take on such role and therefore, a supportive framework need to be developed to help achieve our national objectives.
- **District heating solutions:** Ireland has the lowest level of household gas connectivity among the countries compared, which provides an opportunity to explore decentralised heating solutions. Decentralised district heating solutions can help improve distribution losses, and encourage local business opportunities through engaging facilities management companies or energy service companies locally. This will also significantly help in reducing or spreading the cost of transmission and distribution pipelines and possibly improving the rate of return on investments on district

---

[2] https://www.dccae.gov.ie/en-ie/energy/consultations/Pages/Ireland%E2%80%99s-Draft-National-Energy-and-Climate-Plan-2021-2030.aspx

[3] https://www.dccae.gov.ie/en-ie/climate-action/topics/climate-action-plan/Pages/climate-action.aspx

[4] Report of the Joint Oireachtas Committee on Climate Action:https://data.oireachtas.ie/ie/oireachtas/committee/dail/32/joint_committee_on_climate_action/reports/2019/2019-03-28_report-climate-change-a-cross-party-consensus-for-action_en.pdf

[5] https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf

[6] https://publications.europa.eu/en/publication-detail/-/publication/f428333d-dede-11e6-ad7c-01aa75ed71a1/language-en

[7] https://www.codema.ie/projects/local-projects/tallaght-district-heating-scheme/

heating networks. According to a 2018 report by the Department for Business, Energy and Industrial Strategy (BEIS) for the UK government[8], the rate of Return on Investment (ROI) was the most important parameter for local authorities. Local authorities in UK have reported being prepared to accept ROIs in the range 4-10% for such projects.

- **Focus on sector coupling:** With the increasing renewable mix in the electricity generation and its future potential, renewable heat technology needs strong support through financial as well as non-financial measures for faster uptake, especially with a special focus on sector coupling[9]. Cross-sectorial cooperation could optimise efforts to decarbonise the economy and technologies such as heat pumps, micro-CHPs, district heating, biomass, hydrogen and solar thermal for heating sector[10]. Developing innovative and effective policy support for these technologies will be key to achieving the decarbonisation in the domestic heating sector as well as other sectors such as buildings, industry etc.
- **Exploring innovative options for decarbonising existing gas grid:** Significant research, development and demonstration (RD&D) investment is required to support early stage research and expedite pilots and live project reference sites for the use of biogas and hydrogen in the gas network. This also recently came out as strong recommendation by IEA Country Review[11]. The recently funded project for developing the installation of central grid injection facility for renewable gas[12] through the Climate Action Fund is a good example. Related technical, economic and regulatory barriers also need to be addressed. Accompanying SEAI's report on the assessment of bioenergy supply in Ireland 2015-2035[13], a further study to compare Ireland's biomass resources, and relevant strategies and policies with those of France, would benefit the larger policy informing activity.
- **Addressing energy poverty:** Government's Better Energy Warmer Homes Scheme is already prioritising delivery of energy efficiency measures to households that are vulnerable to energy poverty[14]. But, Ireland still has the highest energy poverty among the selected similar-climate countries that need to be addressed and also, we need to ensure that low carbon technology deployment do not disproportionately affect these low income households. A key issue here is to ensure demand reduction to offset any increase ascribed to technology cost. Thermally inefficient homes (especially the home owners living with energy poverty) need to be prioritised for energy efficiency improvement and low-carbon heat solutions need to be explored and supported through providing considerable financial incentives and focused policy actions.
- **Adopting technology neutral approach:** Technology neutral approaches need to be considered until there is significant empirical evidence gathered on the specific technology potential, its costs, resource potential, abatement potential, impact, and scale. Grants, subsidies, and tax incentives have significantly helped countries in the uptake of various low carbon heating technologies.

---

[8] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/699301/Wave_2_Evaluation_of_the_Heat_Networks_Development_Unit_-_FINAL_VERSION.pdf

[9] Sector coupling refers to the idea of interconnecting (integrating) the energy consuming sectors - buildings (heating and cooling), transport, and industry - with the power producing sector.

[10] https://www.cleanenergywire.org/factsheets/sector-coupling-shaping-integrated-renewable-power-system

[11] Energy Policies of IEA Countries: Ireland 2019 review, https://webstore.iea.org/energy-policies-of-iea-countries-ireland-2019-review

[12] https://merrionstreet.ie/en/News-Room/News/Government_Announces_First_Successful_projects_under_Round_One_of_%E2%82%AC500_million_Climate_Action_Fund.html

[13] https://www.seai.ie/resources/publications/Bioenergy-Supply-in-Ireland-2015-2035-Summary-Report.pdf

[14] https://www.gov.ie/en/service/better-energy-warmer-homes-scheme/

While carbon taxes have shown to be helpful in many instances, the revenue collected from carbon taxes has not / is not often dedicated to low carbon actions, as it is economically inefficient. The recommendation is that part of this revenue can be used to offset the new burdens that a carbon tax places on consumers and communities and to help assist the low-carbon transition at local levels.

- **Sequence, coordination, combination and stability of policies:** The sequence, coordination, combination and stability of policies has helped several countries in improving the effectiveness of the policies. Stability of policies can considerably promote industry, as well as, consumer confidence. In case of district heating, it can also significantly boost local authorities' confidence and create a competitive environment for financial institutions to innovate and fund district heating projects. Governments' close coordination with technology associations, consumer associations, and other community partnerships such as with trades associations, manufacturers, and energy suppliers have significantly helped the countries that are leading the deployment of low-carbon heating technologies.
- **Skill building for low-carbon heating technologies:** The Irish skills base for the installation and maintenance of new low-carbon heating technologies and for deep retrofits of buildings need to be significantly enhanced through a range of measures such as certifications, training, workshops, etc. A shortage of skills in the supply chain can lead to poor specification, installations and maintenance of these technologies. Quality assurance and certification schemes through independent and third party agencies will help build consumer trust on new technologies.
- **Consumer awareness and engagement:** Consumer engagement and technology awareness will also be very important for the uptake of low-carbon heating technologies. Marketing, promotion and information campaigns through a range of channels and through a range of actors such as government, utilities, manufactures, installers, and industry associations need to be considered. Organising local community events for information dissemination has also been very helpful in leading EU countries.
- **Leveraging digitalising potential:** Digitalisation can provide an opportunity to increase the share of renewables to balance heating & cooling demand and significantly reduce the cost of decarbonisation by optimising operations, automating planning and business models decision trees, and by connecting producers of heat, users, local stakeholders and energy markets[15]. There is a major lack of awareness of the benefits of digitalising heating systems and how the emerging technologies such as Internet-of-Things, Blockchain, and Artificial Intelligence can help achieve decarbonisation goals, especially through remote controlled operation and behaviour based optimisation. The key recommendation is to leverage digital opportunities for the decarbonisation of heating within a supportive regulatory and policy framework.
- **Energy Efficiency policy integration:** Although this is not in the scope of this report, integrated policy approaches to technology adoption alongside improving energy efficiency will be key to decarbonising the heating sector. While integrated approaches are common in building design practices, there is significant scope to improve on this for heating applications. There is a need for more stringent energy efficiency regulations and a strengthening of building energy ratings for the use of innovative ICTs (Information and communication technologies), automation and sensor technologies.

[15] http://publications.jrc.ec.europa.eu/repository/bitstream/JRC116074/kjna29702enn.pdf

# 2. Introduction to heating sector

## 2.1 Introduction

European countries are very different in terms of geography, climatic conditions, energy mix, environmental policies, efficiency of the housing stock, industry intensity, and research and development resources. In terms of weather and climate, regional variation is an important driver of the magnitude and type of thermal-related energy consumption:  temperature patterns strongly influence the amount of heating or cooling demand in buildings and businesses. Further, this variation in heating and cooling demand strongly influences the local demand for fuels (or other energy vectors) to meet these service requirements. The price of the energy commodities can be affected e.g. natural gas or heating oil prices can be noticeably higher in severe winters.  Therefore, to understand the energy requirement for the heating and/or cooling demand in a specific country, it is important to understand the weather and temperature related data. Any country's heating/cooling energy policies and strategies are strongly influenced by the energy consumption patterns, which are determined by local weather conditions. Temperature corrected energy consumption data provides a perspective for real energy consumption trends and further contributes to the design and measurement of policy goals.

There are many other contributory factors to heating demand, such as the energy performance of the building envelope, the type of heating system available, occupant behaviour and energy prices. However, the external temperature is the only component, which can also be affected by climate change. Key drivers for the variation in heating consumption per dwelling in the EU during the years 2000-2015 is shown in Fig 2.1 below[16] where larger dwellings and penetration of central heating (mainly in the south of Europe) have offset around 1/3 of energy efficiency gains at the EU level.

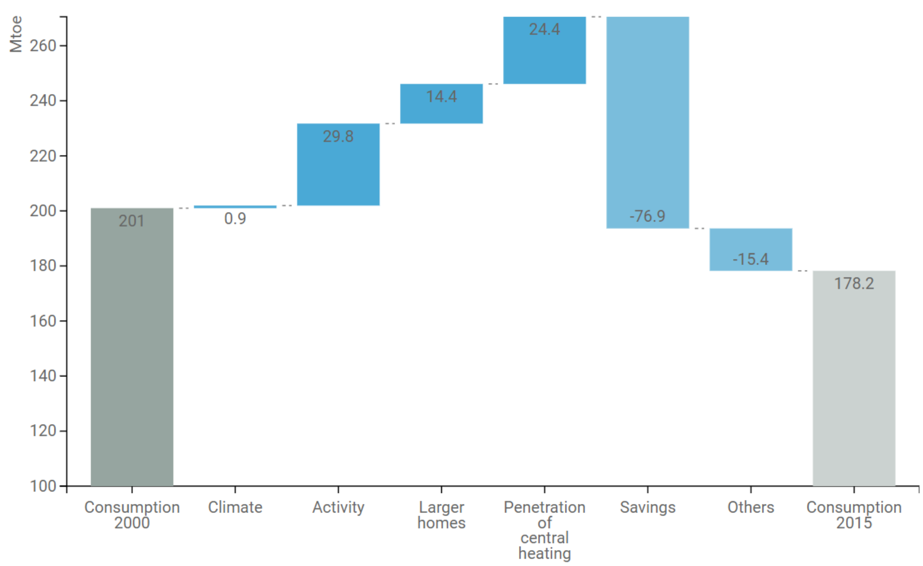



Fig 2.1 Drivers of the variation in heating consumption per dwelling in EU (Source: Odyssee-Mure Database)

[16] http://www.odyssee-mure.eu/publications/efficiency-by-sector/households/drivers-heating-consumption-dwelling-europe.html

## 2.2 EU Heating and Cooling Strategy

The European Union has a 2030 Framework for Climate and Energy to help the EU achieve a more comptetitive, secure and sustainable energy system. This framework provides the EU-wide energy targets and the policy objectives for the period 2020 to 2030. The energy efficiency and renewable energy related targets for 2030 are[17] [18]:

- a 40% cut in greenhouse gas emissions compared to 1990 levels
- at least a 32% share of renewable energy consumption
- indicative target for an improvement in energy efficiency at EU level of at least 32.5%

The EU also has a long-term goal of reducing GHG emissions by 80-95%, when compared to 1990 levels, by 2050[19]. The Energy Roadmap 2050[20] provides the guidelines for the low-carbon energy transition, providing compatibility with the GHG reduction target, while also increasing competitiveness and security of supply.

Heating and cooling in buildings and industry accounts for 50% of EU's annual energy consumption, and 75% of heating and cooling in the EU is met by fossil fuels. Natural gas is the largest primary energy source for heating and cooling (46%), followed by coal (about 15%), biomass (about 11%), fuel oil (10%), nuclear energy (7%) and some renewable energy sources (wind, PV and hydro, about 5%). Other renewables, such as solar (thermal) energy, ambient heat and geothermal energy, account for 1.5% altogether and other fossil fuels for 4%[21]. In 2017, renewable energy accounted for 19.5 % of the total energy used for heating and cooling in the European Union. In four EU Member States, more than half of the total energy used for heating and cooling came from renewable energy sources in 2017: Sweden (69.1 %), Finland (54.8 %), Latvia (54.6 %) and Estonia (51.6 %). In contrast, the lowest shares were in the Netherlands (5.9 %), Ireland (6.9 %) and the United Kingdom (7.5 %)[22]. According to the EU, currently the amount of waste heat produced from industrial processes would meet the entire heating needs in residential and tertiary buildings (EU wide)[23] [24].

In 2016, the EU proposed the heating and cooling strategy, which the EU Parliament adopted in September 2016. A timeline for the three key activities in 2016 is shown in Fig. 2.2.

The EU Strategy on Heating and Cooling has given specific focus to the following four areas:

- Energy-efficiency first principle and demand response programmes – deep renovation of buildings and making it easier to renovate
- Increasing the share of renewables through combined heat and power, co-generation and district heating and cooling

[17] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy
[18] https://ec.europa.eu/clima/policies/strategies/2030_en
[19] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-energy-strategy
[20] https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf
[21] https://setis.ec.europa.eu/setis-reports/setis-magazine/low-carbon-heating-cooling/eu-strategy-heating-and-cooling
[22] https://ec.europa.eu/info/news/energy-heating-cooling-renewable-sources-2019-mar-04_en
[23] http://europa.eu/rapid/press-release_MEMO-16-311_en.htm#_ftn1
[24] Fraunhofer et al. (2015 - ongoing), "Study on Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)", ENER/C2/2014-641

- Reuse of waste energy from industry - recovering all the waste energy and utilising it for heating/cooling purposes
- Getting consumers and industries involved – providing better information and empowering them to control their own energy use

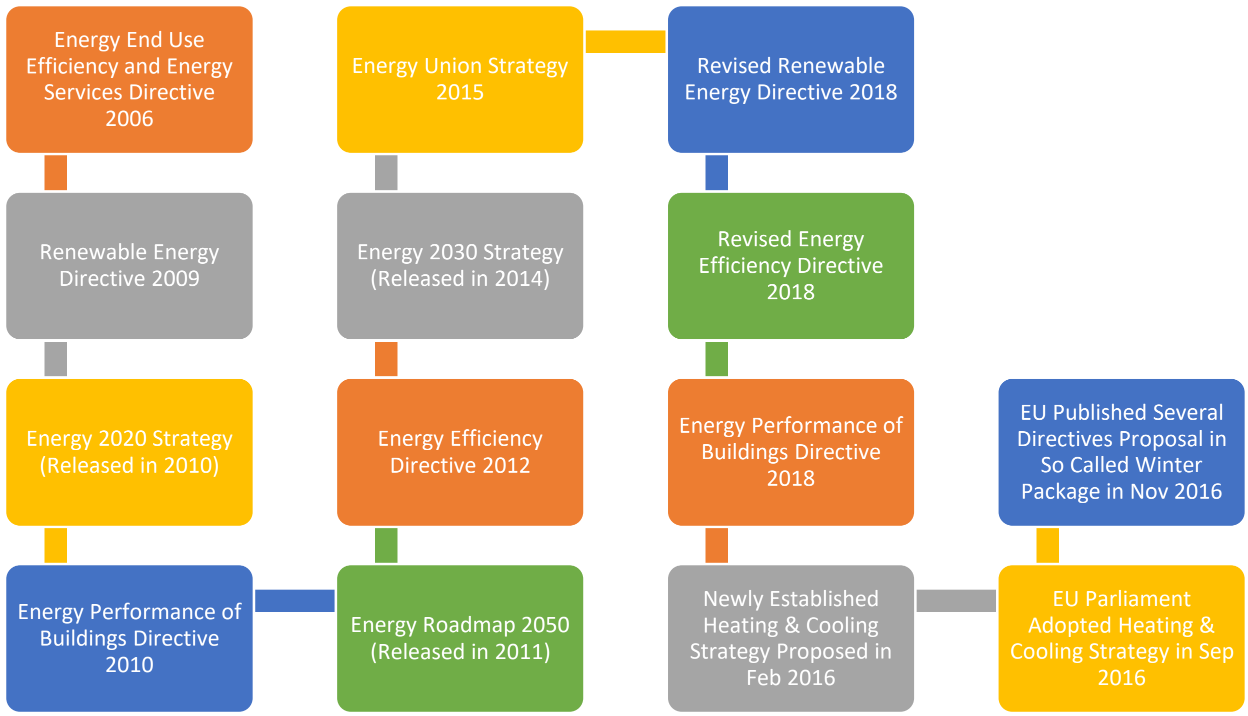



Fig 2.2 Timelines for key directives and strategies pertinent to heating & cooling (2006-2016)[25]

The main regulation concerning heating and cooling has been proposed in the EU Renewable Energy Directive[26] and the Energy Efficiency Directive[27]. The Renewable Energy Directive has made a proposal to increase share of renewables in heating and cooling by one percentage point annually and has clearly highlighted the importance of integrating electricity into the heating/cooling system. The Energy Efficiency Directive has made a proposal requiring the measurement of heat use at a building unit level for buildings with a central source of heat or hot water, as this will be important for the district heating sector[28].

## 2.3 Selection of specific countries

This study compares the Netherlands, France, Belgium and UK with Ireland in terms of policies and initiatives to decarbonise the domestic heating sector. We have chosen these countries due to their similar temperate climates, and with the expectation that the housing stock will have similarities in terms of the insulation levels and age of construction. Average annual temperature for the capital cities of these

[25] https://setis.ec.europa.eu/setis-reports/setis-magazine/low-carbon-heating-cooling/eu-strategy-heating-and-cooling
[26] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN
[27] https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive
[28] https://norden.diva-portal.org/smash/get/diva2:1098961/FULLTEXT01.pdf, last accessed 11/05/2019

countries[29] are shown in Table 2.1 which reflects a moderate temperature in all these countries. The heating degree days (HDD) and cooling degree days (CDD)[30] are a measure of both severity and duration of temperature conditions in a location. Average HDD and CDD for each of these countries for last two years are also shown in the Table 2.2[31].

Table 2.1: Average temperature of capital cities

| Country | City | Degree C |
|---|---|---|
| Belgium | Brussels | 10.5 |
| France | Paris | 12.3 |
| Ireland | Dublin | 9.8 |
| Netherlands | Amsterdam | 10.2 |
| UK | London | 10.3 |

Table 2.2: Average national HDD and CDD

| Country | 2017 | | 2018 | |
|---|---|---|---|---|
| | CDD | HDD | CDD | HDD |
| Belgium | 17 | 2580 | 33 | 2514 |
| France | 66 | 2338 | 65 | 2184 |
| Ireland | 0 | 2670 | 0 | 2756 |
| Netherlands | 6 | 2544 | 31 | 2527 |
| UK | 0.22 | 2865 | 1 | 2936 |

Space heating is responsible for a large component of the building energy use in these countries[32], so a decrease in the use of space heating has the potential to lead to a significant decrease in overall energy consumption of the building. The number of HDD can be considered a proxy for space heating energy demand, and hence an indicator for the overall thermal energy use. As we can see the HDD data were of approximately same magnitude in all these countries and possibly, it could be an indication for the similar level of heating requirements. The HDD difference between Ireland and Belgium or Netherlands is somewhere around 9%, which is reasonable for comparison of space heating demand. Accordingly, we can assume that similar strategies and policies need to be adapted for these countries.

Climate corrected data for consumption per dwelling and the consumption per m$^2$ for space heating is shown in Fig. 2.3 and 2.4 respectively. There was no data available for Belgium for the energy consumption per m$^2$ for space heating. In the case of energy consumption per dwelling, Belgium has been the highest energy consuming country for space heating in last 10 years. The other notable point is that Ireland has seen the highest decline in energy consumption per dwelling as shown in Fig. 2.3 (>38% for the period 2006 to 2016). Ireland has also shown a declining trend in terms of energy consumption per m$^2$ of space heating as compared to three of the other countries and the largest decline occurred during the period

[29] https://en.wikipedia.org/wiki/List_of_European_cities_by_temperature

[30] HDD index is a weather-based technical index designed to describe the need for the heating energy requirements of buildings. CDD index is a weather-based technical index designed to describe the need for the cooling (air-conditioning) requirements of buildings.

[31] https://ec.europa.eu/eurostat/web/energy/data/database

[32] Heating and cooling energy demand has been discussed under section 4.1.

2006-2012. Ireland also had a deep recession at this time and oil prices spiked. Dependence on oil and a reduction in incomes during this recession played a significant role in this decline.

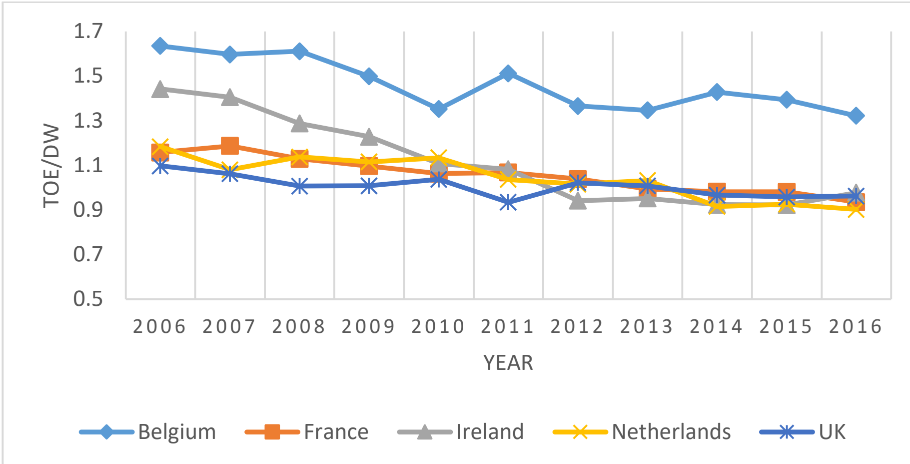



Fig 2.3. Unit consumption per dwelling for space heating with climatic correction (toe/dw)

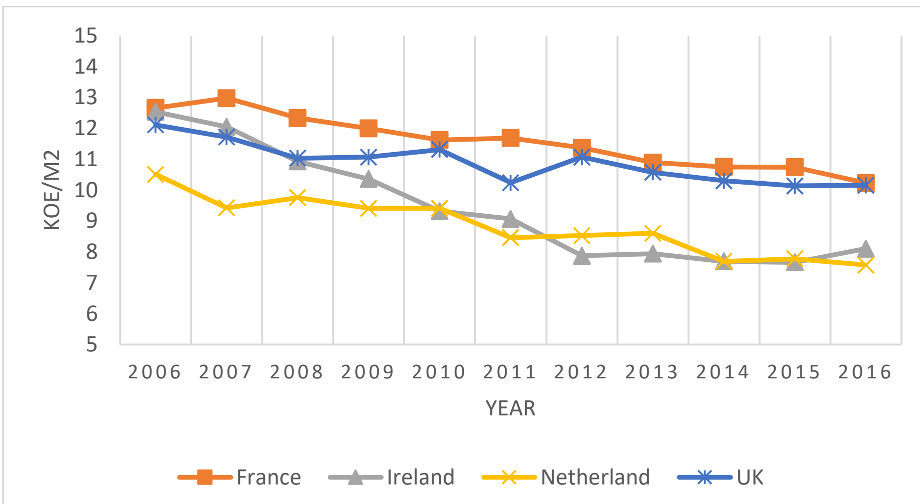



Fig 2.4: Unit consumption per m$^2$ for space heating with climatic corrections (koe/m$^2$)

Climate corrected energy consumption for average space heating for the years 2000-2015 both per m$^2$ of floor area and per dwelling for 24 EU member states is shown in Fig. 2.5. This compares the trend between Ireland, Netherlands and France from our selection of countries and it could be seen that Ireland has more average annual reduction in terms of space heating requirement either per dwelling[33] or per m$^2$ of floor area[34]. Overall, the energy consumption per dwelling decreased less than the consumption per m$^2$. This was due to an increase in the average dwelling size in all the countries. There was a decrease of 1.7%/year for the consumption per dwelling and 2.1%/year for the consumption per m$^2$ at the EU level whereas, the

[33] Reduction in the space heating energy requirement per dwelling was 2.78%, 2.5% and 2.12 % respectively for Ireland, Netherland and France.
[34] Reduction in the space heating energy requirement per m$^2$ of floor area was 3.51%, 3.23% and 2.28% respectively for Ireland, Netherland and France.

dwelling size increased by 6% since 2000 which means that part of the energy efficiency progress for heating has been offset by the larger size of dwellings (as also discussed in the introduction section)[35].

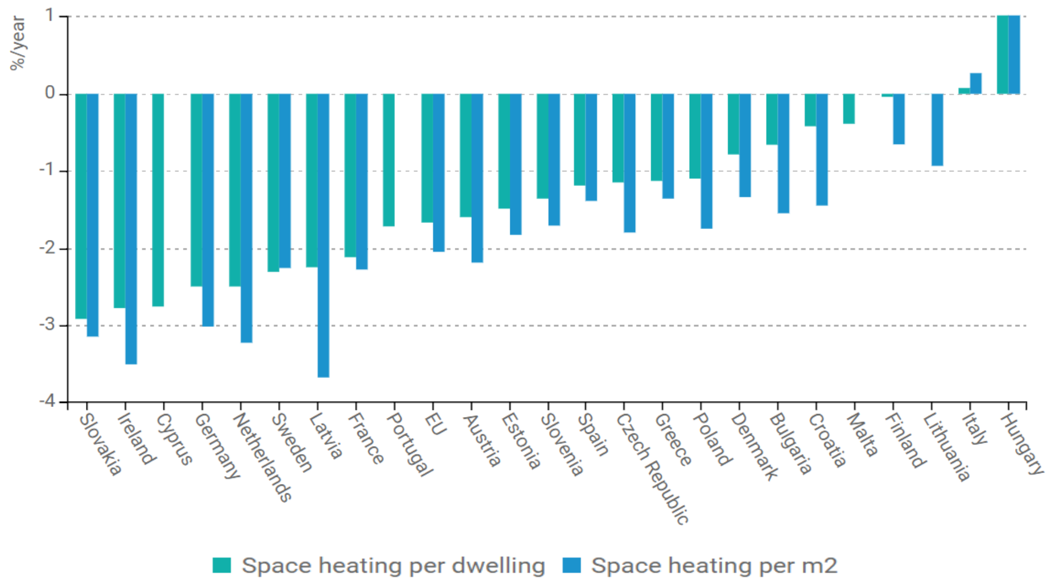



Fig 2.5: Average consumption per m$^2$ Vs consumption per dwelling for space heating (climate corrected)

## 2.4 Country profile and energy statistics

Population, land area and GDP statistics for the study countries are shown in Table 2.3 below. It is important to highlight here that Ireland has the lowest population density among these selected countries, which is approximately half of the EU population density. Ireland contributes only 1.8% to EU GDP whereas, France and UK have around 15% contribution each.

Table 2.3: Key statistics of countries (Source: DG Energy Europe country datasheets)

| Country | Population (million) | GDP GDP2010 [Mrd EUR at 2010 exchange rates] | Land area (km2) | Population Density(inhabitants per km2) | Population (%) | GDP (%) |
|---|---|---|---|---|---|---|
| EU28 | 510.277 | 13,825 | 4,422,773 | 115.37 | | |
| Belgium | 11.311 | 389 | 30,278 | 373.57 | 2.2 | 2.8 |
| Ireland | 4.726 | 251 | 68,883 | 68.61 | 0.9 | 1.8 |
| France | 66.73 | 2122 | 549,970 | 121.33 | 13.1 | 15.3 |
| Netherlands | 16.979 | 672 | 33,893 | 500.96 | 3.3 | 4.9 |
| UK | 65.383 | 2080 | 241,930 | 270.26 | 12.8 | 15.0 |

The renewable energy mix in the countries' energy profile is shown in Table 2.4 below. France has the highest share of renewable energy with 10.6% (Ireland and UK have 10.4% and 9.8% respectively) in gross

[35] http://www.odyssee-mure.eu/publications/efficiency-by-sector/households/heating-consumption-per-m2.html

inland consumption whereas, in terms of share of renewable energy in the electricity generation, Ireland and UK are leading with 30.1% and 28.1% respectively, which is dominated by wind.

Table 2.4 Renewable energy mix in total energy and electricity in 2017

| Country | % of renewable energy in gross inland consumption | RE share in electricity generation |
|---|---|---|
| Ireland[36] | 10.6 | 30.1 |
| Netherlands[37] | 6.6 | 13.9 |
| France[38] [39] | 10.4 | 19.9 |
| Belgium[40] [41] | 7.2 | 17.2 |
| UK[42] [43] | 9.8 | 28.1 |

The share of renewables for the period 2013 to 2017 used for heating and cooling in the study countries is shown in Table 2.5. It can be seen that France, with around 21% share of renewable energy, is the leading country among these selected countries. The other countries have approximately similar renewable heat share in the range of 5-8%. UK has seen the highest increase of renewables with around 85%, and Belgium, the lowest, with around 8% increase in the heating system in these five years.

Table 2.5 Percentage share of renewables in heating/cooling[44]

| Country | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Belgium | 7.42 | 7.68 | 7.73 | 8.09 | 8.03 |
| France | 18.55 | 19.14 | 19.89 | 21.1 | 21.35 |
| Ireland | 5.22 | 6.33 | 6.25 | 6.3 | 6.86 |
| Netherlands | 4.09 | 5.07 | 5.35 | 5.38 | 5.93 |
| UK | 4.02 | 4.65 | 6.07 | 6.97 | 7.45 |

[36] https://www.seai.ie/resources/publications/Energy-in-Ireland-2018.pdf
[37] https://ec.europa.eu/energy/sites/ener/files/documents/netherlands_draftnecp_en.pdf.pdf
[38] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Share_of_renewables_in_gross_inland_energy_consumption,_2017_(%25).png
[39] https://ec.europa.eu/eurostat/statistics-explained/images/3/32/Share_of_electricity_from_renewable_sources_in_gross_electricity_consumption%2C_2004-2017_%28%25%29.png
[40] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Share_of_renewables_in_gross_inland_energy_consumption,_2017_(%25).png
[41] https://ec.europa.eu/eurostat/statistics-explained/images/3/32/Share_of_electricity_from_renewable_sources_in_gross_electricity_consumption%2C_2004-2017_%28%25%29.png
[42] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Share_of_renewables_in_gross_inland_energy_consumption,_2017_(%25).png
[43] https://ec.europa.eu/eurostat/statistics-explained/images/3/32/Share_of_electricity_from_renewable_sources_in_gross_electricity_consumption%2C_2004-2017_%28%25%29.png
[44] Source: EuroStat 2019, nrg_ind_ren

# 3. Housing stock Review of selected country cases

## 3.1 Physical characteristics of housing stock

Population is one of the main determinants of the number of dwellings. Table 3.1 shows the population number for these selected countries. The population increase during last 20 years was highest in Ireland with around 27%, which was significantly higher than the percentage increase in other countries. The Netherlands has recorded the lowest population increase with only 9% during this period.

Table 3.1: Countries' population and percentage increase in the period 1998-2018[45]

| Country | 1998 | 2003 | 2008 | 2013 | 2018 | Population increase between 1998-2018 |
|---|---|---|---|---|---|---|
| Belgium | 10,192,264 | 10,355,844 | 10,666,866 | 11,137,974 | 11,398,589 | 11% |
| France | 59,934,884 | 61,864,088 | 64,007,193 | 65,600,350 | 66,926,166 | 11% |
| Ireland | 3,693,386 | 3,964,191 | 4,457,765 | 4,609,779 | 4,830,392 | 27% |
| Netherlands | 15,654,192 | 16,192,572 | 16,405,399 | 16,779,575 | 17,181,084 | 9% |
| UK | 58,394,596 | 59,501,394 | 61,571,647 | 63,905,342 | 66,273,576 | 13% |

This population increase is a clear indication for the increasing requirement of the number of dwellings. The total number of dwellings also depends on average number of persons per household[46]. The physical characteristics of the housing stock and the number of persons living in the house strongly influence the energy demand of the house. Number of persons living in the house can significantly affect the thermal energy use of the house as more rooms will require to be heated, increased hot water usage and longer usage of cooking appliances. Along with the number of persons, the amount of time people spend in the house is also a factor that affects the thermal energy use.

Fig. 3.1 shows the average number of persons per household in the selected countries. Ireland's houses have consistently higher number of occupants as compared to other similar climate-countries. In 2018, Ireland has on average 2.6 persons per household, which is 20% higher than France and Netherlands, and 16% higher than Belgium and UK. Higher numbers of average persons per household in Ireland is attributed in part to the housing supply shortfall that became increasingly pronounced during the last decade.

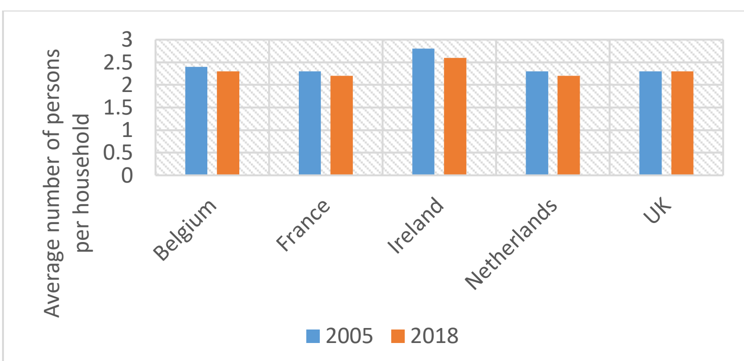



Fig 3.1: Average number of persons per households[47]

[45] https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tps00001&plugin=1
[46] https://www.seai.ie/resources/publications/Energy-in-the-Residential-Sector-2018-Final.pdf
[47] source: Eurostat |(https://www.pordata.pt/en/Europe/Average+number+of+persons+per+household-1613)

In terms of owner-occupier status, Fig. 3.2 shows a comparison of residential homes in selected countries. Research shows that house owner-occupiers have a greater economic incentive to invest in energy efficiency measures compared to the tenants who rent the property. This is because tenants have no investable incentive to improve the value of a property, and landlords have less motivation to invest in improvements, as they are not the direct beneficiaries[48 49]. Considering this, it is important to understand the occupier status of homes in these selected countries, which could be a reflection of the complexities involved in improving the thermal efficiency. As Fig. 3.2 shows, in comparing these selected countries, there was no major difference observed. Tenant occupied homes vary in the range of 27-36%. Countries that have the larger population size such as France and UK have a slightly greater rented proportion as compared to other countries. Note that, Ireland has the lowest population among these countries but still has around 30% of its population, somewhat similar to other countries, living in rented properties where improving insulations or taking any energy efficiency actions could be complex.

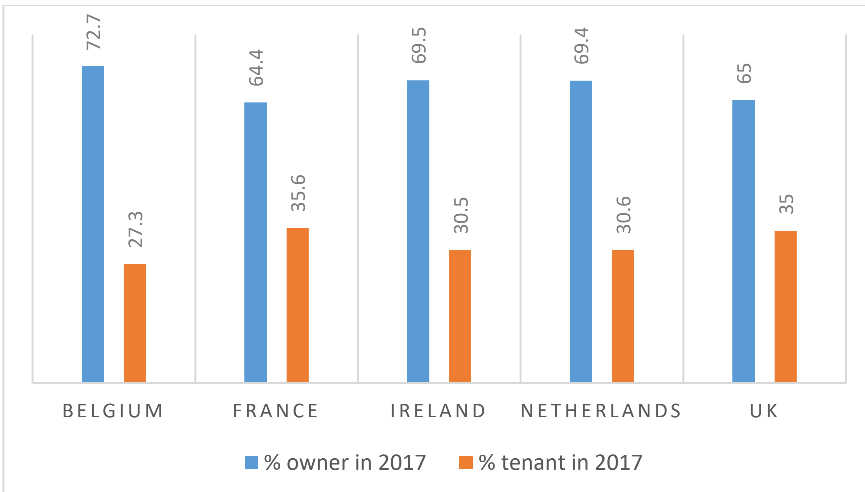



Fig 3.2: Share of owner occupied dwellings vs rented dwellings in 2017; Source: Eurostat[50]

The type of dwellings is a major factor in heating energy consumption. Apartments typically have the lowest heat loss as compared to houses as they have less exposed surface area. Detached houses are standalone buildings and therefore have more exposed surface area as compared to semi-detached and mid-terrace houses[51]. Detached houses are also likely to be larger. Comparing the dwelling types between these countries, Fig. 3.3 shows that most of the countries except France have more semi-detached houses than detached houses, and this proportion is very high in the Netherlands and UK. France has the highest share of apartments with 33.1%, whereas only 8.3% of the population live in apartments in Ireland. In fact, Ireland has the lowest share of apartment dwellers in the EU. Ireland has the second highest share of detached houses among these countries, which indicates a particular need to focus on tackling the heating needs of these types of houses.

---

[48] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf
[49] https://www.seai.ie/resources/publications/Behavioural-insights-on-energy-efficiency-in-the-residential-sector.pdf
[50] https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20171102-1?inheritRedirect=true
https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20171102-1?inheritRedirect=true
[51] https://www.seai.ie/resources/publications/Energy-in-the-Residential-Sector-2018-Final.pdf

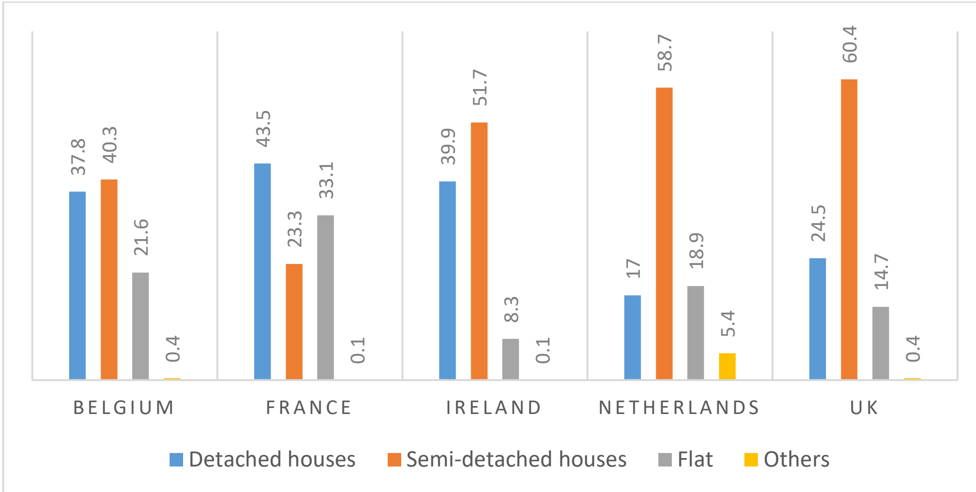



Fig 3.3: Distribution of Population by dwelling types in 2017; Source: Eurostat[52]

The degree of urbanisation is another important consideration in any heat decarbonisation strategy, as the location and proximity of dwellings can have a major impact on the type of heat delivery options that are economically or practically available. For example, high-density towns and cities have greater access to the gas network or to district heating networks. By contrast, the low-density areas might be better suited to standalone schemes such as heat pumps, biomass boilers, or bottled biogas. As shown in Fig. 3.4, in 2017, the UK had the highest proportion living in cities with 59%, whereas Belgium had the lowest share at only 27%. Among the smaller countries of the group, Ireland has the largest rural population at 31%, with another 22% living in potentially low-density towns and suburbs. Only France has a greater proportion of a rural population.

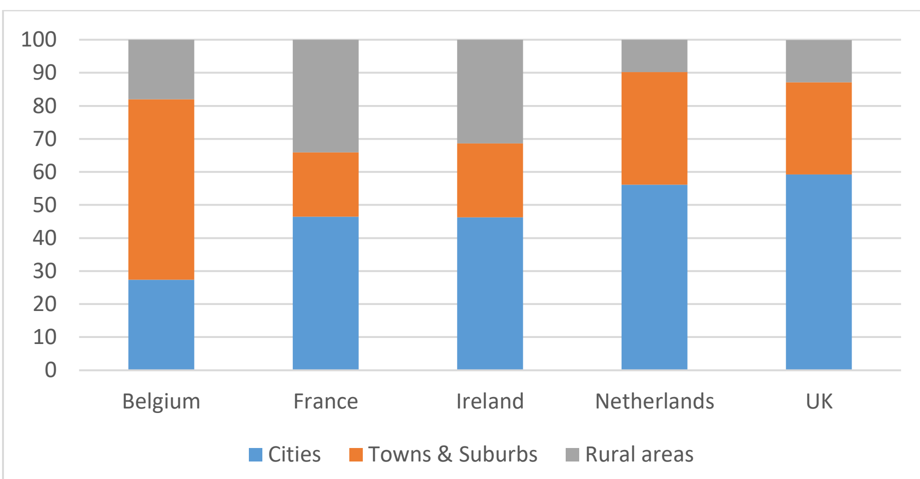



Fig 3.4: Share of population by degree of urbanisation in 2017; Source: Eurostat[53]

This study also looked at the energy poverty situation, shown in Fig. 3.5, for these countries. There is a myriad of definitions for energy poverty. The key idea is the inability to heat ones' home when living a colder climate. There are a number of reasons for such a situation including unemployment, or having not

[52] http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

[53] http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

enough income to meet the demand for electricity or gas to heat/power the home, or to have adequate insulation for the house. Fig. 3.5 shows Ireland has approximately 3% higher share of population who are at the risk of energy poverty compared to the EU 28 countries. However, energy poverty risk seems to be improving in recent years in Ireland unlike the Netherlands, which has lowest share of population at the risk of energy poverty but has shown an increasing percentage over the years. A 2015 study by the Economic and Social Research Institute has clearly highlighted that Ireland's energy poverty is not an energy issue, but a function of inadequate resources to cover the living cost[54].

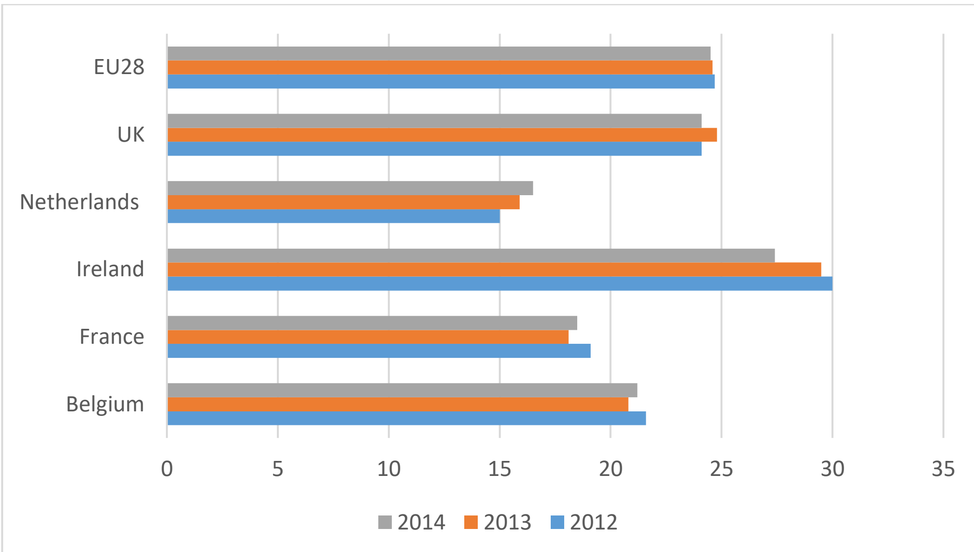



Fig 3.5: Share of population at risk of energy poverty or social exclusion (Source: EU Building Database[55])

The EU also collects data about specifics such as the portion of the population who struggle to maintain their homes sufficiently warm which is one of the important issues under energy poverty. As shown in Fig. 3.6, in 2014 in the Netherlands only 2.6 % of people fell into this category as compared to the highest in UK with 9.3% or the EU28 average with 10.2%. Ireland has significantly higher proportion of people struggling to keep their home warm as compared to Belgium, France and the Netherlands during the year 2012-2014. It is also important to highlight here that during 2012-2014 Ireland was starting to move out of a serious recession. In 2013, Ireland saw a comparatively higher percentage, with approximately 10% of people who were not able to heat their homes adequately. This number was only slightly lower as compared to EU28 average during that year.

On average, Ireland has a lower proportion of inhabitants struggling to keep their home warm as compared to EU28 average in any year. However, compared with these similar climate countries except the UK, a significant gap exists indicating opportunities for further improvements, with a potential to bring much wider benefits to Irish society by helping to tackle problems of health, wellbeing and social inclusion.

[54] Is Fuel Poverty in Ireland a Distinct Type of Deprivation? – Dorothy Watson & Bertrand Maitre – *https://www.esri.ie/pubs/JACB201504.pdf*

[55] https://ec.europa.eu/energy/en/eu-buildings-database)

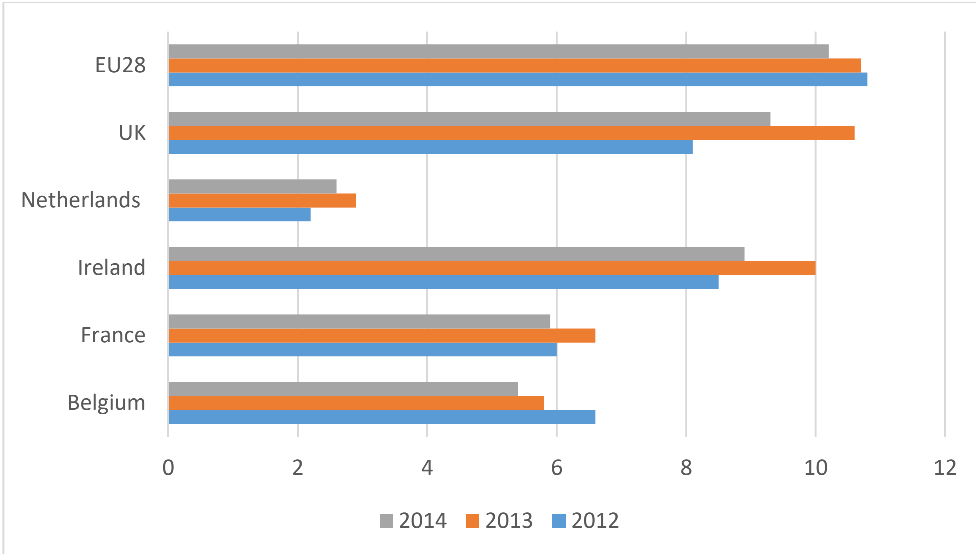



Fig 3.6: Proportion of inhabitants unable to keep home adequately warm (Source: https://ec.europa.eu/energy/en/eu-buildings-database)

## 3.2 Building Energy Ratings

Building Energy Ratings (BER) are a measure that illustrates the expected energy performance of a building. This has essentially the same operational result as the Energy Performance Certificate (EPC). The EPC shows the modelled energy performance on an easily readable scale from A (best performance) to G (worst performance). However, the BER Certificate is slightly more detailed in that it subdivides the A- G scale into A1, A2, A3, B1, B2, B3 etc. The information on both certificates is in the same format so it is easy to compare them[56]. EPCs or BERs are compulsory for all homes offered for sale or rent according to the Energy Performance of Buildings Directive (EPBD) 2002. The 2010 recast of the EPBD includes a new set of requirements to improve the quality, usability and public acceptance of EPCs[57]. All 28-member states have formally implemented the EPBD requirements in their national legislations. Ireland uses the BER rating scale. The other selected countries use the EPC rating[58]. EPC/BER ratings depend on (i) the amount of energy used per $m^2$ and (ii) the level of $CO_2$ emissions per year.

Looking at the energy performance ratings of dwellings in different countries, the latest EU buildings data is available for 2015 only and without the data available for Belgium. Table 3.2 shows the EPC grading in the year 2015 in these five countries. In 2015, only 0.98% dwellings in Ireland were 'A rated' which is significantly lower than France at 7.95% in the same year. It is also important to highlight that an A rated dwelling typically consumes 60%-75% less energy to heat the dwelling at a comfortable level year-round as compared to an equivalent C rated dwelling. The total of A-C rated buildings is highest in Ireland out of these five countries. Conversely, Ireland has lowest D and below D rated buildings.

[56] http://allanarc.com/434-2/
[57] http://bpie.eu/publication/energy-performance-certificates-across-the-eu/
[58] http://bpie.eu/wp-content/uploads/2015/10/BPIE_EPC_report_2010.pdf

Table 3.2: Share of dwellings with label (%)[59] (All 2015 data except Netherlands which is 2012 data. No values mean data was not available)

| Country | Rating A | Rating B | Rating C | Rating D | Rating >D |
|---|---|---|---|---|---|
| Belgium | | | | | |
| France | 7.95 | 11.91 | 14.77 | 29.77 | 35.60 |
| Ireland | 0.98 | 11.56 | 36.88 | 25.35 | 25.22 |
| Netherlands | 3 | 11.90 | 29.70 | 26.70 | 28.70 |
| UK | 0.15 | 8.32 | 26.79 | 41.07 | 23.68 |

Fig. 3.7 represents the number of dwellings with energy performance certificates (some of data were not available) and shows that UK and France have significantly higher number of dwellings with energy performance certificates. Looking at the total number of EPCs issued for dwellings, in 2015, France issued 11 times more EPCs as compared to Ireland. It is important to note that France[60] had 35 million dwellings while Ireland[61] had 2 million dwellings in 2015 and 2016 respectively.

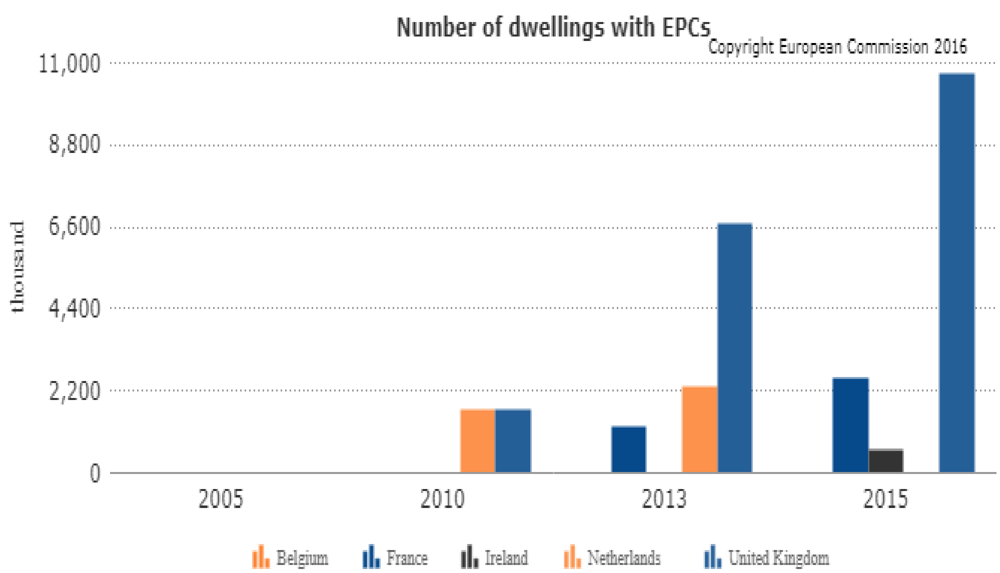



Fig. 3.7: Number of dwellings with EPCs

Table 3.3 below (a picture of the table displayed on the EU Buildings database website) also shows the total number of EPCs issued for dwellings per year where most of the data were not available.

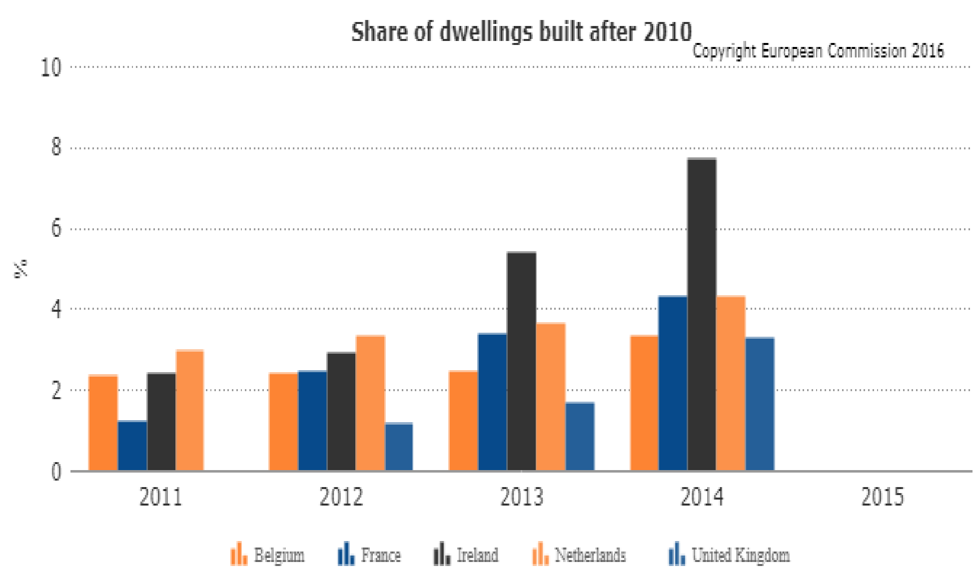
[59] https://ec.europa.eu/energy/en/eu-buildings-database
[60] https://www.statista.com/statistics/767493/number-housing-france/
[61] https://www.cso.ie/en/releasesandpublications/ep/p-cp1hii/cp1hii/hs/

Table 3.3: Total number of EPCs issued for dwellings per year (Source: EU building database[62])

| | Source | Unit | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|
| Belgium | | thousand | - | - | - | - | - |
| France | ZEBRA2020 | thousand | - | - | - | 1,245.06 | - |
| Ireland | EPC registry | thousand | 107.14 | 74.95 | 99.72 | 110.17 | - |
| Netherlands | | thousand | - | - | - | - | - |
| United Kingdom | | thousand | - | - | - | - | - |

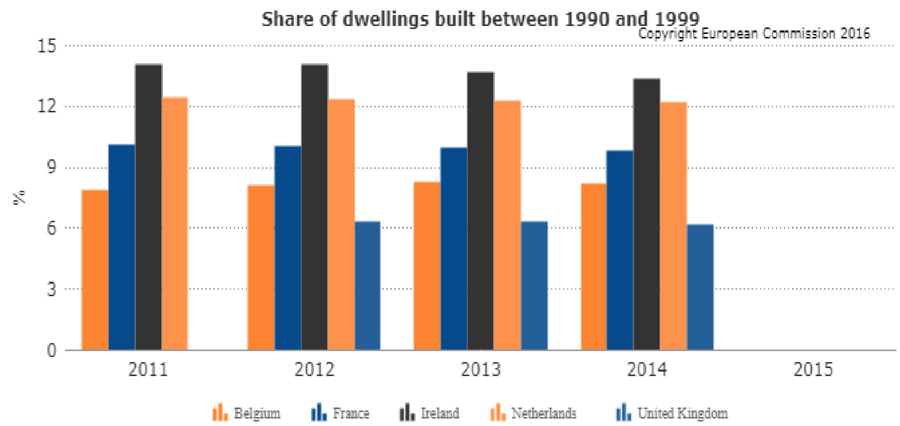
No values mean non-available or non-relevant information

We also looked at the share of dwellings built (a) after 2010 (b) between 1990 and 1999 (c) between 1945 and 1969 (d) built before 1945, during the years 2011-2014, which gives some interesting insights, shown in Fig. 3.8. Ireland had significantly more dwellings built in last 2-3 decades as compared to other similar-climate countries. According to 2016 census records, 9% of all private housing in Ireland are from the construction era prior to 1919 and 7% are dated between 1919-1945[63]. However, compared with other countries, the share of older dwellings (built before 1945 or during the period of 1945-1969) were significantly lower in Ireland.

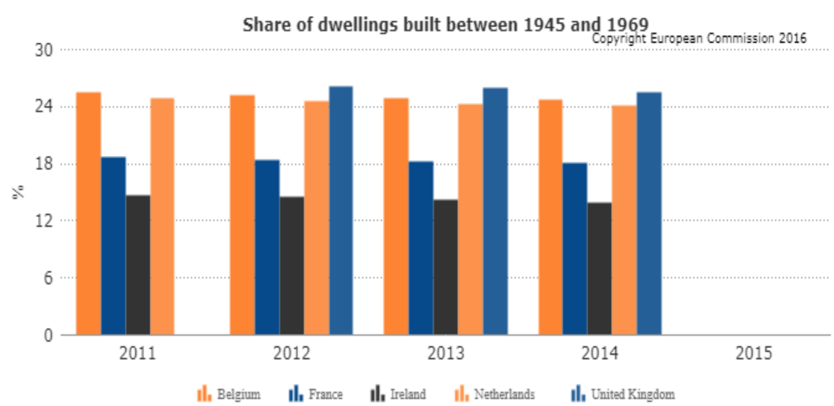



(a)

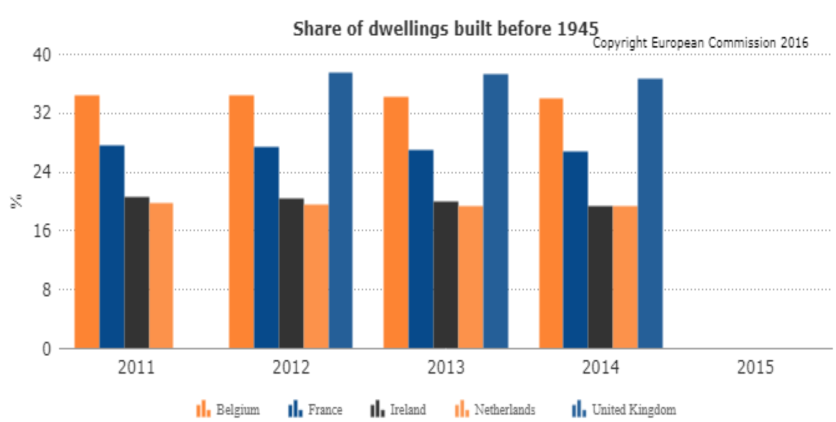
[62] https://ec.europa.eu/energy/en/eu-buildings-database
[63] E1005: Private Households in Permanent Housing Units 2011 to 2016 by Type of Private Accommodation, County and City, Period in which Built and Census Year. Cork: Central Statistics Office. Available at: http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?maintable=E1005&PLanguage=0




(b)




(c)




(d)

Fig. 3.8: share of dwellings built (a) after 2010 (b) between 1990 and 1999 (c) between 1945 and 1969 (d) built before 1945

The share of nearly zero energy buildings data is shown in the Table 3.4 where in 2014, all new construction in France were nearly zero energy buildings (NZEB). There was no data available for Ireland specific to NZEB in this EU Building Database. According to Ireland's Central Statistics Office, 23% of homes constructed in 2010-2014 were given 'A' BER rating but again there was no data available on NZEB[64].

Table 3.4: Share of NZEB in new construction for residential

| | Source | Unit | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|
| Belgium | ZEBRA2020 | % | 3.41 | 3.36 | 5.77 | 9.68 | - |
| France | ZEBRA2020 | % | 25.37 | 28.15 | 100.00 | 100.00 | - |
| Ireland | | % | - | - | - | - | - |
| Netherlands | ZEBRA2020 | % | - | - | - | 0.20 | - |
| United Kingdom | ZEBRA2020 | % | 1.10 | 0.90 | 1.00 | 1.60 | 2.00 |

No values mean non-available or non-relevant information

This study attempted to compare the energy related investments for the renovation of residential buildings in these countries, however, there was no relevant data available for any of these countries.

[64] https://www.cso.ie/en/media/csoie/releasespublications/documents/environment/2014/DberQ12014.pdf

# 4. Heating energy profile and fuel reserves

## 4.1 Heating energy demand

The table 4.1 shows the fuel sources used for heating/cooling purposes in 2015. Oil, gas, coal, electricity, and biomass are the top four fuel sources in these countries for domestic heating. With the exception of Ireland, where oil is the main source for heating, natural gas is the dominant fuel for heating purposes. Ireland is the only country where coal meets a significant proportion of the heating demand, 19% in 2015[65]. In the 2016 census, around 13% of Irish residential buildings used solid fuel for central heating[66]. According to Heat Roadmap EU dataset[67], the Netherlands fulfils 4% of their heating requirement through district heating schemes, which is highest among these countries. France employs biomass for 20% of heating energy demand.

Table 4.1: Share of energy carrier in the total final heating and cooling demand in 2015 (Source: Heat Roadmap Europe – Final data set – 15.3.2017)

| Country | Domestic Heating/cooling Fuel (%) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Oil | Gas | Coal | Electricity | Biomass | District Heating | Solar thermal | Heat Pump |
| Ireland[68] | 40 | 25 | 19 | 14 | 1 | 0 | <1 | <1 |
| Netherlands | <1 | 84 | 0 | 5 | 6 | 4 | <1 | 1 |
| France | 18 | 37 | 1 | 19 | 20 | 3 | <1 | 2 |
| Belgium | 36 | 46 | 1 | 10 | 7 | <1 | <1 | <1 |
| UK | 9 | 75 | 2 | 10 | 4 | <1 | 0 | <1 |

Fig. 4.1 shows that space heating is by far the dominant requirement for thermal energy as compared to other purposes. The energy requirement patterns for the four different end uses in all the countries are very similar. Looking at the specific energy requirement (in absolute numbers) shown in Table 4.2, France heat demand for space heating is around 325 TWh per annum whereas, Ireland has the lowest with 22.3 TWh per annum. To understand the comparison better, this study analysed the annual energy demand for space heating by average dwellings and floor area. Fig. 4.2 shows final energy demand by average dwelling and by floor area. It can be seen that Ireland consumes 15,548 kWh/dwelling, which is the second highest among these countries. On the other hand, Ireland has the lowest energy demand among these countries when compared against the floor area, which was primarily driven by the increasing number of dwellings; up by 39% between 2000 and 2016, together with the increase in average floor area per dwelling. In 2016, the average dwelling was 21% larger than in 1990, and 15% larger than in 2000. Comparing Ireland and UK, the number of new dwellings have significantly increased in Ireland since 1990 which are more energy efficient, and that is reflecting in terms of reduced consumption per m$^2$ of floor

[65] SEAI 2016 figures have reported coal at 7% and Peat at 7% (https://www.seai.ie/resources/publications/Energy-in-the-Residential-Sector-2018-Final.pdf)
[66] https://www.seai.ie/resources/publications/Energy-in-the-Residential-Sector-2018-Final.pdf
[67] https://heatroadmap.eu/heating-and-cooling-energy-demand-profiles/
[68] As per SEAI, in 2016, space heating accounted for 61% of residential final energy. Oil accounted for 47% of energy used for space heating, gas 25% and solid fuels 21%.

area. Also, Ireland has significantly more detached houses as compared to UK and therefore, it has significantly higher energy consumption per dwelling.

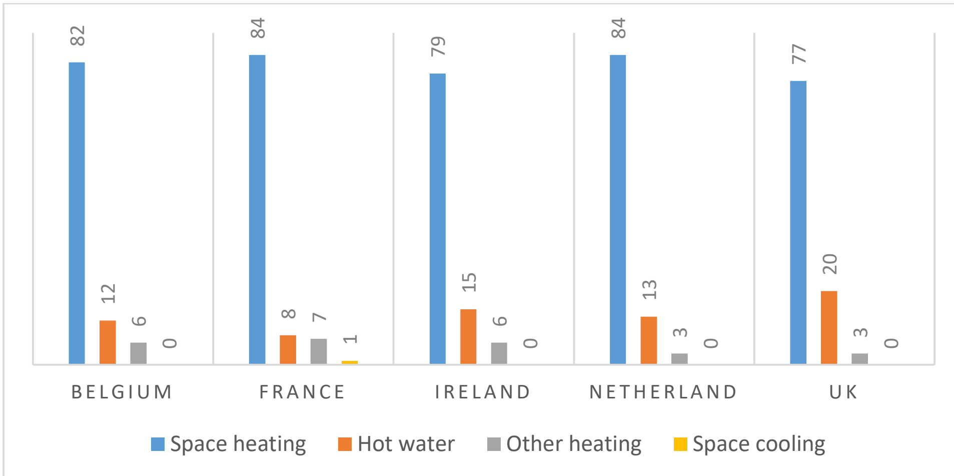
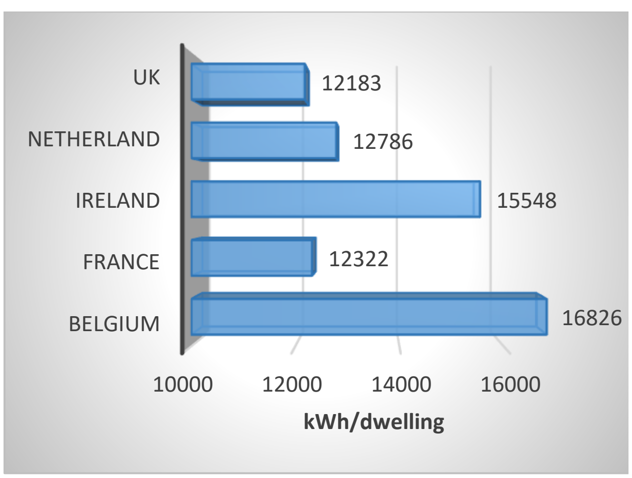



Fig 4.1: Percentage share of type of heat for the final residential heat demand

Table 4.2: Residential space heating consumption in 2015

| | Belgium | France | Ireland | Netherlands | UK |
|---|---|---|---|---|---|
| Residential Space heating (TWh in 2015) | 69.1 | 325 | 22.3 | 84.8 | 273.5 |



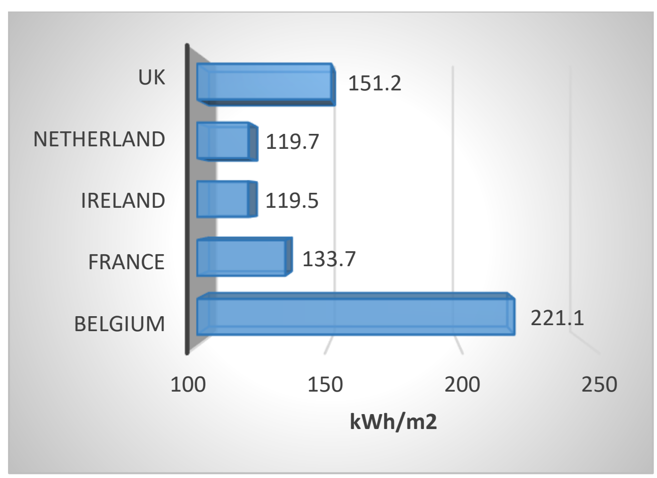




Fig 4.2: Comparison of Final energy demand by average dwelling (kWh/dwelling) and final energy demand by floor area (kWh/$m^2$)[69]

[69] Source: EU Heat Roadmap: Excel Sheet

## 4.2 Fuel reserves and households' connectivity

Resource endowments such as availability of hydropower, natural gas or oil reserves have a very important impact on policies. Heating/cooling energy strategy of any country largely depends on the available resources, the existing infrastructure and its ability to be adapted to new uses. Table 4.3 shows the fuel reserves and households' connectivity to the gas network. The UK and the Netherlands reveal a significantly higher percentage of residences connected as compared to other countries. The heating markets in UK and the Netherlands are currently dominated by piped natural gas, delivered via extensive distribution networks, and combusted in boilers to provide heat. This system is well established, relatively inexpensive, reliable, and efficient. These two countries benefitted from significant domestic gas reserves, gas infrastructure development aided by uptake of gas in power generation, and higher population densities enabling cost-effective rollout of gas distribution infrastructure[70]. It has also been reported in one of the works of UK Energy Research Centre that both countries have limited hydro resources and, maybe, therefore, very low penetration of heat pumps[71]. Immaturity of heat pump technology, price of electricity, and poorer efficiencies for heat pumps with DHW (domestic hot water) are also considered as other major barriers. The small percentage of district heating in these countries is mainly due to the connectivity of extensive gas infrastructure. District heating was common in the UK in the 1960s and 1970s, but fell out of favour due to issues of network efficiency and billing practices.

On the other hand, France and Ireland have approximately similar percentage of households' connectivity with the gas network and similar level of gas reserves. Having a significantly lower level of households' connectivity as compared to UK and Netherland indicates a significant opportunity for standalone schemes such as heat pumps or for developing district heating schemes while exploring the opportunities for supplying low carbon gases through the existing gas network.

Table 4.3: Fuel reserves and households' connectivity

| Country | Population Density (inhabitant per km$^2$) | % of households access with gas network | Gas reserves (trillion cubic feet)[72] | Crude oil reserve (Thousand barrels per day) – August 2018[73] |
|---|---|---|---|---|
| Ireland | 70 | 39% (2014)[74] | 0.40 | 0.00 |
| Netherlands | 505 | 97% (1998)[75] | 28 | 16 |
| France | 122 | 41% (1998)[76] | 0.30 | 16 |
| Belgium | 376 | 55% (1998)[77] | 0 | 0.00 |
| UK | 273 | 82% (1998)[78] | 6.20 | 842 |

[70] https://www.theccc.org.uk/wp-content/uploads/2013/12/Frontier-Economics-Element-Energy-Pathways-to-high-penetration-of-heat-pumps.pdf
[71] UKERC Technology and Policy Assessment Best practice in heat decarbonisation policy: A review of the international experience of policies to promote the uptake of low-carbon heat supply
[72] https://knoema.com/atlas/topics/Energy
[73] https://knoema.com/atlas/topics/Energy
[74] http://www.ervia.ie/decarbonising-domestic-he/KPMG-Irish-Gas-Pathways-Report.pdf
[75] https://www.eci.ox.ac.uk/research/energy/downloads/lcfreport/appendix-r.pdf
[76] https://www.eci.ox.ac.uk/research/energy/downloads/countrypictures/cp_france.pdf
[77] https://www.eci.ox.ac.uk/research/energy/downloads/countrypictures/cp_belgium.pdf
[78] https://www.eci.ox.ac.uk/research/energy/downloads/lcfreport/appendix-r.pdf

# 5. Current policy support and future strategies

## 5.1 The UK

In the UK, approximately 84% households are connected with the gas network[79]. A survey has been conducted in the country which has reported high levels of satisfaction with the gas central heating system, and there is not much willingness to try any other alternatives[80]. However, the government has taken several initiatives to integrate renewables into the system. UK Government introduced the domestic renewable heat incentive in 2014 to cover the additional costs of the low-carbon heating installation. This scheme covers biomass boilers, solar water heating and certain heat pumps[81] [82].

To facilitate the market for district heating, the UK Government set up the Heat Network Delivery Unit (HNDU) in 2013 to support local authorities in England and Wales through the early stages of heat network project development. Through HNDU support, the UK Government has invested over £17 million in grant funding to more than 200 projects across 140 local authorities[83]. UK government further announced the launch in 2018 of the £320 million Heat Networks Investment Project (HNIP) to offer loans and grants to both the public and private sectors in England and Wales for the development of heat networks serving two or more buildings. This £320 million fund is being provided as 'gap funding' which aims to overcome the number of barriers and leverage in around £1bn of private and other investment in order to support the design and construction of heat networks[84]. The Mayor of London also published a plan in December 2017 where there is a very strong focus on the development of heat networks[85]. This plan identifies a number of heat network priority areas and recommends major development proposals for communal heating systems.

To further facilitate the heat network investment, the BEIS (Department of Business, Energy & Industrial Strategy, UK) website also publishes a list of investors with a brief summary to help enable projects and to reduce the uncertainty of local authorities regarding which third party investors are actively considering investment in the heat network sector[86]. A community heat network toolkit is also provided by the government to help develop community-led heat network projects[87]. Heat suppliers are also regulated through Heat Network (Metering and Billing) Regulations 2014[88].

In addition, looking into the future of UK heating, the government has published a strategy document, 'Clean Growth – Transforming Heating', in December 2018 which provides a long term policy framework. Two other reports focusing on substantial growth of low carbon heating in the shorter term have also

---

[79] https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheatingpdf
[80] https://s3-eu-west-1.amazonaws.com/assets.eti.co.uk/legacyUploads/2015/11/3501-Consumer-Insights.pdf?dl=1
[81] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774235/national_energy_and_climate_plan.pdf
[82] https://www.gov.uk/domestic-renewable-heat-incentive
[83] Heat Networks Delivery Unit, https://www.gov.uk/guidance/heat-networks-delivery-unit
[84] https://www.twobirds.com/en/news/articles/2018/uk/bird-and-bird-and-heat-decarbonisation-policy-in-the-uk
[85] https://www.london.gov.uk/sites/default/files/new_london_plan_december_2017.pdf
[86] https://www.gov.uk/guidance/heat-networks-overview
[87] https://hub.communityenergyengland.org/resources/resource/151/community-led-heat-projects-a-toolkit-for-heat-net/
[88] https://www.gov.uk/guidance/heat-networks

been published: (i) Government's Response to a Future Framework for Heat in Buildings - Call for Evidence (for off-gas grid buildings)[89]; (ii) A Future Market Framework for Heat Networks[90] . The key highlights are:

- The UK government is committed to reduce heat demand of buildings through integrating energy efficiency policy in future plans for low carbon heating. Use of digital technologies, data and control sensors all being explored to provide heat as a packaged service rather than simply as unit of fuel[91] [92].
- The government understands the availability of a range of technologies for the low-carbon heating, but there is no consensus on which technologies will be able to achieve this most economically and effectively at the scale required.
- Based on the research and evidence available so far to the government, technologies using electricity, hydrogen and bioenergy have the potential to make important contributions to the transition to low carbon heating in UK, and government is committed to examine these technologies with a number of activities. Table 5.1 suggests the key considerations for each of these technologies[93]:

Table 5.1: Key activities under consideration in UK

| **Technology** | **Key activities to be considered** |
|---|---|
| Electric Heating | • Developing new and strengthening of the existing infrastructure to generate, store and distribute low carbon electricity<br>• Improve understanding of potential future requirements for electricity generation and network reinforcement under different circumstances, and how these might be cost effectively and practicably met<br>• Innovations in demand reduction, system flexibility and energy storage for demand side management<br>• Develop plans for a substantial new project to demonstrate modern electric heating solutions across a range of building types and consumers |
| Use of hydrogen | • Develop a comprehensive programme of work to demonstrate the technical and practical feasibility of using hydrogen in place of natural gas for heating<br>• Enable a more informed debate on the potential of using hydrogen for heat<br>• Safety feasibility of repurposing the gas grid[94] |

89 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762546/Future_Framework_for_Heat_in_Buildings_Govt_Response__2_.pdf

90 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774586/heat-networks-ensuring-sustained-investment-protecting-consumers.pdf

91 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762546/Future_Framework_for_Heat_in_Buildings_Govt_Response__2_.pdf

92 Catapult Energy Systems, Using the connected home to deliver low carbon energy services that people value, Online News Article, February 2018 https://es.catapult.org.uk/news/the-fight-against-carbon-howtechnology-can-help-us-heat-our-homes-the-cleaner-way/

93 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf

94 https://www.policyconnect.org.uk/sites/site_pc/files/report/1001/fieldreportdownload/futuregaspt1nextstepsforthegasgridwebcompressed.pdf

| | |
|---|---|
| | • Developing new infrastructure including new transmission system, hydrogen production and storage facilities, and carbon capture and storage facility<br>• Practical feasibility of producing sufficient volumes of very low carbon hydrogen and the potential for methane leakage |
| Bioenergy | • Assessing the potential for expanding the supply of biomass in ways which are sustainable and affordable<br>• Production of bio-methane for use in the gas grid.<br>• Assessment of the scale of emissions reduction potential by the volume of biomass available<br>• The prioritisation of its use across the energy economy and lifecycle emissions from production. |

A comprehensive policy framework, combination of technologies, tighter building regulations, consumer awareness through a range of information sources, consumer's confidence and protection, and up-skilling for engineers and installers are the key approaches which are being considered.

## 5.2 The Netherlands

In the Netherlands 38% of energy consumption goes to heating, and residential heating contributes around 10% of Dutch $CO_2$ emissions[95]. Here the government is committed to transform the domestic heating sector and has identified space heating as the key priority area where natural gas should be replaced by other sources of heat. The initial vision for sustainable heat was presented in the society-wide Energy Agreement for Sustainable Growth that was concluded in September 2013 in The Netherlands with industries, non-governmental organisations and governments[96] [97]. It was followed by a Heat Vision[98] in 2015 and further the Energy Agenda[99] in 2016. "Energy Agenda", indicates the policies that should lead to an almost carbon-neutral economy in 2050. With regard to emissions from buildings, the two main policies are:

- better insulation to reduce heat demand, and
- the replacement of natural gas by alternative fuels with lower emissions[100].

Some of the key policies under implementation for low-carbon heating are [101]:

- Tightening of energy performance requirements for social and private rented sector[102]
- Encourage homeowners to install further energy saving measures through subsidies, low-interest loans and an information campaigns[103]

[95] https://energypost.eu/a-revolution-the-netherlands-kisses-gas-goodbye-but-will-it-help-the-climate/
[96] https://www.government.nl/documents/publications/2013/09/06/energy-agreement-for-sustainable-growth
[97] https://www.energieakkoordser.nl/doen/engels.aspx
[98] https://www.rijksoverheid.nl/documenten/kamerstukken/2015/04/02/kamerbrief-warmtevisie
[99] https://www.rijksoverheid.nl/documenten/rapporten/2016/12/07/ea
[100] https://energypost.eu/a-revolution-the-netherlands-kisses-gas-goodbye-but-will-it-help-the-climate/
[101] https://www.climatexchange.org.uk/media/2084/eu_case_studies_netherlands_heat_policy.pdf
[102] https://www.rijksoverheid.nl/onderwerpen/duurzame-energie/rijksoverheid-stimuleert-energiebesparing
[103] https://www.energiebesparendoejenu.nl/

- Working with the housing construction sector to ensure that all the new buildings are practically energy neutral by end of 2020.
- Investment Subsidy in Renewable Energy (ISDE): financial incentive to stimulate the uptake of solar thermal, heat pumps and biomass boilers[104].
- Shifting tax burden from electricity to gas in order to stimulate uptake of heat pumps[105]
- Climate agreement from Netherlands also considered no gas connection for new built neighborhoods[106].
- Government has also developed a 'Heating Supply Act' to prepare for the low carbon energy supply in the heating sector. It was also recently amended to give a better protection to consumers to deal with the monopolist heating suppliers[107].
- Geothermal based heating is being explored[108]. In 2015, government announced 3.6 million euros available for a test drilling to extract heat from the deep earth in Westland which can potentially provide 80% of heat demand in Westland[109].
- Complete heat market reform is being considered to stimulate the development of district heating.
- Electrification is also being considered through heat pumps and hybrid heat pumps. To get the best use of heat pumps, housing insulations are also being improved.
- As of 1 July 2018, there is no longer a requirement for newly built houses to have a gas connection. To achieve the low carbon heating vision, 170,000 houses would need to disconnected from gas grid every year. Local authorities are playing a key role in this process of deciding for each neighborhood, block or even individual house what the best alternative heating source is.

A range of strategies and technology options for space heating have been considered in the Energy Report[110] (pp 67-78) published by Ministry of Economic Affairs of the Netherlands. During the domestic heat transition the changing role of different stakeholders have been explained in detail in a report published by Delta Energy[111]. Some of the key technologies and supportive policies are considered for heat pumps, hybrid heat pumps, geothermal pumps, seasonal heat and cold storage, residual heat, locally available biomass, and district heating.

The Netherlands government also believes that decision making on the heat transition will have to become more of a regional concern than it is today, with a greater role for local authorities, building managers, property developers and residents. The starting point needs to be a regional heating plan, and government will support the joint efforts and local decision-making process where possible, by reviewing the policy and market rules for the supply of energy and the maintenance of the infrastructure[112].

---

[104] https://www.rvo.nl/subsidies-regelingen/investeringssubsidie-duurzame-energie-isde
[105] https://www.ehpa.org/fileadmin/red/03._Media/Publications/ehpa-white-paper-111018.pdf
[106] https://ec.europa.eu/energy/sites/ener/files/documents/01.b.02_mf31_presentation_nl-fuel_switch-vanthof.pdf
[107] https://www.lexology.com/library/detail.aspx?g=7813c329-9854-436a-8b15-9025b9bbcf3d
[108] https://ec.europa.eu/energy/sites/ener/files/documents/netherlands_draftnecp_en.pdf.pdf
[109] https://www.rijksoverheid.nl/actueel/nieuws/2015/04/02/kabinet-stimuleert-overstap-van-gas-naar-duurzame-warmte
[110] https://www.government.nl/documents/reports/2016/01/01/energy-report-transition-to-sustainable-energy
[111] Towards a heat transition in the housing sector in the Netherlands Roles and responsibilities of different actors
[112] https://www.government.nl/documents/reports/2016/04/28/energy-report-transition-tot-sustainable-energy

According to the recent Draft National Climate and Energy Plan[113], the government is further committed to ensuring a substantial percentage of buildings are no longer heated using natural gas. In order to achieve the long-term climate targets, the Netherlands Environmental Assessment Agency expects that 20-30% of homes should be connected to district heating by 2050 (PBL, 2017) and suggests that this will only be feasible if homes are only allowed very limited access to natural gas.

## 5.3 Belgium

The Energy Pact, which outlines the country's energy and climate policy until 2050 was released in 2017 and eventually approved in March 2018[114]. The key strategies mentioned are closing down nuclear plants by 2025, strengthening the energy standards applicable to all types of consumer goods; speeding up the renovation of residential, tertiary and public buildings; and banning sales of oil boilers from 2035. The aim is to raise the energy performance of residential buildings to the level of 100 kWh/m$^2$ by 2050. Public buildings and offices will be required to become energy neutral by 2040 and 2050 respectively[115][116].

Like other countries, Belgium also has a national binding target for renewable energy stated in the EU Renewable Energy Directive (2009/28/EC) to account for 13% of gross final energy consumption in 2020[117]. The heating/cooling sector need to achieve 12% renewables by 2020. In 2016, Belgium had 8.1% share of renewable energy in heating and cooling sector[118].

Belgium is the third most densely populated country in Europe. However, this density varies from one part of the country to another, with the north of the country being much more densely populated than the south. Currently, Flanders is home to 57.5 % of the population, Wallonia 32.0 % and the Brussels-Capital Region 10.5 %. Energy policy responsibility in Belgium is divided between the federal government and the three regions (Flanders, Wallonia, and Brussels)[119]. The three regions of Belgium have adopted numerous policies and measures, to support renewable energy technologies through investment subsidies and green certificates[120]. Additionally, both the federal and regional authorities offer tax incentives for investments in renewable technologies[121].

The number of households in Belgium has increased by 20% since 1995 and the current housing stock includes a high proportion of old buildings where natural gas is the main source of heating[122]. Federal and regional governments have a long-term renovation strategy for these residential buildings. The three regions have developed their own strategies to decarbonise the heating systems in residential buildings. They have directly or indirectly obliged contractors to install solar panels or heat pumps to make sure that the new buildings are targeted for low-carbon or zero carbon emissions. They provide grant subsidies for small-scale renewable energy infrastructure, and prosumers can also benefit through a net-metering

113 https://ec.europa.eu/energy/sites/ener/files/documents/netherlands_draftnecp_en.pdf.pdf
114 https://home.kpmg/be/en/home/insights/2018/10/a-belgian-interfederal-energy-pact.html
115 http://www.brusselstimes.com/brussels/9809/brussels-government-approves-energy-pact
116 http://energy.sia-partners.com/20180404/energy-pact-belgium-cost-analysis-envisaged-ambitions
117 https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans
118 http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_ind_335a&lang=en
119 Insights in a clean energy future for Belgium, Impact assessment of the 2030 Climate and Energy Framework, May 2018, Working Paper 5-18, Federal Planning Bureau
120 https://www.ieabioenergy.com/wp-content/uploads/2018/10/CountryReport2018_Belgium_final.pdf
121 https://webstore.iea.org/energy-policies-of-iea-countries-belgium-2016-review
122 https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf

policy. There are number of other policy tools such as beneficial credit terms for investments in renewable energy projects, investment grants, tax exemptions, VAT reductions, training programmes for installers of renewables and awareness campaigns. The regions also offer investment and tax support for local research, development and demonstration programmes[123].

**Flemish Region**

Flemish Region residential buildings are looking at a range of technologies including high efficiency condensing boilers, micro cogeneration systems, heat pumps, and decentralised heating appliances with a total maximum output of 15 $W/m^2$, and connection to efficient district heating systems[124]. On 28 September 2012, the Energy Regulation was revised transposing the building obligations for heat from renewable energy into Flemish law. For schools and public office buildings the obligations apply since 1 January 2013. Accordingly, an obligation of renewable heat of at least 10 kWh per $m^2$ usable floor area of the building is introduced[125]. In June 2017, Flemish government also approved the strategy on heating & cooling which provides area-based renewable heating policies and envisaged to facilitate the use of waste heat and renewable energy, especially through district heating[126].

In terms of support, grid operators and municipalities are responsible for setting up premium schemes to encourage heating and cooling from renewable energy. The amount of premium attributed and eligible technologies differs among municipalities. In Flanders, CHP producers are also eligible for CHP certificates. The amount of CHP certificates granted for 1000 kWh of primary energy saved in a qualitative CHP-facility compared to a situation in which the same quantity of electricity or heat were produced separately is multiplied with the respective technology-specific banding factor[127].

Flanders region also committed to show an exemplary role of public authorities. The action plan ‘Bijna-energieneutrale gebouwen in Vlaanderen’ published in 2012 focuses on innovation, quality, communication, finance and energy for energy neutral buildings in cooperation with stakeholders. Further, all the new governmental buildings built after 31 December 2018 and owned by the government need to be “almost energy neutral buildings” according to law[128].

Flanders region also has its own RD&D policy – The Environment & Energy Technology Innovation Platform which was created by Flemish government in 2005. Currently, the projects under this innovation platform are divided into four categories[129]: (1) recovery of materials and recycling; (2) reuse of energy, materials and water; (3) renewable energy and materials; and (4) new business models.

The Flemish government also determines the legal framework for education and certification of installers of renewable energy technologies[130]. The quality and standards of training centres and energy experts are

[123] https://thelawreviews.co.uk/edition/the-renewable-energy-law-review-edition-1/1173953/belgium
[124] https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf
[125] http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/policy/aid/flanders-res-h-building-obligation/lastp/107/
[126] http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/policy/aid/flanders-support-of-res-h-infrastructure/lastp/107/
[127] http://www.res-legal.eu/search-by-country/belgium/tools-list/c/belgium/s/res-e/t/promotion/sum/108/lpid/107/
[128] http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/policy/aid/flanders-exemplary-role-of-public-authorities/lastp/107/
[129] http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/policy/aid/flanders-rdd-policies/lastp/107/
[130] http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/policy/aid/flanders-training-programmes-for-installers/lastp/107/

determined by the Flemish government. The training to the installers is organised in existing training centres, which are recognised by the Flemish Energy Agency (VEA). According to VEA, certificates are recognised on an individual basis after having passed specific training (32 hours plus exam). The certificates are valid for a period of 7 years. A certificate of competency is awarded if the installer has passed the exam successfully. This voluntary certification regime for installers has been introduced concerning the following technologies:

- photovoltaic installations
- solar thermal installations for domestic hot water
- solar thermal installations for the combined production of sanitary hot water and heating
- biomass stove for decentralised heating
- biomass boiler for the production of sanitary hot water or heating;
- heat pumps, except for shallow geothermal installations
- heat recovery by shallow geothermal installations

According to recent Draft National Climate energy plan[131], wider uptake of heat pumps is being encouraged by improving the cost-effectiveness in dwellings; reducing heating demand and integrating heat pumps into the electricity market and power grid. The region is adopting a more flexible approach to heat pumps so that operators could plan for lower energy tariffs during periods of peak electricity. District heating is also part of the current policy to support developing the new infrastructure to facilitate conversion and utilisation of renewable energy sources e.g. geothermal energy. The focus will continue to be on district heating that facilitates the use of renewable or residual heat, bio-methane injection and renewable energy. Thermal solar energy systems, Photovoltaic solar energy systems, Biomass (boiler, stove or qualitative CHP) and other innovative technologies are also being considered[132].

**Walloon Region[133]**

Walloon region has a range of subsidy and loan programmes to support the heating & cooling technologies. Households willing to improve the energy performance of their houses can benefit from Ecopack which provides a zero percent interest instalment loan for the installation of heat pumps, biomass boilers, solar water heaters as well as pellet wood stoves. The zero-per cent interest loan is granted for the construction of at least one energy-saving work. The loanable amount lies between € 1,000 and € 30,000, and is repayable over up to 15 years. The credit committee determines the repayment term depending on the financial situation of the applicant[134].

*Subsidy (Primes Énergie)[135]:* The installation of heating plants through biomass, solar thermal energy (solar water heaters), shallow geothermal energy, aerothermal or hydrothermal heat pumps is eligible for this Primes Énergie subsidy from 1 April 2015. Subsidy amounts were slightly modified from 1 March 2018. The subsidy amounts to € 1,750 is available for the installation of a fully automated biomass boiler and

131 https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf
132 https://ec.europa.eu/energy/sites/ener/files/documents/belgium_en_version.pdf
133 https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf
134 http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/promotion/aid/wallonia-loan-ecopack/lastp/107/
135 http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/promotion/aid/wallonia-subsidy-primes-energie-2012-1/lastp/107/

also for the installation of a fully automated heat pump in a dwelling. The amount of subsidy for biomass heating plants or heat pumps cannot exceed 70% of the total installation cost (VAT included). There is also € 1,500 subsidy amount available for the installation of a solar water heater in a dwelling where again the amount of the subsidy for solar water heaters cannot exceed 70 % of the total installation costs (VAT included).

*Subsidy (Aide à l'investissement):* Through this subsidy programme, Walloon region provides investment assistance for companies to support renewable energy projects – biogas and biomass CHP plants, biomass heating plants, and solar thermal installations and geo thermal installations. The minimum investment costs eligible for the investment assistance is around € 25,000. The subsidy is calculated on the basis of the additional costs borne by companies compared with the costs of conventional energy production plants with the same capacity. The amount of subsidy differs according to the company based on the SME or large company status[136].

*Subsidy (Subventions UREBA)[137]:* The Walloon region provides UREBA subsidies which aim at supporting public bodies such as towns and provinces in their efforts towards using renewable energy in the buildings. The material as well as the installation of renewable energy plants for the production of heat for the exclusive use of the building are eligible. The minimum investment costs shall amount to at least € 2,500. The subsidy amounts to 30 % of the investment costs (inc. VAT). However, in case the investments are subject to other support schemes accounting for over 40 % of the eligible amount of the UREBA subsidies, then the percentage is based on the share of investments which is not covered by the other subsidies.

In the recent draft NECP[138], Walloon region has a significant focus on improving the energy efficiency of homes. However, a range of new innovative technologies are being explored (and supported) based on the following factors:

- available potential (space, resources, waterways, land, etc.);
- type of project, ideally integrated with industrial/economic activities;
- cost of production and expected future development;
- socioeconomic implications (jobs);
- environmental impact (recoverable by-products, waste management, etc.);
- whether it is variable or constant;
- the overall trend of current developments.

By 2030, renewable heat production will cover around 25% of heat consumption for all applications combined. This target will be achieved using geothermal energy, solid biomass (wafer, pellets, boilers, stoves or cogeneration), biogas (all sources combined), tertiary and residential heat pumps and, to a lesser extent, solar thermal energy. Natural gas is considered a transitional fuel and is therefore will be part of the 2030 mix[139].

136 http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/promotion/aid/wallonia-subsidy-aide-a-linvestissement-1/lastp/107/
137 http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/promotion/aid/wallonia-subsidy-subventions-ureba-1/lastp/107/
138 https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf
139 https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf

**Brussels-Capital Region**

The use of renewable energy in the region is expected to change significantly between 2021 and 2030. Government of Brussels-Capital Region has also developed its own regional section of Energy & Climate Plan[140]. Currently, Brussels Capital Region provides energy subsidies to residential buildings (also to industry and service sector buildings) which are allocated based on income level for renovation of buildings.

Energy subsidy scheme - Primes énergie 2018

A range of heat pump technologies such as air-source heat pumps for the production of heat and/or domestic hot water, geothermal heat pumps for production of heat, solar thermal systems for the exclusive production of domestic hot water, and hydrothermal heat pumps for production of heat are supported through this energy subsidy scheme - Primes énergie 2018)[141]. This subsidy is allocated according to the income level and there are three level of subsidies possible:

- Base income: > € 67,050.72 for singles and > € 82,050.72 for couples
- Middle income: € 33,525.36 - 67,050.72 for singles and € 48,525.36 - 82,050.72 for couples
- Low income: < € 33,525.36 for singles and < € 48,525.36 for couples

The subsidy is increased by 10 % for residential buildings situated within a Housing and Renovation Development Area. Solar water heaters as well as heat pumps for the production of heat and sanitary hot water can be supported by the energy subsidies.

*For solar thermal systems for 2017:* Base income: € 2,500 EUR per m² up to 4m² and € 200 per m² above; Middle income: € 3,000 per m² up to 4m² and € 200 per m² above; Low income: € 3,500 per m² up to 4m² and € 200 per m² above. The amount of the subsidy cannot exceed 50 % of the installation costs. In residential buildings, the amount of the subsidy is calculated according to the number of flats benefiting of the solar water heater.

*For aerothermal heat pumps in residential buildings for the production of sanitary hot water:* Base income: € 1,400 per dwelling; Middle income: € 1,500 per dwelling; Low income: € 1,600 per dwelling. The amount of the subsidy for residential buildings cannot exceed 50 % of the installation costs.

*For aerothermal, hydrothermal and geothermal heat pumps for heat production in residential buildings for 2016*: Base income: € 4,250 per dwelling; Middle income: € 4,500 dwelling; Low income: € 4,750 dwelling. The amount of the subsidy for residential buildings cannot exceed 50 % of the installation costs. For service sector buildings, the subsidy amounts to 25 % of the eligible costs.

[140] https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf
[141] http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/promotion/aid/national-subsidy-primes-energie-2012/lastp/107/

Subsidy (Aide à l'investissement)

This subsidy provides investment assistance for companies which develop environmental projects which includes investments in renewable energy system[142]. Eligible are investments in heat pumps for the production of heat as well as biogas and biomass CHP and tri-generation plants for the production of heating, cooling and electricity. Moreover, the eligible investment shall amount to at least € 7,500 and shall concern investments planned within the Brussels-Capital region. The amount of the investment assistance depends on the size of the company: Micro and small enterprises: 40 % of the eligible costs; Medium enterprises: 40 % of the eligible costs; Large enterprises: 20 % of the eligible costs

The training centre of the Brussels capital region currently does not offer training programmes for installers of renewable energy devices. However, training programmes are provided by several Walloon and Flemish training centres and certificates issued by other EU members states are acknowledged by the Brussels-Capital Region[143].

According to recent draft National Energy & Climate Plan, during the period 2021-2030, the Brussels Government will examine the issue of mains gas and consider the possibility of a ban on the installation of cooking, heating and domestic hot water appliances that use natural gas or butane/propane from 2030. Government will also work with industry, the Federal Government and neighbouring Regions to develop an action plan by 2030, with a view to phasing out the gas distribution network in the Brussels region by 2050[144].

## 5.4 France

According to the Energy Market Barometer Report published by Grenoble Ecole de Management[145] which explores the opinion of French Energy Experts reports that the residential building stock is the sector with the highest potential to contribute to the French Energy Transition Targets, and building codes and subsidies will be the most important drivers for thermal renovation of buildings. Compared to other EU countries, the average performance of its building stock in terms of energy consumption is significantly poorer. For example, the energy consumption per $m^2$ for space heating for a French dwelling is 50% higher compared to a Dutch dwelling when adjusted for differences in climate conditions[146].

The French government has a number of support schemes to decarbonise the heating sector. The Heat Fund (Fonds Chaleur) supports the production of heat through renewable energy plants as well as the use of district heating[147]. The Thermal Regulation 2012 also mandates to use renewable energies in family houses[148]. It applies to all new buildings for which the building permit was filed after 1st January 2013. Buildings must have primary energy consumption of below 50 kWhPE/m²/year on average which can relate to consumption for heating, cooling, lighting, generating hot water and auxiliary systems (pumps

[142] http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/promotion/aid/brussels-subsidy-aide-a-linvestissement-1/lastp/107/
[143] http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/policy/aid/brussels-training-programmes-for-installers/lastp/107/
[144] https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf
[145] https://en.grenoble-em.com/sites/default/files/public/kcfinder/files/barometre-energie-ete-2018-EN.pdf
[146] http://theconversation.com/france-the-road-to-a-low-carbon-building-sector-by-2050-will-be-a-long-one-103485
[147] The supply of heat through a district heating networks can be subject to a reduced VAT of 5.5%.
[148] http://www.res-legal.eu/search-by-country/france/tools-list/c/france/s/res-hc/t/policy/sum/132/lpid/131/

and ventilators). Furthermore, this threshold is modulated according to geographic location, altitude, type of building use, average surface area of accommodation and GHG emissions[149].

Generation of heat through renewable energy plants is also promoted through energy subsidies, tax regulation mechanisms as well as through the granting of a zero percent-interest loan which are briefly explained in next few paragraphs.

A national programme called "habiter mieux" has been introduced to support households with low income in the thermal renovation of their buildings. The National Agency for Housing (ANAH - Agence Nationale pour l´Habitat) is in charge of the implementation of the support programme. This subsidy is given in form of a premium, which can only be granted in addition to a subsidy of the National Agency for Housing, provided the renovation works improve the energetic performance of the housing unit by at least 25% for homeowners, and at least 35% for landlords and associations of co-owners (compared to conventional energy consumption)[150]

The production of heat from renewable energy sources is promoted through several tax incentives. A certain percentage of investments in renewable energy technologies can be deducted from income tax - called the tax credit programme. This initially ran until the end of 2012 but for certain installations it has been extended until the end of 2019[151].

Heat generation installations in buildings are eligible for a reduced VAT rate which applies to services, equipment and delivery. The purchase of these installations by private individuals is indirectly promoted. In order for the equipment to be eligible, it shall be delivered and installed by the same company (either directly by this company or by a sub-contractor), and the equipment and the installation works shall be listed on the same invoice. The renewable energy technologies such as boilers, heat pumps, fireplace inserts, wood burning stoves, solar water heaters are eligible under this scheme[152].

The government has also introduced the zero percent interest loan for housing renovation, where reduced advanced cash payments and interest makes improving housing energy performance more affordable.

In France, local authorities are responsible for the public distribution of heating & cooling[153]. In order to promote the use of renewable energies, local authorities are entitled to classify heating networks located in their area. Grid classification is also a way of identifying zones in which any new installation must be connected to the grid, providing that, in particular, at least 50 % of the grid supply comes from renewable or recovered energy[154]. The Programmation pluriannuelle de l'énergie, PPE also sets out objectives for 2018 and 2023 for developing renewable energy and recovery within district heating and cooling which are also listed in their National Energy Efficiency Action Plan[155]. New and renovated buildings located

---

149 https://www.iea.org/policiesandmeasures/pams/france/name-50424-en.php
150 http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/promotion/aid/subsidy-aide-habiter-mieux/lastp/131/
151 http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/promotion/aid/tax-regulation-mechanism-credit-dimpot-developpement-durable/lastp/131/
152 http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/promotion/aid/tax-regulation-mechanisms-ii-value-added-tax-reduction-1/lastp/131/
153 https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/ca-res_working_group_publication_no_4_en.pdf
154 https://ec.europa.eu/energy/sites/ener/files/documents/CogenerationheatReportFrance_en.pdf
155 https://ec.europa.eu/energy/sites/ener/files/documents/CogenerationheatReportFrance_en.pdf

within a classified area are obliged to be connected to the heating network[156]. The application for the classification of a heating network shall be submitted by the owner of the heating network. It shall contain a feasibility study, as well as information regarding the economic and technological performances of the heating network. The service area of the classified heating network is defined as a priority development area. Heat production plants with a capacity over 30 kW installed in new buildings as well as in buildings subjected to significant renovations and located within priority development areas are obliged to be connected to the heating network. The heat production plant can only be connected to the heating network if the connecting costs are below the tariffs set by the territorial collectives for each priority development area. The costs related to the connection to a heating network as well as all the related expenses shall be borne by the end consumer[157].

The French government also has certification schemes for renewable energy technologies/installations and different types of training programmes for the installers. The main French certification organisation AFNOR (Association Francaise de Normalisation) delivers certification labels[158] for heat pumps including aerothermal and geothermal heat pumps, biomass installations using wood charcoal, wood fuel, wood briquettes and wood pellets and solar water heaters. The label ensures the compliance to the French and European Standards as well as to technical and other requirements set by the relevant standard committee. The cost of these labellisations are borne by the applicants. In order to promote the quality installations, in the field of solar thermal energy, photovoltaic, biomass as well as heat pumps and geothermal probes, the association Qualit´EnR was established in 2006. This association was established for private households willing to install a renewable energy plant, with the aim to ensure them a quality installation. Usually, the company of the installer bears the costs of the training programme[159].

There is also a qualification programme by Qualibat which grants qualifications to professionals in the building trade, including installers of renewable energy devices. Qualibat grants certification to the professional installers of photovoltaic, solar thermal, geothermal and biomass devices[160].

In France, heating is already considered one of the priority area for sustainable development. The French government set up the RD&D programme in 2010 - "Investments for the Future" programme ("Investissements d'Avenir") which was created in order to promote the development of innovative projects in different areas, including the heating sector. The French Energy Agency ADEME is responsible for the implementation of the environmental and energy transition innovation and the agency was granted a budget of € 3.3 billion in 2014 to support innovative projects for the developments of smart grid and renewable energies. In 2018, ADEME further received a budget of € 540 million and, in 2019, the budget would total around € 761 million[161]. On the basis of strategic roadmaps, the ADEME publishes call for expression of interest for companies.

156 Renewable energy policy database and support – RES-LEGAL EUROPE National profile: France, http://www.res-legal.eu/search-by-country/france/

157 http://www.res-legal.eu/search-by-country/france/tools-list/c/france/s/res-hc/t/gridaccess/sum/132/lpid/131/

158 http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/policy/aid/certification-programmes-for-res-installations-nf-pac/lastp/131/

159 http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/policy/aid/training-programmes-for-installers-qualitenr/lastp/131/

160 http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/policy/aid/training-programmes-for-installers-qualibat/lastp/131/

161 http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/policy/aid/rdd-policies-fonds-demonstrateur/lastp/131/

# 6. Key technologies and policy consideration in leading countries

This section presents the key heat supply technologies for the decarbonisation of the heating sector. A list of important heat technologies which are under consideration for domestic heat decarbonisation is summarised in Table 6.1. CHP, district heating and heat pump technologies are most widely discussed and being considered for policy support in these selected countries. To find out the best practices and policies, we looked at the countries that are leading the implementation of these three key technologies. We have also presented some market related statistics and discussed some of the barriers that these countries have faced in promoting these technologies.

Table 6.1: Key technologies for domestic heating decarbonisation

| Technology | Characteristics and application |
|---|---|
| Co-generation / Combine heat and power | A micro-CHP plant can be installed in an individual house to replace the gas central heating boiler and provide the majority of the family's electricity needs in addition to heat and hot water. There are different types here – reciprocating engine (typical), micro-turbine (not commercial), Stirling engine (trials not fully successful), and fuel cells (requiring $H_2$ or natural gas reforming) |
| District heating /Heat network | It is a method of delivering thermal energy in the form of heat or hot water through a network of highly insulated pipelines. It can help integrate high levels of CHP, waste heat and renewables, and can provide significant economies of scale. In many countries it is seen as a means of both improving energy efficiency and renewable deployment[162]. District heating networks also have the greatest potential for the development of co-generation[163]. |
| Electrification of heating / Heat pumps | Homes can have heat pumps supplied with electricity for heating purposes.<br><br>(i) Ground Source Heat Pumps and Air Source Heat Pumps are the two key available technologies. Surface water source heat pump (harnessing energy from the sea, rivers, canals and lakes) is also being recognised as key heat pump technology as it could be more efficient than air source heat pump because river is warmer than the air in winter[164] [165].<br><br>(ii) Gas fired heat pump is another efficient heat pump technology and it does not use harmful refrigerants like |

[162] https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf
[163] https://www.sciencedirect.com/science/article/pii/S1364032116301149
[164] https://www.cibse.org/getmedia/caafced3-e548-4ec0-b63b-55b237d49cab/CP2-A-guide-for-owners-v1-2-(no-bleeds).pdf.aspx
[165] https://www.icax.co.uk/SWSHP.html

| | |
|---|---|
| | electric heat pumps[166]. It can be fully powered by biogas[167]. The other major differences with electrical driven heat pumps is that part of the heat released by the engine is recovered and used for heating the water[168].<br><br>(iii) Direct electrical resistance heating may also be viable where excess renewably generated electricity is available, particularly in conjunction with DHW storage. This should only be considered when other technologies are not viable. |
| Hybrid heat pumps (in combination with gas boiler) | Hybrid heat pump system uses a combination of renewable energy, biomethane, hydrogen and fossil fuels to heat the home. This can comprise a heat pump (ASHP or GSHP), and a traditional gas, oil, or LPG fuelled boiler[169]. |
| Repurposing of existing gas grid for use with hydrogen or biogas | Repurposing the gas grid to transfer higher proportions of hydrogen or biogas could be a route to deliver extensive heat decarbonisation. While hydrogen presents significant new challenges, the injection of bio-methane is a feasible early option. |
| Biomass boiler | Biomass boilers can be used to fulfil domestic space heating and hot water requirement. Biomass fuel can be generated quickly from local agriculture and forestry activity although its sustainability in question because of air pollution. Biomass boiler has a slower response time as compared to oil or gas heating system and it requires more space and more maintenance[170] [171]. |
| Solar Thermal | The solar thermal technology could be used to support hot water and space heating demand either directly in the building or via a district heating network[172] [173]. While currently there is not much evidence as a large scale solution, it can nevertheless provide a source of heat in large scale GSHP storage systems. |

For detailed policy analysis, we have considered only three key technologies – Co-generation system, heat pump and district heating as these have been most widely considered technologies across the identified country case studies.

## 6.1 Combined heat and power

166 https://www.gasnetworks.ie/home/gas-benefits/natural-gas-appliances/gas-fired-heat-pump/
167 http://www.ehi.eu/heating-technologies/gas-heat-pumps/
168 https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/proheatpump_report_on_renewables_and_heat_pumps.pdf
169 https://smartrenewableheat.com/blog/what-is-hybrid-heat-pump-system-dual-fuel/
170 https://www.seai.ie/resources/publications/Biomass-Boilers-Implementation-Guide.pdf
171 https://www.seai.ie/resources/publications/Biomass-Boilers-Technology-Guide.pdf
172 https://vbn.aau.dk/ws/portalfiles/portal/265304574/IEA_SHC_Task_52_STA_AAU_report_20170914.pdf
173 http://www.estif.org/fileadmin/estif/content/publications/downloads/Potential%20of%20Solar%20Thermal%20in%20Europe_Full%20version.pdf

Combined heat and power, also known as co-generation system, is an approach applying to existing technology which can produce heat and electricity in a single integrated system. Heat that is normally wasted in conventional power generation is recovered as useful energy, which avoids the losses that would otherwise be incurred from separate generation of heat and power. While the conventional method of producing usable heat and power separately has a typical combined efficiency of 45 percent, CHP systems can operate at levels as high as 80 percent[174] [175]. There are usually two types of CHPs based on operating priorities – heat led and electricity led. CHPs are heat led in most cases and it means that the plant runs when the heat is needed, and the resulting power can be fed to the grid, if supportive regulations are in place.

CHP installation vary in type, depending on the end user[176]: very large installations, medium installations, and small-scale installations called micro-CHPs. Micro-CHPs are mainly considered for domestic applications and it meets the need for heat generation first with the secondary product being electricity. Micro-CHPs are being considered as future replacement of the present domestic heating systems, typically with electric capacities of less than 50 kW[177]. Usually, unlike typical CHP projects, micro-CHP projects are sized not to exceed heating requirements[178].

The implementation of micro CHP systems for residential space heating and hot water production is becoming popular in several countries, especially in Germany, United Kingdom and the Netherlands[179]. As per a recent study, growth in domestic micro-CHP was strong recently in several European countries, representing 36% of European installed CHP capacity in Austria, Germany and France[180].

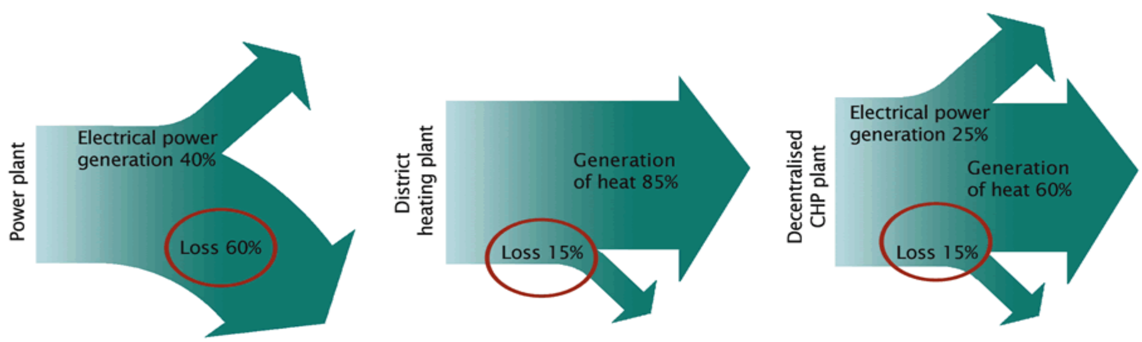



Fig 6.1: why CHP is attractive? (Source: https://passivehouseplus.ie/articles/renewable-energy/new-power-generation)

The main competing technologies for the micro-CHP applications are internal combustion engine (ICE), external combustion engine (ECE), and fuel cells. Although some micro-scale CHP technologies are primary

[174] https://aceee.org/topics/combined-heat-and-power-chp
[175] U.S. EPA (United States Environmental Protection Agency). 2013. CHP: Efficiency Benefits. http://www.epa.gov/chp/basic/efficiency.htm
[176] https://www.flogas.ie/business/business-heating/chp-combined-heat-and-power-systems.html
[177] EC (European Commission). 2004. "Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the Promotion of Cogeneration based on a Useful Heat Demand in the Internal Energy Market and Amending Directive 92/42/EEC." Official Journal of the European Union 47 (52): 50-60.
[178] https://understandingchp.com/overview/what-is-chp/micro-chp/
[179] COGEN Europe (Cogeneration Europe). 2005. The European association for the promotion of cogeneration. News archive.
[180] http://kojenturk.org/uploads/dokumanlar/Key%20Note%20Speaker%20Hans%20Korteweg-Cogeneration%20as%20Part%20of%20a%20Sustainable%20Energy%20Future.pdf

used to convert fossil fuels, like the Internal combustion engine (ICE) and micro gas turbine, it is also possible to use these technologies with renewable energy resources[181]. Among these technologies, fuel cells have better prospects in terms of performance, especially in terms of electrical efficiency. This attribute will be more important in future CHP applications when the buildings thermal efficiency will be very high and not much heat requirement would be there. In this case, when electricity efficiency will be high, households can generate higher revenues by selling electricity to the grid[182].

ACEEE (American Council for an Energy-Efficient Economy) has conducted a study on the environmental performance and economic feasibility of a 1 kWe internal combustion engine (ICE) micro-CHP system and results have presented opportunities for significant energy cost savings. The analysis has reported a simple payback period of about 4.8 years while it has been highlighted that both the running hours and price of electricity have significant effects on the payback period of the project. Micro-CHPs high initial costs (when compared to high efficiency condensing boilers), are reported as the major factor hampering market diffusion[183].

Micro-CHPs is emerging as a proven technology for energy savings and environmental benefits. Strong and stable support schemes in some market such as Germany and Slovenia have supported the uptake of this technology in last few years. However, there are still significant barriers to the growth of the micro-CHP market in many countries[184]:

- Lack of awareness among consumers, installers, utilities and policymakers
- Micro-CHPs has not been considered in the assessment of CHP potential in members' states. An approach to estimate the micro-CHP potential in member states has been explained in a report funded by Intelligent Energy Europe which explains Ireland potential as well[185].
- Unstable and/or unfavourable regulatory framework (e.g. cumbersome grid connection in France and elsewhere).
- Although EU commission, some of the national governments and industries are committed to reduce the cost of micro-CHPs, it is still very costly for residential users. There is not enough support for the upfront cost available to residential users.

CHP related data is available through EuroHeat Statistics[186] and through Co-Gen Europe[187] . The best practices related to CHP, not specifically micro-CHP, are organised according to the CODE2 regions and are available online[188]. A summary of the potential of micro-CHPs for residential application by 2030 is presented in the table 6.2 below[189]:

---

[181] https://www.ieabioenergy.com/wp-content/uploads/2019/05/T32_CHP_Report_01_2019.pdf
[182] https://read.oecd-ilibrary.org/environment/better-policies-to-support-eco-innovation/micro-combined-heat-and-power-generation_9789264096684-8-en#page6
[183] https://aceee.org/files/proceedings/2016/data/papers/1_8.pdf
[184] https://www.slideshare.net/COGENEurope/cogen-europe-presentation-on-microchp
[185] http://www.code2-project.eu/wp-content/uploads/D2.5-2014-12-micro-CHP-potential-analysis_final.pdf
[186] https://ec.europa.eu/eurostat/web/energy/data
[187] http://kojenturk.org/uploads/dokumanlar/Key%20Note%20Speaker%20Hans%20Korteweg-Cogeneration%20as%20Part%20of%20a%20Sustainable%20Energy%20Future.pdf
[188] http://www.code2-project.eu/north-western-european-region/
[189] http://www.code2-project.eu/wp-content/uploads/D2.5-2014-12-micro-CHP-potential-analysis_final.pdf

Table 6.2: Sales and stock of residential micro-CHP systems in the in 2030 according to the expected potential scenario

| Country | Sales in 2030 | Stock in 2030 |
|---|---|---|
| Belgium | 89 | 488 |
| France | 289 | 1323 |
| Ireland | 35 | 156 |
| Netherlands | 303 | 1843 |
| UK | 763 | 3717 |

Following are some of the key policies and strategies considered for promotion and adoption of micro-CHPs for domestic applications (Source: OECD Report[190], PhD thesis by Arash Rezaeian[191]). Germany has the highest penetration of micro-CHPs and some of their key strategies are also presented. The regulatory framework related to micro-CHP application in Germany, is supportive but at the same time, very complicated. It depends on the application, technology type, operating time of a plant, kind of fuel it uses, output power of the plant and the ownership situation of the plant all influence the application of regulations and can led to very different results.

- **Supporting research and demonstration programmes:** Promoting and supporting micro-CHP research activities in terms of technology, component, material and evaluating the overall system performance in real operating conditions has been key strategy including Germany, France and US. Research related to reliability assessment, consumer acceptance, impact of economies of scale have also been conducted.
- **Feed-in-tariff and other regulatory support:** The most important policy in Germany is the CHP Act which provides supports by the means of feed-in tariffs and obliges the distributed network operators to buy electricity from producers. In addition, there exist many supporting acts from the central and state governments for encouraging investments and reducing the costs of investment in micro CHP plants. Micro-CHP owners receive a CHP bonus regardless of whether they feed electricity into the grid or not. In this way, the CHP Act also encourages the generators to consume the generated electricity mostly internally rather than feeding it into the grid.
  Renewable Energy Heat Act in Germany mandates the use of renewable energy in new buildings built after 1st January 2009 which provides conditions to use the biomass in a CHP plant and to produce heat come via CHP unit. As an alternative, building owners are also allowed to cover the heat demand of the building to at least 50% directly from high-efficiency CHP plants as well as district heating.
- **Loan and subsidy programmes:** Loan and subsidy programmes at the federal level, such as mini-CHP incentives and the KfW Incentive Program in Germany, provide support for investments in micro-CHP but it has also been reported that the terms and conditions and the application

[190] https://read.oecd-ilibrary.org/environment/better-policies-to-support-eco-innovation/micro-combined-heat-and-power-generation_9789264096684-8-en#page17
[191] https://d-nb.info/1082237868/34

procedure is overly complicated. The role of the state governments is as important as that of the federal government. At the state level, each German state propose attractive incentives for the promotion of highly efficient technologies including micro-CHPs. The analysis shows that the installed capacity of micro-CHP in Germany is directly related to the amount of incentives provided by each state[192].

- **Tax incentive:** Germany's energy tax law provides some tax refunds for high efficiency stationary CHP until 2 MW with an efficiency of at least 70% in case their operating hours are more than 60% of their annual capacity. According to the Electricity Tax Law, small electricity producers with production capacities of less than 2 MW, are exempt from paying electricity consumption taxes. The tax exemption is only valid if the electricity is used for internal consumption or directly delivered to end users. The value added tax act also provides some support as if the owner of a single-family house operates the CHP plant, a full deduction in VAT is usually possible.
- **Planning, governance and coordination:** Coordination with different stakeholders on developing public and private investments, strategic plans and roles of different stakeholders, developing user trust, reducing uncertainty and creating consensus has also been key policy instruments in several countries.

## 6.2 District heating or heat network

There is a wide range of variation in the penetration of district heating across Europe. Denmark, Sweden and Finland, with 50-60% of buildings supplied by district heating are the leading countries whereas the countries such as Ireland, Belgium, Cyprus, Spain, Greece, Malta Portugal, UK are either not connected or only less than 5 % citizens are connected with the district heating network[193]. In Ireland less than 0.8% of heat demand is covered by district heating. Fig. 6.2 shows the percentage of users who had access to district heating network for different countries of OECD in 2012.

Some of the policies adopted in leading countries have been discussed below:

- **Stable policy and planning:** District heating requires a high degree of local, regional or urban coordination and planning. Policy continuity, financial support and the quality of the consumer experience are reported as key characterises. For example, in UK, short-term and abruptly changing policies have created uncertainty and perceived risk for the local government and businesses[194], and therefore, there has not been enough investment in skills and supply chains. It has also raised the concerns about future risks to district heating. It has been recommended to include a package of policies rather than a single policy to support deployment of district heating. A detailed and timely heat planning has been recognised as highly useful strategy by stakeholders across a range of countries. In Denmark, local authorities are required to develop local heat strategy identifying the current and future heat demand of buildings as well as heat sources along

[192] https://d-nb.info/1082237868/34
[193] https://www.sciencedirect.com/science/article/pii/S1364032116301149
[194] https://heatandthecity.org.uk/project/heat-and-the-city/

with its socio-economic benefit analysis[195]. The Danish Heat Law of 1979 provide mandates to local authorities to connect new buildings to district heating. In Sweden, heat networks were managed by municipalities and some of the district heating systems were later sold to national and international utilities. Sweden, Germany and Norway have mandated local authorities to create local heat plans and support district heating.

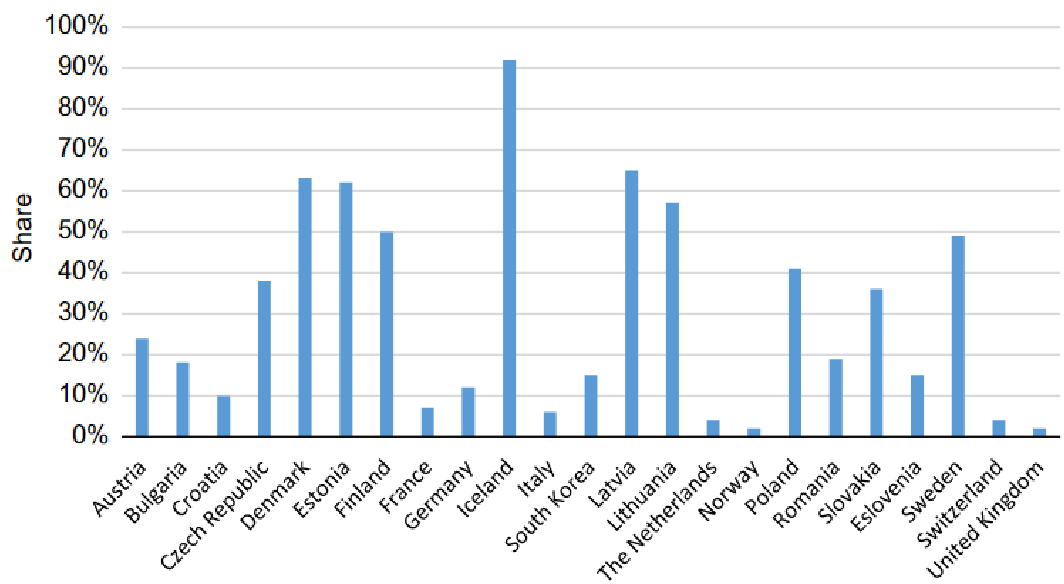



Fig 6.2: Percentage of citizens who have access to district heating networks in 2012

- **Investment subsidies:** District heating is capital intensive. It needs support in terms of investment subsidies which can be provided as a grant or loan as well as ongoing financial incentives. Stakeholders from countries where district heating is not significantly developed have reported investment grants for network development as highly important[196]. Germany, Sweden, Norway and Netherlands have seen significant investment during last couple of decades. Investment subsidies have been widely involved in the development of district heating post liberalisation. Prague's' district heating system is unusual as much of its development has taken place with no subsidy or grant. In Norway, investment subsides have been the most important measure for expanding district heating and investment of € 89 million were made during 2008-09. In Germany, investment subsidies for heat networks are available based on the length and diameter of pipes which has encouraged significant interest in planning and beginning work on district heating.

[195] https://www.researchgate.net/publication/311809970_Best_practice_in_heat_decarbonisation_policy_a_review_of_the_international_experience_of_policies_to_promote_the_uptake_of_low-carbon_heat_supply

[196] https://www.euroheat.org/wp-content/uploads/2016/04/Ecoheat4EU_Best_Practise_Support_Schemes.pdf

- **Waste heat related regulations:** Mandatory regulations requiring the use of waste heat and its coordinated planning can also encourage the development of district heating[197]. It has been very successful in Norway where waste accounts for the major share (60%) of the total energy input used for district heat production in 2015, and it has been major energy input since the mid-1980s. The waste landfill ban was introduced in Norway in 2009, and this has been an important driver for waste incineration plant investments, and the use of waste in district heat production[198]. In Sweden, the available waste heat from industry was an important factor for district heating development in some towns such as Gotherburg, where 30% of the district heat is waste heat from industry mainly from Shell's and Preem's refineries[199]. Subsidies were also considered important to recover waste heat from industries[200].
- **Technical standards:** Technical standards are important as they provided the basis for mutual trust between different stakeholders. Having design standards for district heating system will reduce the risk and uncertainty of the projects. CIBSE (Chartered Institution of Building Services Engineers) has provided guidelines regarding feasibility, design, construction, installation, operation and maintenance, and customer obligations for heat networks[201]. Technical standard will also help creating a national market for standard products for the heat networks. In Sweden, Swedish District Heating Association played an important role in setting performance and interoperability standards.
- **Pricing mechanism and consumer protection:** Price regulation can increase consumer confidence in district heating[202]. Some of the district heating leading countries such as Iceland, Norway and Denmark have already regulated prices whereas in Finland and Sweden heat prices are not regulated. Different approaches have been adopted for price setting in different countries[203]. Sweden has also mandated through law for the price transparency of the district heating and they have set up an independent District Heating Board for dispute resolution. Germany already has a standard framework for district heating related business conditions and contacts since 1980 which still continues to protect consumers. Price regulation and other consumer protection mechanism have been suggested for the countries where district heating is not yet developed, and heat planning is being used to support the infrastructure planning and development[204].

  A specific district heating marketing campaign in Sweden has been very successful in turning consumer interests towards district heating. Companies in Sweden had several meetings with local residents, arrange with the bank to offer attractive loans and having regular demonstration vehicles to show the prospective consumers how district heating operates[205].

---

[197] Organisation and governance of urban energy systems: district heating and cooling in the UK. Journal of Cleaner Production, 50, 22- 31.
[198] Nordic Heating & Cooling-Nordic Approach to EU's Heating & Cooling Strategy, Nordic Council of Ministers, 2017
[199] Nordic Heating & Cooling-Nordic Approach to EU's Heating & Cooling Strategy, Nordic Council of Ministers, 2017
[200] Introduction and development of the Swedish district heating systems - Critical factors and lessons learned, Lund University
[201] https://www.seai.ie/resources/publications/2016_RDD_79._Guide_District_Heating_Irl_-_CODEMA.pdf
[202] https://setis.ec.europa.eu/system/files/1.DHCpotentials.pdf
[203] https://norden.diva-portal.org/smash/get/diva2:1098961/FULLTEXT01.pdf
[204] http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/best-practice-in-heat-decarbonisation-policy.html
[205] https://www.researchgate.net/publication/227412975_Influencing_Swedish_homeowners_to_adopt_district_heating_system

## 6.3 Heat pump technologies

The progress of heat pump market, as expressed by sales of heat pump, is very mixed. On this basis, mature market can be identified as France, Finland, Germany, Norway, Switzerland, Sweden, Austria while the UK, Netherlands, Czech Republic, Poland and others are the developing market. Key actors in the formulation and implementation of policies to support heat pumps include government, utilities, trade associations, installers, manufacturers, the building sector and research institutes. Countries which are heat pump market leaders don't have domestic natural gas reserves such as Finland, Sweden and Switzerland. Finland and Sweden have also high insulations levels due to climatic conditions which makes it very suitable for heat pump technologies. Countries like UK and the Netherlands which have high gas connections and high gas reserves are working towards introducing supportive policies for heat pump technologies. Some of the countries like France, Germany and Italy have a high penetrations of natural gas connection and also have high deployment of heat pumps.

To get an indication of the selected countries, development of heat pump sales over the year between 2006-2014 is shown in the Table 6.3[206] and units sold by country in 19 EU countries are shown in Fig 6.2 where it can be seen the France has significantly major contribution as compared to other countries which is presumably because of low carbon electricity due to nuclear capacity on the grid.

Table 6.3: Development of heat pumps sales from 2006-2014

| Country | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|---|---|---|
| Belgium | | | | | 101% | 73% | 22% | 2% | -15% |
| France | 71% | 29% | 71% | -12% | -31% | 18% | 2% | 8% | 27% |
| Ireland | | | | | 43% | -15% | 13% | 9% | 54% |
| Netherlands | | -7% | 47% | 20% | -4% | 10% | -3% | -15% | -8% |
| UK | 149% | 103% | 125% | 92% | 14% | -1% | -3% | -1% | 6% |

[206] https://www.ehpa.org/fileadmin/red/07._Market_Data/2014/EHPA_European_Heat_Pump_Market_and_Statistics_Report_2015_-_executive_Summary.pdf

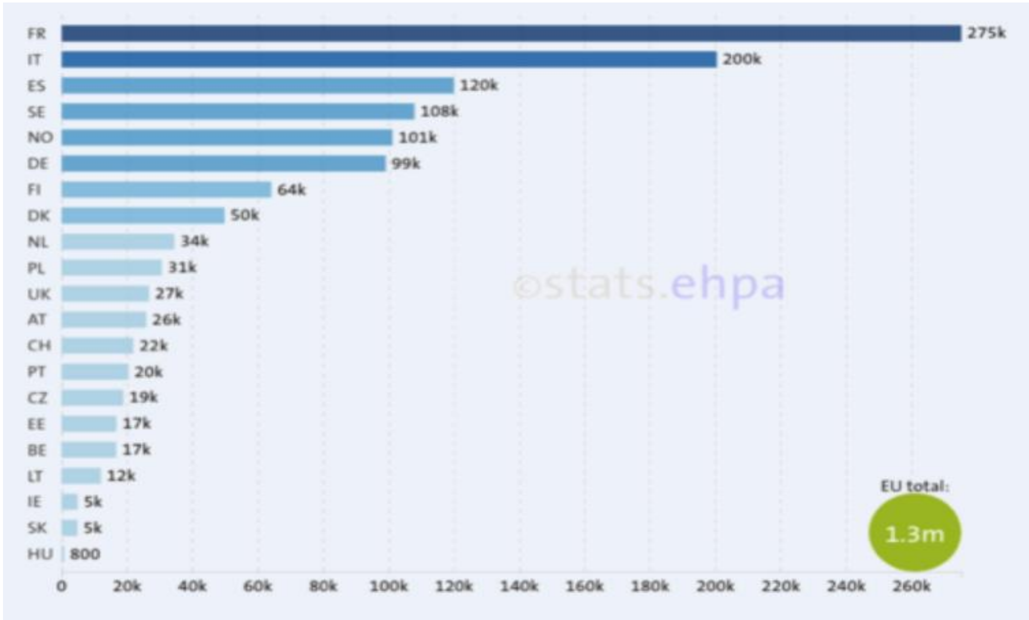



Fig 6.2: 2018 units sold by country, 19 EU countries (Source: EHPA[207])

Some of the key policy support from the leading countries are presented below:

- **Financial support:** Similar to other technologies, the high capital costs for heat pumps[208] is the primary barrier for the market uptake. Especially in the case of ground source heat pump which is approximately three to five times higher than air source heat pump, it is considered as one of the major barrier. The additional cost for the ground source heat pump installation comes from the costs of digging a ground loop into the land outside a property to absorb the heat from the ground. Despite the greater upfront cost of installing a ground source heat pump, it is more efficient when it comes to heating the home[209]. It is also important to note that air source heat pump is much more dependent on climate factors, it would have to work harder to produce heat when the outside temperature is lower.

  All the governments that are leading heat pump installations provides support in terms of grants, subsidies, tax exemptions which significantly help reducing the initial cost of equipment and its installation. Tax breaks on labour costs and capital grants to cover a certain portion of the installation cost has been the two most common financial incentives to support the uptake of heat pumps[210]. Sweden has implemented investment subsidies to incentivise the replacement of direct electric heating with heat pump technologies. Swiss government had also introduced it but it was discontinued within only two years. It is also important to highlight here that investment subsidies have been criticised severely. According to a survey conducted in Switzerland, 85% of

[207] https://www.ehpa.org/market-data/market-overview/
[208] In some cases, there is also a need of high level investments to make the homes ready for heat pump technologies.
[209] https://www.energysavingtrust.org.uk/blog/air-source-heat-pumps-vs-ground-source-heat-pumps
[210] http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/best-practice-in-heat-decarbonisation-policy.html

the people would have installed the heat pumps even if the subsidy was not available[211]. Introduction of carbon taxes on domestic fuels also encouraged the adoption of heat pumps significantly, particularly where this was combined with the use of oil-fired heating systems. Sweden strongly believes that having a stringent carbon tax has helped significantly for the growth of heat pumps in the country. There has also been a strong linkage reported between the prices of oil and gas and the heat pumps installations in several countries.

- **Technical standards:** Availability of information and advice about the right heat pump technologies from a reliable source are very important to build customer trust and confidence[212]. Switzerland and Sweden have test centres since 1980 to test the quality of the heat pump and further raise the technical standards. Sweden also developed a unique procurement programme to bring technically advanced and higher efficiency heat pumps into the market at a cheaper rate[213]. Austria, Switzerland, Sweden, Germany and other countries which are leading the heat pump market have published a number of technical standards and also introduced the 'contractor certifications and quality awards' to reduce the industry risks and build consumer confidence[214] [215]. In December 2012, EU Commission requested member states to introduce certification schemes or equivalent for ground source heat pump installers. Training and certification for designers and installers has been identified as key step to improve the heat pump performance improvement and its market uptake[216] [217].
- **Consumer awareness and engagement:** A research published by Delta Energy & Environment in January 2015 highlights the following four key issues regards to consumers with the heat pump market penetration[218]:
    - Customer awareness of heat pump technology is very low.
    - Mistrust of heat pumps still pervades amongst both installers and end-users
    - Installers are not focusing on heat pumps because there is insufficient "customer pull"
    - The customer proposition for heat pumps is not easy to sell - installers want to be able to offer more attractive propositions with financing options

There has been number of strategies considered in countries with higher uptake of heat pumps[219] [220]. In Germany, utilities have been driving the heat pump market and they have helped set up the German HP association which has taken the information campaigns and marketing events at the

211 https://www.delta-ee.com/downloads/1-research-downloads/39-heat-research/1046-delta-ee-report-for-danish-energy-agency-policy-measures-for-heat-pump-market-growth.html
212 https://www.sciencedirect.com/science/article/pii/S030626191400542X
213 KISS, B., NEJJ, L. & JAKOB, M. 2014. Heat pumps: a comparative assessment of innovation and diffusion policies in Sweden and Switzerland. In: GRUBLER, A. & WILSON, C. (eds.) Energy technology innovation: Learning from historical successes and failures. Cambridge: Cambridge University Press.
214 http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/best-practice-in-heat-decarbonisation-policy.html
215 RIZZI, F., FREY, M. & IRALDO, F. 2011. Towards an integrated design of voluntary approaches and standardization processes: An analysis of issues and trends in the Italian regulation on ground coupled heat pumps. Energy Conversion and Management, 52 3120-3131.
216 http://hpc2017.org/wp-content/uploads/2017/05/P.2.7.13-GEOTRAINET-Training-for-ground-source-heat-pump-designers-and-installers.pdf
217 http://sepemo.ehpa.org/uploads/media/D6_9_8_Nowak_HPC2_5.pdf
218 https://www.delta-ee.com/downloads/1-research-downloads/39-heat-research/747-overcoming-the-human-barriers-to-heat-pumps.html#
219 https://www.delta-ee.com/downloads/1-research-downloads/39-heat-research/747-overcoming-the-human-barriers-to-heat-pumps.html#
220 https://www.ehpa.org/fileadmin/red/03._Media/03.02_Studies_and_reports/EHPA_BestPractice_FINAL_3.pdf

community level. Utilities have worked closely with the local government to offer online information portals which includes recommended installers in the local area and other detail. On the other hand, Swedish government has taken a significant step in setting up a Heat Pump Court to bring installers into account making false claims and boosting consumer confidence. In Denmark, government has funded a number of demonstration projects to examine innovation business models to unlock the market growth for heat pumps. Danish Energy Agency has also considered other policy instruments such as a strong and community level information campaign and subsidies to increase the heat pump installations. The Swiss heat pump promotion programme has also considered an extensive information dissemination in each Swiss region through community events with municipal utilities, installers and manufacturers. TV advertising has also been a key strategy in Switzerland.

- **Building regulations:** Research published by Frontier Economics has reported that in Switzerland and Germany, renewable energy standards on new buildings have helped drive uptake of heat pumps[221]. In Zurich, having a requirement that 20% hot water and space heating to be met by renewables such as heat pumps, biomass or solar water heater or through extra insulation has created a strong incentive for heat pumps. In UK, having a minimum requirement for renewable energy in buildings and aligning renewable heat incentive requirements with building regulations has been effective in terms of unlocking the market growth of heat pumps[222]. Having a national and regional building regulations for minimum energy efficiency requirements in new buildings contributed to boost the heat pump sales in Italy as well[223]. In future, according to delta-ee research[224], cities will be going beyond the minimum regulations and that will further push the market for heat pumps[225].

[221] https://www.theccc.org.uk/wp-content/uploads/2013/12/Frontier-Economics-Element-Energy-Pathways-to-high-penetration-of-heat-pumps.pdf
[222] https://www.openaccessgovernment.org/uk-heat-pump-market-is-growing-again/44301/
[223] http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/best-practice-in-heat-decarbonisation-policy.html
[224] https://www.delta-ee.com/delta-ee-blog/uk-heat-pump-market-likely-to-double-by-2025.html
[225] https://www.delta-ee.com/delta-ee-blog/uk-heat-pump-market-likely-to-double-by-2025.html

# 7. Conclusion

In this study, we have conducted a comparative analysis of similar-climate countries and also discussed policy support of the countries which are leading key domestic heat decarbonisation technologies, and how these learnings could be explored for its possible application in the Irish context.

Heat is the most valuable service in terms of health and well-being. Where electricity adds greatly to quality of life, heat is fundamental to life and therefore, the value proposition for heat needs to be re-aligned to societal needs. Low carbon heat is difficult because heat is usually at low cost; the marginal cost of fossil fuels is low and the capital costs are known. The capital costs for low-carbon heat technologies are also either high or unknown (except perhaps biomass boilers and Air Source Heat Pump[226]), and also the marginal cost of renewable fuels is currently high. Additionally, the cost required on existing homes to make them suitable for heat pumps is also understood to be high. So, the returns with low-carbon heat technologies are very low without high rates of subsidy. When compared to renewable electricity[227] (falling capital costs, zero marginal costs, high value), renewable heat is in a very difficult position.

Tailor made solutions need to be developed and local authority involvement is strongly encouraged. Policy intervention has a large role to play here, but at the same time, customer engagement through more effective propositions is also very critical**.** There is a greater need to build confidence among consumers about the new type of heating system and technologies and further providing better consumer protection as any lack or failure of consumer services and protections can exacerbate fuel poverty. There is definitely a significant investment requirement towards renewable electricity and gas generation which can bolster the uptake of appropriate technologies in the heating sector. It is important to acknowledge that there is no single solution and it would not be appropriate to develop a technology specific policy or support, and therefore, we need look for a combination of technologies that can help meet our heating decarbonisation target. Government also need to closely coordinate with technology associations, consumer associations, and other community partnerships such as with trades associations, manufacturers, and energy suppliers for collective effort and deployment of low-carbon heating technologies.

Overall, it was found that the selected similar-climate countries are still exploring the best possible technology or technology mix for their country, while there is some support already being provided on proven technologies. There has been no detailed analysis on comparing implementation cost of these different technologies, total system cost or cost of abatement of heating decarbonisation which is important to be carried out.

[226] The current technology is to be phased out. The cost of heat pumps using natural refrigerants is also unknown and is yet to be proved.
[227] Issue of intermittency and storage with renewable electricity still need to be addressed.

# References


- A Future Framework for Heat in Buildings, BEIS, UK, December 2018, Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762546/Future_Framework_for_Heat_in_Buildings_Govt_Response__2_.pdf
- A Guide to District Heating in Ireland, October 2016, Available at: https://www.seai.ie/resources/publications/2016_RDD_79._Guide_District_Heating_Irl_-_CODEMA.pdf
- ACEEE, American Council for an Energy Efficient Economy Website, Page on Combined Heat and Power, available online at: https://aceee.org/topics/combined-heat-and-power-chp
- Allan Curran Architects Blog (No Date) EPC versus BER – how does the house we designed in Co. Fermanagh rate? Available online at: http://allanarc.com/434-2/ accessed May 2019
- An EU Strategy on Heating and Cooling, Communication from the Commission to the European Parliament, The Council, The European Economic and Social Committee and The Committee of the Regions, February 2016, Available at: https://ec.europa.eu/transparency/regdoc/rep/1/2016/EN/1-2016-51-EN-F1-1.PDF
- Anciaux, S., (2019), Flanders:RES-H building obligation published in SRES Legal Legal Sources on Renewable Energy, available online at: http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/policy/aid/flanders-res-h-building-obligation/lastp/107/
- Andrews, D., Riekkala, A.K., Tzimas, E., Serpa, J., Carlsson, J., Pardo-Carcia, N., Papaioannou, I., (2012), Background Report on EU-27 District Heating and Cooling Potentials, Barriers, Best Practice and Measures of Promotion, published by the Joint Research Centre, Report EUR 25289 EN, available online at: https://setis.ec.europa.eu/system/files/1.DHCpotentials.pdf
- Appunn, K., (2018), Sector coupling – Shaping an integrated renewable energy system, published on the Clean Energy Wire Website 25th of April 2018; https://www.cleanenergywire.org/factsheets/sector-coupling-shaping-integrated-renewable-power-system, Accessed May 2019
- Arcipowska, A., Anagnostopoulos, F., Mariottini, F., Kunkel, S., (2014), Energy Performance Certificates Across the EU, published by the Buildings Performance Institute Europe (BPIE) ISBN: 9789491143106, available online at: http://bpie.eu/publication/energy-performance-certificates-across-the-eu/ ISBN: 9789491143007
- Arvaniti, E., Gray, Cl, & Higson, A., (2015), Energy, fuels and environmental policies relevant to algae production and use in NW Europe, Report WP2A8.01, output of the Energetic Algae EnAlgae INTERREG project, available online at: http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/promotion/aid/tax-regulation-mechanisms-ii-value-added-tax-reduction-1/lastp/131/
- Balcombe, P., Rigby, D., Azapagic, A., (2014), Investigating the importance of motivations and barriers related to microgeneration uptake in the UK, published in Applied Energy, Volume 130, No 1, pp 403-418, Available at: https://www.sciencedirect.com/science/article/pii/S030626191400542X
- Belgian Government (2018), Belgium's Integrated National Energy and Climate Plan 2021-2030 (Courtesy Translation Document), available online at: https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf
- Belgium National Plan - Nearly Zero Energy Building, Brussels, September 2012, Available at: https://ec.europa.eu/energy/sites/ener/files/documents/belgium_en_version.pdf

- Belgium's National Energy & Climate Plan 2021-2030 (Draft), December 2018, Available at: https://ec.europa.eu/energy/sites/ener/files/documents/ec_courtesy_translation_be_necp.pdf
- Bennett, J. (2017), Brussles Government approves Energy Pact, published in The Brussles Times, available online at: http://www.brusselstimes.com/brussels/9809/brussels-government-approves-energy-pact
- Best Practise Support Schemes, Intelligent Energy Europe, Available at: https://www.euroheat.org/wp-content/uploads/2016/04/Ecoheat4EU_Best_Practise_Support_Schemes.pdf
- Bio Energy Supply in Ireland, SEAI, 2015, Available at: https://www.seai.ie/resources/publications/Bioenergy-Supply-in-Ireland-2015-2035-Summary-Report.pdf
- BPIE (2010), Energy Performance Certificates across Europe, From Design to implementation, published by the Buildings Performance Institute Europe (BPIE) available online at: http://bpie.eu/wp-content/uploads/2015/10/BPIE_EPC_report_2010.pdf ISBN: 9789491143007
- Castadot, R., Peeters, V., & Calderan, J., (2018), Energy pact Belgium: Cost analysis of the envisaged ambitions, published in Energy Outlook by Sia Partners, available online at:http://energy.sia-partners.com/20180404/energy-pact-belgium-cost-analysis-envisaged-ambitions
- Catapult Energy Systems, Using the connected home to deliver low carbon energy services that people value, Online News Article, February 2018 https://es.catapult.org.uk/news/the-fight-against-carbon-howtechnology-can-help-us-heat-our-homes-the-cleaner-way/
- Co-generation as part of Sustainable Energy Future, May 2018, Turkey, Available at: http://kojenturk.org/uploads/dokumanlar/Key%20Note%20Speaker%20Hans%20Korteweg-Cogeneration%20as%20Part%20of%20a%20Sustainable%20Energy%20Future.pdf
- CIBSE, Using surface water source heat pumps: Codes of Practice for the UK, Harnessing energy from the sea, rivers, canals and lakes, a guide for building owners and developers, 2016, available online at: https://www.cibse.org/getmedia/caafced3-e548-4ec0-b63b-55b237d49cab/CP2-A-guide-for-owners-v1-2-(no-bleeds).pdf.aspx
- ClimateXchange, Strategy for heat – The Netherlands, available online at: https://www.rijksoverheid.nl/actueel/nieuws/2015/04/02/kabinet-stimuleert-overstap-van-gas-naar-duurzame-warmte
- Codema, Dublin's Energy Agency Official Website Site – Tallaght District Heating Scheme Web Page, available online at: https://www.codema.ie/projects/local-projects/tallaght-district-heating-scheme/, accessed May 2019
- COGEN Europe (Cogeneration Europe), The European association for the promotion of cogeneration. News archive, https://www.cogeneurope.eu/ , Accessed on 16 February 2019
- Co-generation Heat Report France, Note from French Authorities, December 2015, Available at: https://ec.europa.eu/energy/sites/ener/files/documents/CogenerationheatReportFrance_en.pdf
- Cogeneration Observatory and Dissemination Europe, Project Website: http://www.code2-project.eu/north-western-european-region/ , Accessed on February 15, 2019
- Colmenar-Santos, A., Rosales-Asensio, E., Borge-Diez, D., & Balens-Piero, J.J., (2016), District heating and cogeneration in the EU-28: Current situation, potential and proposed energy strategy for its generalisation, published in Renewable and Sustainable Energy Reviews, Volume

62, pp621-639, available online at: https://www.sciencedirect.com/science/article/pii/S1364032116301149

- Community Energy Hub (2019), Web Resources, Community-led Heat Projects: A Toolkit for Heat Networks, available online at:
- Community Led Heat Projects: A Toolkit for Heat Networks, Accessed Mat 2019, Available at: https://hub.communityenergyengland.org/resources/resource/151/community-led-heat-projects-a-toolkit-for-heat-net/
- Country Pictures: Belgium, The Environmental Change Institute, University of Oxford, Available at: https://www.eci.ox.ac.uk/research/energy/downloads/countrypictures/cp_belgium.pdf
- Country Pictures: France, The Environmental Change Institute, University of Oxford, Available at: https://www.eci.ox.ac.uk/research/energy/downloads/countrypictures/cp_france.pdf
- CSO (2014), Domestic Building Energy Ratings Quarter 1 2014, available online at: https://www.cso.ie/en/media/csoie/releasespublications/documents/environment/2014/DberQ12014.pdf Accessed May 2019
- CSO (2019) Census of Population 2016 – Profile 1 Housing in Ireland, official website of the Central Statistics Office of Ireland
- CSO (2019) StatBank Profile 1 Housing in Ireland, E1005: Private Households in Permanent Housing Units 2011 to 2016 by Type of Private Accommodation, County and City, Period in which Built and Census Year. Cork: Central Statistics Office. Official website of the Central Statistics Office of Ireland.
- Clean Growth – Transforming Heating, Overview of Current Evidence, December 2018, published by the Department for Business, Energy & Industrial Strategy, London. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/766109/decarbonising-heating.pdf
- Heat Networks: Ensuring Sustained Investment and Protecting Consumers, published by the Department for Business, Energy & Industrial Strategy, London. Available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774586/heat-networks-ensuring-sustained-investment-protecting-consumers.pdf
- Energy Policies of IEA Countries: Ireland 2019 Review, IEA, 2019, Available online at: https://webstore.iea.org/energy-policies-of-iea-countries-ireland-2019-review
- Evaluation of the heat networks delivery unit, Wave 2: Final Report, prepared by CAG Consultants for the Department for Business, Energy & Industrial Strategy, (UK), available online at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/699301/Wave_2_Evaluation_of_the_Heat_Networks_Development_Unit_-_FINAL_VERSION.pdf
- DECC (2013), The Future of Heating: Meeting the challenge, published by the Heat Strategy Team, Department of Energy and Climate Change, London, available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/190149/16_04-DECC-The_Future_of_Heating_Accessible-10.pdf
- DeltaEE (2013) Delta-ee Report for Danish Energy Agecny Policy measures for heat pump market growth, available online at: https://www.delta-ee.com/downloads/1-research-downloads/39-heat-research/1046-delta-ee-report-for-danish-energy-agency-policy-measures-for-heat-pump-market-growth.html
- Department for Exiting the European Union, (No Date), Citizens' Rights – EU citizens in the UK and UK nationals in the EU, Policy Paper, available online at:

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/762546/Future_Framework_for_Heat_in_Buildings_Govt_Response__2_.pdf

- Deyne, L. Cleemput, R., Van Thuyne, V., (2018), The Renewable Energy Law Review – Edition 1, Belgium, published in The Law Reviews available online at: https://thelawreviews.co.uk/edition/the-renewable-energy-law-review-edition-1/1173953/belgium
- Downy, F., Carmichael, E., & Raytcheva, M. (No date) RES and district heating, published by the CA-RES, Concerted Action Renewable Energy Sources Directive Working Group 4, Available online at: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/ca-res_working_group_publication_no_4_en.pdf
- Draft Integrated National Energy & Climate Plan 2021-2030, Version 2.1, The Netherlands, November 2018, Available at: https://ec.europa.eu/energy/sites/ener/files/documents/netherlands_draftnecp_en.pdf.pdf
- EC (2011), Energy Roadmap 2050, (brochure), COM (2011) 885 final of 15 December 2011, published by the publications office of the European Union, Luxembourg, available at: https://ec.europa.eu/energy/sites/ener/files/documents/2012_energy_roadmap_2050_en_0.pdf
- EC (2016), EU Reference Scenario 2016, Energy, transport and GHG emissions, Trends to 2050.
- EC (2018), Commission Staff Working Document, Tax Policies in the European Union: 2018 Survey, Brussles, 7.12.2018, SWD (2018) 493 final, available at: https://www.government.nl/documents/reports/2016/01/01/energy-report-transition-to-sustainable-energy
- EC (2019), Renewable Energy, Moving towards a low carbon economy, web page of the European Commission, available at; https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans
- EC (European Commission). 2004. "Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the Promotion of Cogeneration based on a Useful Heat Demand in the Internal Energy Market and Amending Directive 92/42/EEC." Official Journal of the European Union 47 (52): 50-60.
- EC Energy Directive Website: Energy Efficiency Directive, Available at: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive accessed May 2019
- EC Factsheet (2016), Towards a smart, efficient and sustainable heating and cooling sector, European Commission Fact Sheet, 16th of February 2016, Available at: http://europa.eu/rapid/press-release_MEMO-16-311_en.htm#_ftn1 accessed May 2019
- EC News (2019) Energy for heating/cooling from renewable sources, European Commission News Website, 4th of March 2019, Available at: https://ec.europa.eu/info/news/energy-heating-cooling-renewable-sources-2019-mar-04_en Accessed May 2019
- EHI Website, Gas Heat Pumps, available online at: http://www.ehi.eu/heating-technologies/gas-heat-pumps/, Accessed May 2019
- Energy Agenda: Towards a Low Energy Supply, December 2016, Netherland, Available at: https://www.rijksoverheid.nl/documenten/rapporten/2016/12/07/ea (not sure how to cite this)
- Energy Market Barometer Report – Summer 2018, GEM Lab Studies, Available at: https://en.grenoble-em.com/sites/default/files/public/kcfinder/files/barometre-energie-ete-2018-EN.pdf

- Energy Matters (2014), Micro-CHP potential analysis, European level report, report for CODE 2, Cogeneration Observatory and Dissemination Europe, available online at: http://www.code2-project.eu/wp-content/uploads/D2.5-2014-12-micro-CHP-potential-analysis_final.pdf
- Energy Report Transition to Sustainable Energy, The Netherlands, Accessed May 2019, Available at: https://www.government.nl/documents/reports/2016/04/28/energy-report-transition-tot-sustainable-energy
- Energy Saving Trust Website, Air source heat pumps vs ground source heat pumps, available online at: https://www.energysavingtrust.org.uk/blog/air-source-heat-pumps-vs-ground-source-heat-pumps
- ESC Energy Solutions Centre Website, Understanding CHP, Available online at: https://understandingchp.com/overview/what-is-chp/micro-chp/
- EU Buildings Database official website, available online at: https://ec.europa.eu/energy/en/eu-buildings-database Accessed May 2019
- EU Directives on the Promotion of the Use of Energy from Renewable Sources, December 2018, Available at: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN
- European Commission 2030 Energy Strategy Official Website: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2030-energy-strategy Accessed May 2019
- European Commission 2050 Energy Strategy Official Website. Available at: https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/2050-energy-strategy accessed May 2019
- European Heat Pump Markets Statistics, EHPA, 2015, Available at: https://www.ehpa.org/fileadmin/red/07._Market_Data/2014/EHPA_European_Heat_Pump_Market_and_Statistics_Report_2015_-_executive_Summary.pdf
- European Innovation Scoreboard 2016, Available at: https://publications.europa.eu/en/publication-detail/-/publication/f428333d-dede-11e6-ad7c-01aa75ed71a1/language-en
- Eurostat (2019) Share of renewables in gross inland energy consumption (2017) (%), Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Share_of_renewables_in_gross_inland_energy_consumption,_2017_(%25).png
- Eurostat (2019), Average numbers of persons per household, available at: https://www.pordata.pt/en/Europe/Average+number+of+persons+per+household-1613
- Eurostat (2019), Population on 1 January, available at: https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tps00001&plugin=1 Accessed May 2019
- Eurostat Database, http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do
- Eurostat News on Dwellings, Eurostat, November 2017, Accessed March 2019, Available at: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20171102-1?inheritRedirect=true
- Eurostat Energy Database, Available at: https://ec.europa.eu/eurostat/web/energy/data , Accessed March 2019

- Eurostat, Share of energy from renewable sources, Accesses May 2019, http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_ind_335a&lang=en
- Evaluation of the Heat Network Delivery Unit, Wave 2: Final Report, April 2018.
- Flogas website, CHP – Combined Heat & Power Systems, Available online at: https://www.flogas.ie/business/business-heating/chp-combined-heat-and-power-systems.html
- Francia, R., (2016), Deployment of micro-CHP in the European Energy Framework, Micro Gas Turbines in the European Energy Scenario presentation for COGEN Europe, available online at: https://www.slideshare.net/COGENEurope/cogen-europe-presentation-on-microchp
- Fraunhofer et al. (2015 - ongoing), "Study on Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)", ENER/C2/2014-641
- Frontier Economics Ltd (2013), Pathways to high penetration of heat pumps, report prepared for the Committee on Climate Change, published by Frontier Economics Europe (London), and available online at: https://www.theccc.org.uk/wp-content/uploads/2013/12/Frontier-Economics-Element-Energy-Pathways-to-high-penetration-of-heat-pumps.pdf
- Galindo Fernandez, M., Roger-Lacan, C., Gahrs, U., Aumaitre, V., (2016), Efficient district heating and cooling systems in the EU, Case studies analysis, replicable key success factors and potential policy implications, prepared by Tillia GmbH for JRC Science Hub, published bythe Publications Office of the European Union, Luxembourg, ISBN 978-92-79-65048
- Gas Networks Ireland Official Website, Gas fired heat pump web page, available online at: https://www.gasnetworks.ie/home/gas-benefits/natural-gas-appliances/gas-fired-heat-pump/
- Gov.uk (2017), Guidance, Heat networks, official UK Government website, available online at: https://www.gov.uk/guidance/heat-networks-overview Accessed May 2019
- Gov.uk (2019) Domestic Renewable Heat Incentive (RHI) official UK Government website, available at: https://www.gov.uk/domestic-renewable-heat-incentive Accessed May 2019
- Gov.uk (2019), Heat Networks Delivery Unit, official UK Government website, available at: https://www.gov.uk/guidance/heat-networks-delivery-unit Accessed May 2019
- Government of the Netherlands (2019), Central government stimulates energy saving webpage available online at: https://www.rijksoverheid.nl/onderwerpen/duurzame-energie/rijksoverheid-stimuleert-energiebesparing
- Government of the Netherlands (2019), Energy Agreement for Sustainable Growth, official website of the Government of the Netherlands, available at: https://www.government.nl/documents/publications/2013/09/06/energy-agreement-for-sustainable-growth
- Government of the Netherlands (2019), Investment subsidy for renewable energy ISDE, Available online at: https://www.rvo.nl/subsidies-regelingen/investeringssubsidie-duurzame-energie-isde Accessed May 2019
- Griffin, H., Development of the European Gas Network, Supporting Document for Low Carbon Futures, Available at: https://www.eci.ox.ac.uk/research/energy/downloads/lcfreport/appendix-r.pdf
- Gross, Robert & Hanna, Richard. (2019). Path dependency in provision of domestic heating. Nature Energy. 10.1038/s41560-019-0383-5, Available online at: https://s3-eu-west-1.amazonaws.com/assets.eti.co.uk/legacyUploads/2015/11/3501-Consumer-Insights.pdf?dl=1
- Hanna, Richard & Parrish, Bryony & Gross, Robert. (2016). Best practice in heat decarbonisation policy: a review of the international experience of policies to promote the uptake of low-carbon

heat supply, Available online at: http://www.ukerc.ac.uk/programmes/technology-and-policy-assessment/best-practice-in-heat-decarbonisation-policy.html

- Heat and the City Project Website: https://heatandthecity.org.uk/project/heat-and-the-city/
- Heatroadmap.eu, (2019) Heating and Cooling Energy Demands, Profiles and Baselines for heating and cooling energy demands in 2015 for EU28 countries, Available online at: https://heatroadmap.eu/heating-and-cooling-energy-demand-profiles/ accessed May 2019
- Housing in Ireland, Central Statistics Office Database, Accessed May 2019, Ireland, Available: http://www.cso.ie/px/pxeirestat/Statire/SelectVarVal/Define.asp?maintable=E1005&PLanguage=0 ,
- ICAX website, Surface Water Source Heat Pumps, District Heating and Cooling, Available online at: https://www.icax.co.uk/SWSHP.html, accessed May 2019
- IEA Belgium Country Review, 2016, Available at: https://webstore.iea.org/energy-policies-of-iea-countries-belgium-2016-review
- IEA Bioenergy (2018), Country Reports, Belgium – 2018 update, Bioenergy policies and status of implementation, available online at:
- https://www.ieabioenergy.com/wp-content/uploads/2018/10/CountryReport2018_Belgium_final.pdf
- IEA Bioenergy, (2019), Task 32, Best practise report on decentralized biomass fired CHP plants and status of biomass fired small- and micro scale CHP technologies, Available online at: https://www.ieabioenergy.com/wp-content/uploads/2019/05/T32_CHP_Report_01_2019.pdf
- IEA Policies & Measures Database, IEA, Accessed May 2019, Available at: https://www.iea.org/policiesandmeasures/pams/france/name-50424-en.php
- Insights in a clean energy future for Belgium, Impact assessment of the 2030 Climate and Energy Framework, May 2018, Working Paper 5-18, Federal Planning Bureau
- Insights paper on households with electric and other non-gas heating, Ofgem, 11 December 2015, Available at: https://www.ofgem.gov.uk/ofgem-publications/98027/insightspaperonhouseholdswithelectricandothernon-gasheatingpdf
- Introduction and Development of the Swedish District Heating System: Critical Factors and Lesson Learned, March 2019, Available at: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/res-h_policy_introduction_and_development_of_swedish_dh_systms_en.pdf
- Ketteley, J., Rudd, M., Gurdenlu, L, Wilsher, R., (2018), Bird & Bird & Heat Decarbonisation policy in the UK, published in the spring edition of the Energy Management Update on Bird & Bird, available online at: https://www.twobirds.com/en/news/articles/2018/uk/bird-and-bird-and-heat-decarbonisation-policy-in-the-uk
- KISS, B., NEJJ, L. & JAKOB, M. 2014. Heat pumps: a comparative assessment of innovation and diffusion policies in Sweden and Switzerland. In: GRUBLER, A. & WILSON, C. (eds.) Energy technology innovation: Learning from historical successes and failures. Cambridge: Cambridge University Press.
- Kleefkens, O., & Nowak, T., (2011), Certification of Heat Pump Installers, paper presented at the 10th IEA Heat Pump Conference 2011, Available online at: http://sepemo.ehpa.org/uploads/media/D6_9_8_Nowak_HPC2_5.pdf

- Knowma (2019), World Data Atlas, Energy, Available online at: https://knoema.com/atlas/topics/Energy Accessed May 2019
- Kortesoja, A., Bröckl, M., Jonsson, H., Kontiokari, V., & Halonen, M., (2018), Nordic Best Practices, Relevant for UNEP 10YFP on Sustainable Buildings & Construction and Sustainable Food Systems, ISBN 978-92-893-5371-7, published for the Nordic Council of Ministers, Denmark, Available online at: https://norden.diva-portal.org/smash/get/diva2:1098961/FULLTEXT01.pdf, last accessed 11/05/2019
- KPMG (2018), Annex: Overview of action taken by the Member States (Austria), Available online at: https://home.kpmg/be/en/home/insights/2018/10/a-belgian-interfederal-energy-pact.html
- Letter to Parliament on Heat Adjustment, April 2015, Netherland, Available at: https://www.rijksoverheid.nl/documenten/kamerstukken/2015/04/02/kamerbrief-warmtevisie
- Lyons, L (2019), Digitalisation: Opportunities for heating and cooling, JRC Technical Report, published for the European Commission, ISBN 978-92-76-01438-6, available online at: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC116074/kjna29702enn.pdf
- Mahpatra, K., & Gustavsson, L, (2009), Influencing Swedish homeowners to adopt district heating system, in Applied Energy, Volume 86, No 2, pp144-154, available online at: https://www.researchgate.net/publication/227412975_Influencing_Swedish_homeowners_to_adopt_district_heating_system
- Mathiesen, B.V., & Kenneth, H., (2017), The role of Solar thermal in Future Energy Systems, Country cases for Germany, Italy, Austria and Denmark, published by Aalborg University, Denmark, available online at: https://vbn.aau.dk/ws/portalfiles/portal/265304574/IEA_SHC_Task_52_STA_AAU_report_20170914.pdf
- Mayor of London (2017) The London Plan, The Spatial Development Strategy for Greater London, Draft for Public Consultation, available online at: https://www.london.gov.uk/sites/default/files/new_london_plan_december_2017.pdf
- McCarthy, R., Hayes, M., & Smyth, R. (2018), Decarbonising Domestic Heating in Ireland, report prepared by KPMG for Ervia, June 2018, available online at: http://www.ervia.ie/decarbonising-domestic-he/KPMG-Irish-Gas-Pathways-Report.pdf
- Meng, T., Hse, D., & Han, Al, (2016), Measuring Energy Savings from Benchmarking Policies in New York City, ACEEE Summer Study on Energy Efficiency in Buildings, available online at: https://aceee.org/files/proceedings/2016/data/papers/1_8.pdf
- MerrionStreet (2018), First Successful projects under Climate Action Fun announced, Wednesday 28th of November 2018, by the Irish Government News Service, Available at: https://merrionstreet.ie/en/News-Room/News/Government_Announces_First_Successful_projects_under_Round_One_of_%E2%82%AC500_million_Climate_Action_Fund.html, accessed May 2019.
- Miedema, J.H., Van der Windt, H.J. , Moll, H.C., (2018), Opportunities and Barriers for Biomass Gasification for Green Gas in the Dutch Residential Sector, published in Energies, Vol 11 no 11, 2969, Available online at: https://www.mdpi.com/1996-1073/11/11/2969/htm
- NautaDutilh (2018), Amendment of the Dutch heating supply act: shepherded through the house, Lexology Newsfeed article by NautaDutilh International Law Firm, Available online at: https://www.lexology.com/library/detail.aspx?g=7813c329-9854-436a-8b15-9025b9bbcf3d

- Next Step for Gas Grids, Policy Connect, September 2017, Available at: https://www.policyconnect.org.uk/sites/site_pc/files/report/1001/fieldreportdownload/futuregaspt1nextstepsforthegasgridwebcompressed.pdf
- Nordic Heating & Cooling-Nordic Approach to EU's Heating & Cooling Strategy, Nordic Council of Ministers, 2017
- Nowak, T. (2018), Heat Pumps - Integrating technologies to decarbonise heating and cooling, Autumn 2018, published by the European Copper Institute, available online at: https://www.ehpa.org/fileadmin/red/03._Media/Publications/ehpa-white-paper-111018.pdf
- Odyssee-Mure Official Website: http://www.odyssee-mure.eu/publications/efficiency-by-sector/households/drivers-heating-consumption-dwelling-europe.html, Accessed May 2019
- OECD (2011), Micro combined heat and power generation, Policies in Germany, Available online at: https://read.oecd-ilibrary.org/environment/better-policies-to-support-eco-innovation/micro-combined-heat-and-power-generation_9789264096684-8-en#page6
- Oireachtas (2019), Report of the Joint Oireachtas Committee on Climate Action, Climate Change: A Cross Party Consensus for Action, published by the Irish Government, available online at: https://data.oireachtas.ie/ie/oireachtas/committee/dail/32/joint_committee_on_climate_action/reports/2019/2019-03-28_report-climate-change-a-cross-party-consensus-for-action_en.pdf
- Open Access Government Website, Energy News: UK heat pump market is growing again, available online at: https://www.openaccessgovernment.org/uk-heat-pump-market-is-growing-again/44301/
- Organisation and governance of urban energy systems: district heating and cooling in the UK. Journal of Cleaner Production, Voulme 50, pp 22- 31. July 2013
- Overcoming the Human Barriers to Heat Pumps, Delta Energy & Environment, January 2015, Available at: https://www.delta-ee.com/downloads/1-research-downloads/39-heat-research/747-overcoming-the-human-barriers-to-heat-pumps.html#
- Patronen, J., Kaura, E., & Torvestad, C., (2017), Nordica heating and cooling, Nordic approach to EU's Heating and Cooling Strategy, published for the Nordic Council of Ministers, Denmark, ISBN 978-92-893-4992-5, available online at: https://norden.diva-portal.org/smash/get/diva2:1098961/FULLTEXT01.pdf
- Pieterse, R., (2019), UK heat pump market likely to double by 2025, Delta EE Research Blog, Available online at: https://www.delta-ee.com/delta-ee-blog/uk-heat-pump-market-likely-to-double-by-2025.html
- Promotion of Efficient Heat Pumps for Heating, Intelligent Energy Europe, Available at: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/proheatpump_report_on_renewables_and_heat_pumps.pdf
- Renewable energy policy database and support – RES-LEGAL EUROPE National profile: France, http://www.res-legal.eu/search-by-country/france/
- Renewable Energy Policy Database and Support, Accessed January 2019, http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/policy/aid/flanders-support-of-res-h-infrastructure/lastp/107/
- RES and District Heat, Working Group 4 Report, Intelligent Energy Europe, Available at: https://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/ca-res_working_group_publication_no_4_en.pdf

- RES Legal Europe Database, Accessed February 2019, Available at: http://www.res-legal.eu/search-by-country/belgium/single/s/res-hc/t/promotion/aid/wallonia-subsidy-subventions-ureba-1/lastp/107/
- Rezaeian, A., (2015), Development of micro CHP in Germany: analyzing the influences of regulatory framework and institutional setting in combination with German culture on development of entrepreneurial activities, PhD Thesis, Department of Political and Social Sciences, Freie Universitat Berlin, Available online at: https://d-nb.info/1082237868/34
- RIZZI, F., FREY, M. & IRALDO, F., Towards an integrated design of voluntary approaches and standardization processes: An analysis of issues and trends in the Italian regulation on ground coupled heat pumps. Energy Conversion and Management, Volume 52 pp 3120-3131, September 2011
- Roberts, J., Escobar, O., (2015), Involving communities in deliberation: A study of three citizens' juries on onshore wind farms in Scotland, published in Climate Exchange, Scotland's Centre of Expertise on Climate Change, available online at: https://www.climatexchange.org.uk/media/2084/eu_case_studies_netherlands_heat_policy.pdf
- Sanner, B., Dumas, P., & Fernandez, I., (2017), GEOTRAINET: Training for ground-source heat pump designers and installers, conference paper for the 12th IEA Heat Pump Conference in Rotterdam, Available online at: http://hpc2017.org/wp-content/uploads/2017/05/P.2.7.13-GEOTRAINET-Training-for-ground-source-heat-pump-designers-and-installers.pdf
- SEAI (2016), Bioenergy Supply in Ireland 2015-2035, An update of potential resource quantities and costs, Report Summary and Key Findings, published by the Sustainable Energy Authority of Ireland, Available online at: https://www.seai.ie/resources/publications/Bioenergy-Supply-in-Ireland-2015-2035.pdf
- SEAI (2018), Energy in Ireland 2018 Report, published by the Sustainable Energy Authority of Ireland, Available online at: https://www.seai.ie/resources/publications/Energy-in-Ireland-2018.pdf
- SEAI (2018), Energy in the residential sector, 2018 report, published by the Sustainable Energy Authority of Ireland, available online at: https://www.seai.ie/resources/publications/Energy-in-the-Residential-Sector-2018-Final.pdf
- SEAI (2019) Renewable Energy in Ireland, published by the Sustainable Energy Authority of Ireland, available online at: https://www.seai.ie/resources/publications/Renewable-Energy-in-Ireland-2019.pdf
- SEAI (2019), Biomass Boilers – Implementation Guide, published by the Sustainable Energy Authority of Ireland, available at: https://www.seai.ie/resources/publications/Biomass-Boilers-Implementation-Guide.pdf
- SEAI Behavioural insights on energy efficiency in the residential sector, published by the Sustainable Energy Authority of Ireland, Available online at: https://www.seai.ie/resources/publications/Behavioural-insights-on-energy-efficiency-in-the-residential-sector.pdf Accessed May 2019
- Sebi, C, & Schleicg, J. (2018), France: the road to a low-carbon building sector by 2050 will be a long one, published on The Conversation, Available online at: http://theconversation.com/france-the-road-to-a-low-carbon-building-sector-by-2050-will-be-a-long-one-103485

- Sectoral Profile – Household, Odyssee Mure Databse, Accessed May 2019, Available at: http://www.odyssee-mure.eu/publications/efficiency-by-sector/households/heating-consumption-per-m2.html
- SER (2019), Social and Economic Council – Agreement on Energy for Sustainable Growth webpage, Available online at: https://www.energieakkoordser.nl/doen/engels.aspx
- SETIS (2016), Low-carbon Heating & Cooling, in SETIS Magazine Information for Decision-Making, Available online at: https://setis.ec.europa.eu/setis-reports/setis-magazine/low-carbon-heating-cooling/eu-strategy-heating-and-cooling accessed May 2019
- Share of Electricity from Renewable Sources in Gross Electricity Consumption 2004-2017, EuroStat, Accessed, March 2019, Available at: https://ec.europa.eu/eurostat/statistics-explained/images/3/32/Share_of_electricity_from_renewable_sources_in_gross_electricity_consumption%2C_2004-2017_%28%25%29.png
- Smart Renewable Heat Website, Blog: What is a Hybrid (Duel Fuel) Heat Pump System, Available online at: https://smartrenewableheat.com/blog/what-is-hybrid-heat-pump-system-dual-fuel/, Accessed May 2019
- EU Heat Roadmap: Excel Sheet, Accessed February 2019
- Statista website: Number of dwellings in France from 2008 to 2016 available online at: https://www.statista.com/statistics/767493/number-housing-france/ accessed in May 2019
- The Role of Solar Thermal in Future Energy Systems, Aalborg University, 2017, Available at: https://vbn.aau.dk/ws/portalfiles/portal/265304574/IEA_SHC_Task_52_STA_AAU_report_20170914.pdf
- Thonon, B. (Date Unknown), Promotion of efficient heat pumps for heating, (ProHeatPump), Deliverable No 19, Report on renewables and heat pumps, Available online at: https://www.solarthermalworld.org/sites/gstec/files/story/2015-02-19/proheatpump_d21_eng.pdf
- Towards a heat transition in the housing sector in the Netherlands: Roles and responsibilities of different actors, Energy Delta Institute, 20th Jan, 2016
- U.S. EPA (United States Environmental Protection Agency). 2013. CHP: Efficiency Benefits. https://www.epa.gov/chp/chp-benefits
- UK National Energy & Climate Plan, BEIS UK, January 2019, Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/774235/national_energy_and_climate_plan.pdf
- Unleashing the Opportunity – European Best Practice in Successful Heat Pump Markets, EHPA & Delta Energy & Environment, Available at: https://www.ehpa.org/fileadmin/red/03._Media/03.02_Studies_and_reports/EHPA_BestPractice_FINAL_3.pdf
- Van den Ende, Eline (2017), A revolution: The Netherlands kisses gas goodbye – but will it help the climate? Published in EnergyPost.eu, available online at: https://energypost.eu/a-revolution-the-netherlands-kisses-gas-goodbye-but-will-it-help-the-climate/
- Van't Hof, Wim (2018) Energy transition in the Netherlands – phasing out of gas, presentation by the Ministry of Economic Affairs and Climate Policy, Electricity Directorate, available at: https://ec.europa.eu/energy/sites/ener/files/documents/01.b.02_mf31_presentation_nl-fuel_switch-vanthof.pdf

- Vidalic, H., (2019) RD&D Policies (Investissements d'avenir), published in SRES Legal, Legal sources on renewable energy, available online at: http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/policy/aid/rdd-policies-fonds-demonstrateur/lastp/131/
- Vidalic, H., (2019), Grid issues in France, published on SRES Legal, Legal sources on renewable energy. http://www.res-legal.eu/search-by-country/france/tools-list/c/france/s/res-hc/t/gridaccess/sum/132/lpid/131/
- Vidalic, H., (2019), Subsidy (Prime "Habiter mieux"), published on SRES Legal, Legal sources on renewable energy, available online at: http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/promotion/aid/subsidy-aide-habiter-mieux/lastp/131/
- Vidalic, H., (2019), Tax regulation mechanism (Crédit d´impôt pour la transition énergétique), published on SRES Legal, Legal sources on renewable energy, Available online at: http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/promotion/aid/tax-regulation-mechanism-credit-dimpot-developpement-durable/lastp/131/
- Vidalic, H., (2019), Training programmes for Installers (Qualibat), published in SRES Legal, Legal sources on renewable energy, Available online at: http://www.res-legal.eu/search-by-country/france/single/s/res-hc/t/policy/aid/training-programmes-for-installers-qualibat/lastp/131/
- Watson, D., & Maitre, B., (No date) Is Fuel Poverty in Ireland a Distinct Type of Deprivation? Published in *The Economic and Social Review,* v. 46, n. 2, Summer, p. 267–291, june 2015. ISSN 0012-9984. Available at: <https://www.esr.ie/article/view/342>. Date accessed: 12 june 2019.
- Weiss, W., Biermayr, P., Potential of Solar Thermal in Europe, Available at: http://www.estif.org/fileadmin/estif/content/publications/downloads/Potential%20of%20Solar%20Thermal%20in%20Europe_Full%20version.pdf
- Werner, S., (2010), Best practise support schemes, Ecoheat4eu Report.
- Whitehead, A., Heappey, J., & McCaig, C., (2017), Next Steps for the Gas Grid, Future Gas Series: Part 1, Published by Policy Connect, London, sponsored by the Institution of Gas Engineers and Managers, available online at:
- Wikipedia List of European Cities by Temperature, available at: https://en.wikipedia.org/wiki/List_of_European_cities_by_temperature, accessed May 2019