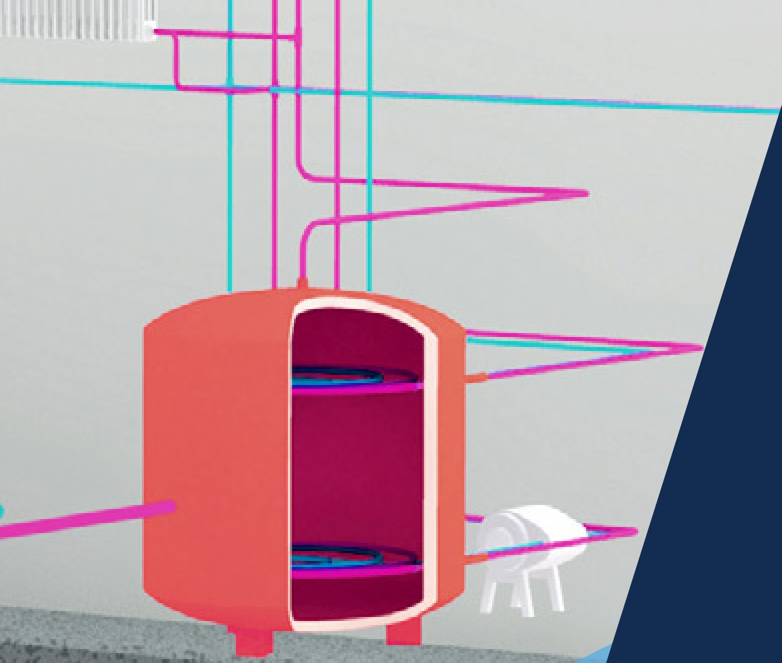

Tyndall National Institute
Institiúid Náisiúnta

IERC
International Energy Research Centre

# Best Practices and Policy Solutions for Ireland's 2030 Heat Pump Target

This report highlights best practices in international policy and extracts policy insights from existing scientific research to identify barriers and pathways for Ireland to meet heat pump targets.

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Coláiste na hOllscoile Corcaigh

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International Energy Research Centre

# Contents

## 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 examines the knowledge gaps through five different research lenses: Technology, Data Analytics, Behaviour, Business Models, and Policy & Regulation.

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Two-minute Brief:

# Achieving Ireland's 2030 Heat Pump Targets

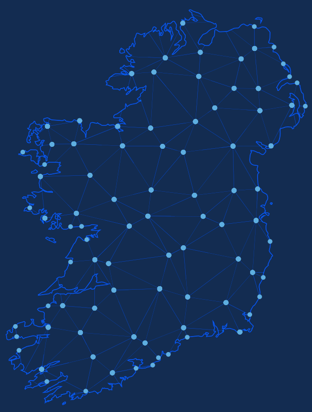
## Best Practices and Policy Solutions

Drawing on the review of policies of countries which have led the way in heat pump implementation, and other scientific and academic literature, it was found that progress in the heat pump market is very mixed. Countries like France, Sweden, Austria, Switzerland, and Germany are examples of fully developed markets while countries like UK, Netherlands, Belgium, and Poland are still developing. In a recent report by the European Heat Pump Association published in 2019, heat pumps are heating approximately 10% of all buildings in EU, showing there is still ample room in the market. EHPA market report survey doesn't take account of heat pump applications so data specific to residential building is not available. As heat pumps have the potential to significantly decarbonise the residential heating sector and also have significant demand-side flexibility potential, heat pumps will be required as part of the energy transition to achieve the EU's ambition of a carbon neutral economy by 2050. In terms of key learnings from other leading countries, IERC makes the following recommendations for Ireland to achieve its 2030 heat pump implementation target. A detailed elaboration of these recommendations is provided in the Executive Summary and throughout the report.

- Overcome the high initial costs of heat pump installations by introducing low or zero interest loans, or investment subsidies to cover a proportion of installation cost, and tax breaks on labour costs.
- Strengthen the role of the industry in developing relevant technical standards and for driving market growth.
- Establish an Independent Redress Board to allow customers to bring claims against installation companies and incentivising manufacturers and installers to improve their product and service quality.
- Develop mandatory standardised training and certification schemes

for installers.

- Organise a third party product quality verification group and develop a verification system for ensuring installation accuracy and efficiency.
- Develop intensive grassroots and onsite promotional programmes in local communities, including direct advertising through TV, radio, social media, and other channels.
- Strengthen building regulations specifically targeting heating and cooling of older and inefficient buildings.
- Explore the possibility of collective purchasing and implementation to provide economy of scale benefits to users.
- Establish and support a group of One Stop Shops of heat pump contractors to provide funding advice and taking responsibility of design, installation and start up to support the initial market development.



## About Ireland's Climate Action Plan 2019

Ireland released a Climate Action Plan on 17th June 2019 which identifies the nature and scale of Ireland's climate challenge and outlines 183 action items targeting all the key sectors including Electricity, Transport, Built Environment, Agriculture, and Industry, and sets an indicative sectoral target for Ireland to 2030.

Ireland supports the adoption of a net zero target by 2050 at the European Union level, and this plan provides a pathway to 2030 which would be consistent with Ireland's 2050 ambition.

This plan was launched as a living document and is being monitored quarterly, as well as annually. If needed, policies will be revisited to ensure that Ireland is on the right track.

Under this plan, Ireland aims to complete 500,000 home retrofits to achieve a Building Energy Rating of B2/ cost optimal equivalent and roll out 600,000 (400,000 in existing buildings) heat pumps in residential buildings by 2030. Ireland is committed to promoting the widespread adoption of heat pumps and other renewable heating options.

# Executive summary and key recommendations

Ireland's government is committed to achieving United Nations' 2030 Sustainable Development Goals, the Paris Agreement on Climate Change, and further supporting the European Union's ambition to achieve a net zero target by 2050. Ireland's Climate Action Plan has set out a detailed sectoral roadmap to deliver a cumulative reduction in emissions, over the period 2021 to 2030, of 58.4 MtCO2eq. outside the ETS, 17 MtCO2eq. within the ETS, and 26.8 MtCO2eq. from land use[1]. Achieving the Climate Action Plan objectives by introducing and implementing a coherent set of policy actions will be crucial to achieve this 2030 objective and a carbon neutral economy by 2050. It will be very important for the government to focus on each of the 183 action items and develop a time bound strategy and clearly defined responsibilities for all relevant stakeholders to achieve these objectives. Unless supportive policies are developed to facilitate a variety of focus areas such as research & innovation, demonstration, market uptake, capacity building and general societal awareness on new technologies; the achievement of these objectives will be extremely challenging and the cost of inaction could be very significant.

One of the targets of critical importance under the Climate Action Plan is the installation of 600,000 heat pumps (400,000 in existing buildings) by 2030 in the residential sector. While installation of heat pumps is key here, ensuring that the dwellings are properly insulated, well ventilated and suitable for the heat pump technology to be effectively deployed will also be critical. Under-insulated or un-insulated dwellings are inefficient and difficult to heat, tend to retain poor indoor air quality due to improper ventilation and can expose occupants to increased risk of illnesses related to cold and damp living conditions, which has been shown to cost hundreds of millions to exchequer in the form of increased medical costs and frequent hospital visits[1] [2]. Subsequently, if the dwellings are not properly insulated there will also be significant heat loss from the premises which will make the complete system highly inefficient and unreliable, even where the heat pumps are powered by renewable electricity. Therefore, a robust and comprehensive heat pump implementation policy is important for both improving the emissions profile of dwellings, and also the general health and wellbeing of the building occupants. With regards to this, SEAI already has some requirements for the buildings to meet certain standards before a grant for the heat pump is offered. Overall, in previous years, there has been much policy focus on integrating renewables in the electricity sector, while energy related emissions from the heating sector have been consistently higher, which offers substantial reduction potential and health benefits.

A review of the EU countries' heat pump markets revealed that the adoption of heat pumps in Ireland significantly lags behind and the growth rate is slow. Only around five thousand heat pumps were sold in Ireland in 2018, far less than most other EU countries. In Ireland, there are 10.38 heat pumps in operation per thousand households as compared to the leading country Norway, which has 438.86 operating heat pumps per thousand households. In terms of 2018 units sold per thousand households, Ireland sold 2.9 compared to 33.2 units sold in Norway [3]. At the EU level, there is an average 12% market growth each year in last 3 years and the European Heat Pump Association (EHPA) expects that the EU heat pump market will double by 2024 [4]. Mature heat pump markets include France, Germany, Switzerland, Sweden, Norway and Austria which have been supporting heat pump implementations for the last two to three decades, while Ireland, Lithuania, Belgium, Czech Republic, Poland and the Netherlands are considered as developing markets for heat pumps. In Ireland, a lower penetration of heat pumps is due to various factors including lack of awareness among citizens, a lack of a strong consumer proposition, and policy supports for the cost of ownership. Heat pump technology has matured and the business model in many countries has evolved over the years which provides the knowledge base of best practices to build a supply chain and a model for aggregation where a package of relevant policies and activities could be delivered.

1 The Asthma Society of Ireland estimate that asthma costs the state €472million per annum. There are 2.4m GP consultations annually relating to asthma.

## Key policy recommendations for consideration are as follows:

**Innovative financial incentives:** Replacement of an oil boiler with an air source heat pump can potentially reduce the annual heating cost by 35-39% per household depending on dwelling type and efficiency. However, the installation cost is still very expensive [5] as it can cost at least €3000 more than an oil boiler [6]. According to Electric Ireland, air source heat pump installations usually cost between €8,500 and €14,500, depending on the size and power of the heat pump, and hot water storage and other requirement [7]. It is also important to note that there is an additional cost associated with making the homes suitable for the installation of heat pumps. SEAI is already offering heat pump grants (to homes built before 2011) and to further support this some electricity suppliers are also offering energy credits towards the electricity bill to reward customers who complete energy efficiency upgrades on their homes. But the high initial cost to end users is still a major barrier to market growth, and therefore, a significant intervention is required from the government to stimulate deployment through innovative financial schemes like very low or zero interest loans, capital grants to support installation cost for all homes, tax reduction on labour costs etc. Activating private capital and relevant supportive policies should also be considered to finance installation of such new technologies.

**Strengthening Heat Pump industrial actors:** Heat pump supply chain cross-industry participation has a vital position in driving the market growth as is evident from the successes of several countries like Sweden, Switzerland, and Germany. This can support developing relevant national technical standards as well as their implementation, creating easily understandable resources for installers and end users, working closely with the government to ensure product quality, and conducting strategic nationwide awareness raising campaigns. National and Regional heat pump industry associations can work closely with the government to organise demonstration programmes in different communities to help build trust among end users and showcase the benefits of the technology to other potential users. Passive house open days are a great example of this[2].

**Independent Redress board:** A dedicated independent redress board (known, for example, as the Heat Pump Court in Sweden) has also helped in building confidence in the technology through allowing customers to bring a claim against installation companies and incentivising manufacturers and installers to improve their product and service quality. A fast track adjudication process will be especially important during the early stage of market development when such high cost technologies are not well proven. Developing an inspection process to check the quality of the installations on a sample basis can also help provide consumer protections and open new markets for third party inspection providers.

**Mandatory training and certification for installers:** Unlike registered gas installers, current low carbon heating system (e.g. heat pump) installers are not mandatorily trained which can act as an obstacle for the market uptake. According to SEAI, currently approximately 5,000 plumbers are active in Ireland and yet only 3% meet the SEAI criterion to install heat pumps [8]. SEAI has a list of Accredited Training Providers for renewable energy installations and maintains a list of installers who have achieved certification from an accredited training provider[3]. Although in some cases, while manufacturers can offer support in calculating heat requirements, installers remain responsible for the installation. Consumers rely on knowledge and advice provided by installers and without upskilling installers knowledge base and ensuring the quality of installations, the deployment to the level required to meet 2030 target cannot be achieved. A comprehensive mandatory training programme along with a certification process for installers can be developed to demonstrate the essential skills, knowledge and ability typically required for a practitioner to competently install, maintain and troubleshoot heat pump systems.

**Verification of product quality and**

2 https://passivehouseplus.ie/news/events/passive-houses-open-to-public-this-november#:~:targetText=The%20International%20Passive%20House%20Days,from%209%20to%2011%20November.

3 https://www.seai.ie/register-with-seai/renewable-energy-installer/

**installed efficiency:** Ensuring heat pump product quality is critical to the market growth as any undesirable performance will engender distrust amongst consumers and they will be reluctant to replace a trusted traditional fossil fuel based heating system. Establishing or coordinating with an independent test facility for quality assurance of heat pumps on a sample basis and publishing relevant data can build significant trust among consumers. Installation efficiency is also critical and it is recommended that a measurement & verification system is introduced. Specific research [9] conducted on labelling process of heat pumps also suggests that considering the technicalities of the heat pump system, a detailed knowledge about local conditions, the building's composite system equipment and insulation standard as well as the implemented control strategy is also required to improve the effectiveness of the heat pump installation.

**Awareness raising:** Some heat pump awareness work has already been conducted by the private industry. The promotion of heat pumps needs to be carried out by all different actors of the heat pump value chain and a national awareness campaign needs to be developed. Awareness at the grassroots level in each municipality and city will be critical in an effort to increase heat pump installations. Local network of climate action and energy agencies in municipalities can be trained for intensive information dissemination campaigns at the local level. Direct creative advertising through TV, radio and other channels along with organising local trade fairs and town halls could also be considered. Public dissemination of independent heat pump test results and carrying out demonstrations in different communities will also raise consumer confidence. An online detailed heat pump database with costs, savings, financial support, local installers information may also raise consumer confidence.

**Tightening regulations for building stock:** Introducing mandatory strict regulations in the form of minimum requirements for the installation of renewable energy in buildings can be very effective in stimulating the deployment of heat pumps, particularly if they target heat specifically. New buildings should be strictly designed as NZEB [10] and relevant education and enforcement strategies need to be developed. Existing homes, where heating replacement is required, can be made suitable for renewables, and installing fossil fuel boilers should not be allowed. Roadmap for further tightening of building regulations over the years can be informed widely to stakeholders to avoid any possible supply chain constraints.

**Collective purchasing and installations:** Collective purchasing and installations at the community level through a cooperative approach and leveraging the group size benefits to end users in terms of discounts on the initial cost may be explored. Working with community associations to offer collective purchasing benefits of heat pumps bundled with other services can also build customers trust [11]. Collective procurement models to bring high efficient heat pump technologies into the market through a competitive process of selection of vendors, purchasing and independent testing of heat pumps has also been an impactful policy in Sweden and it may be another potential strategy for Ireland to overcome the upfront cost and performance risk from the end user.

**One-stop-shop contractors:** Forming a group of One Stop Shop (OSS) heat pump contractors, certify them as qualified installers and make their details available on the SEAI website could be very helpful for the users to get a full service package from a trusted source. These contractors can provide funding advice, and take the responsibility of design, installation, start up and (possibly) maintenance for a certain period of time. Based on their expertise, contractors can also provide insulation and other services to ensure the required level of building quality is achieved before the heat pump is installed on the premises. OSS contractors can also comprehensively facilitate the collective purchasing of heat pumps in different communities and providing economies of scale benefits to customers [12].

# 1. Setting the scene

## 1.1 Ireland's heating energy profile

According to Energy in Ireland 2019 report [13], Ireland's economy continued to grow along with energy use in industry, services, transport and residential sectors in 2018. Overall Ireland's energy use increased by 1.6%, while the economy grew by 1.7% as measured by modified domestic demand (MDD) or by 8.2% as measured by gross domestic product (GDP). In 2018, final energy uses of fossil fuels increased by 4.8% and 67% import dependency was recorded. While significant progress has been made in recent years in increasing renewable sources of electricity, there is still a long way to meet our renewable energy ambitions for heat and transport, which account for almost 80% of final energy demand. Figure 1 shows the share of final energy demand in different sectors and the percentage of energy which came from renewable sources. Heat is the second largest energy consuming sector with 39% of energy demand and around 37.4% of energy related $CO_2$ emissions. In 2018, energy use for heat increased by 6.4% (when corrected for weather the increase was 5.3%), and around 6.5% of total energy demand for heat came from renewable energy sources. Around 50% of heating energy goes to the residential sector, mainly for space heating and hot water purposes, followed by 31% for the industrial sector process heating applications. Table 1 shows the shares of type of heat in the final heating and cooling by sector in 2015, according to the data published by Heat Roadmap Europe [14] which conducted an extensive analysis and comparison with other countries. A total 56.86 TWh of energy was consumed by the heating and cooling sector in 2015. Space heating with 61% of total consumption remained the largest energy consuming application in the heating and cooling sector.

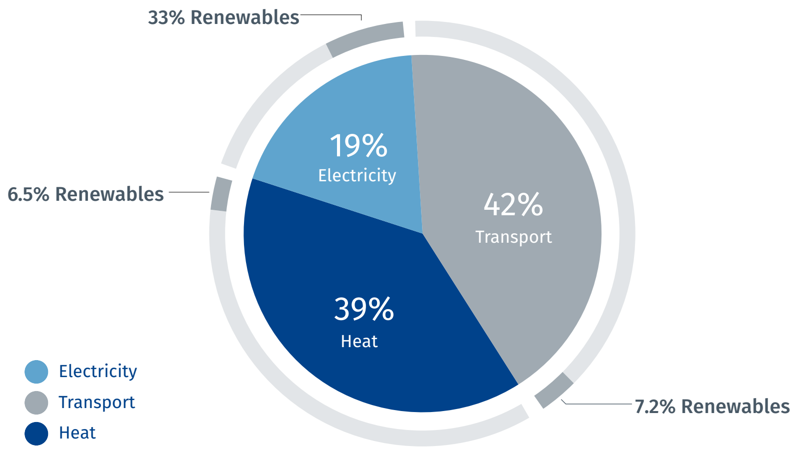



**Figure 1:** *Share of final energy demand in 2018*

Figure 2 shows the share of renewables in heating and cooling in EU member countries [15] and it can be seen that Ireland is at the second lowest position with a significantly lower share as compared to the EU average. In 2017, renewable energy accounted for 19.5 % of the total energy used for heating and cooling in the European Union (EU). 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

**Table 1.** *Shares of type of heat in final heating and cooling by sector in 2015 (TWh)*

| | Space heating | Space cooling | Process heating | Process Cooling | Hot water | Other heating | Total | % Share |
|---|---|---|---|---|---|---|---|---|
| **Residential** | 22.33 | 0.01 | | | 4.28 | 1.57 | 28.19 | 49.58 |
| **Industry** | 3.36 | 0.02 | 13.29 | 0.98 | | | 17.65 | 31.04 |
| **Tertiary** | 8.99 | 0.01 | 0.53 | 0.77 | 0.72 | | 11.02 | 19.38 |
| **TOTAL** | 34.68 | 0.04 | 13.82 | 1.75 | 5 | 1.57 | 56.86 | |

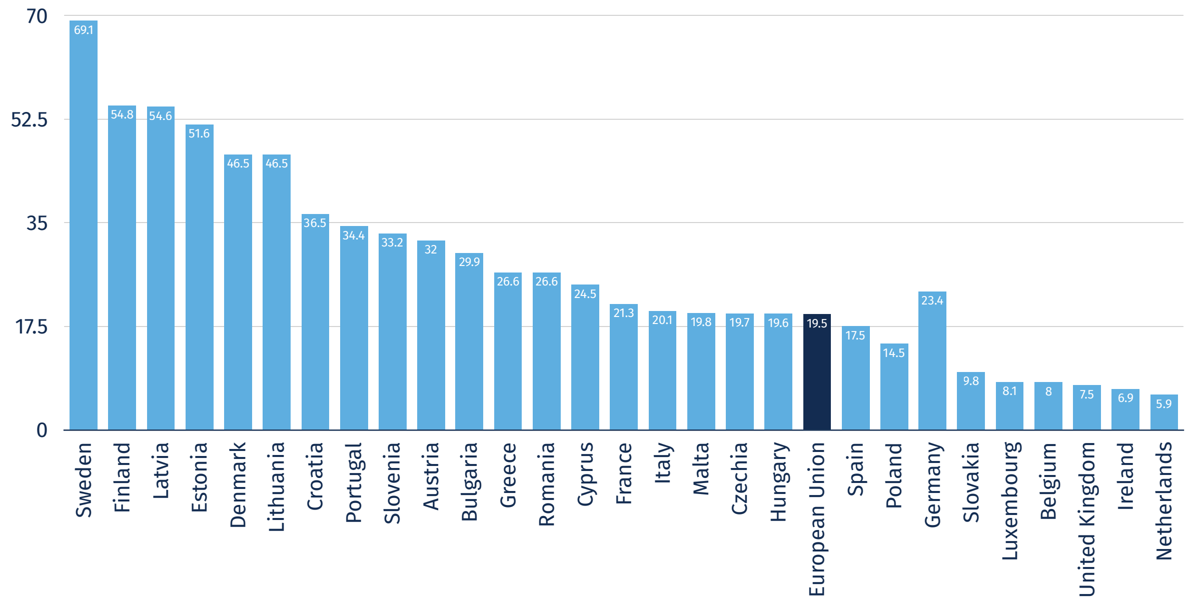



**Figure 2:** *Share of renewable energy in heating & cooling in EU Countries (Source: EU Commission, 2019)*

(51.6 %). In contrast, the lowest shares were in the Netherlands (5.9 %), Ireland (6.9 %) and the United Kingdom (7.5 %).

Figure 3 shows the share of renewables in heating in Ireland which showed more than 95% increase in renewables between 2008-2017 [16]. This growth, dominated by solid biomass, is mostly due to the increased use of wood waste as an energy source in the wood products and food sub-sectors of the industry.

In addition, recent growth in renewable energy use in the residential and services sectors can be attributed to the support of grant schemes and revisions to building regulations requiring a share of the energy demand in new dwellings to come from renewable sources [13]. However, it is important to mention that while there was a push for solar renewables, heat pumps did less favourably in regulations or grant aid. This was due to the high primary energy factor and carbon emissions from the electricity grid and the poorer performance of heat pumps at high temperatures accounted for in BER calculations through DEAP (Dwelling Energy Assessment Procedure)4. The decarbonisation of the electricity grid has helped to reduce the primary energy factor and $CO_2$ emissions from the grid, making heat pumps more favourable. In addition, SEAI updated the methodology for heat pumps in the DEAP. The approach to heat pumps now applicable in DEAP is based on

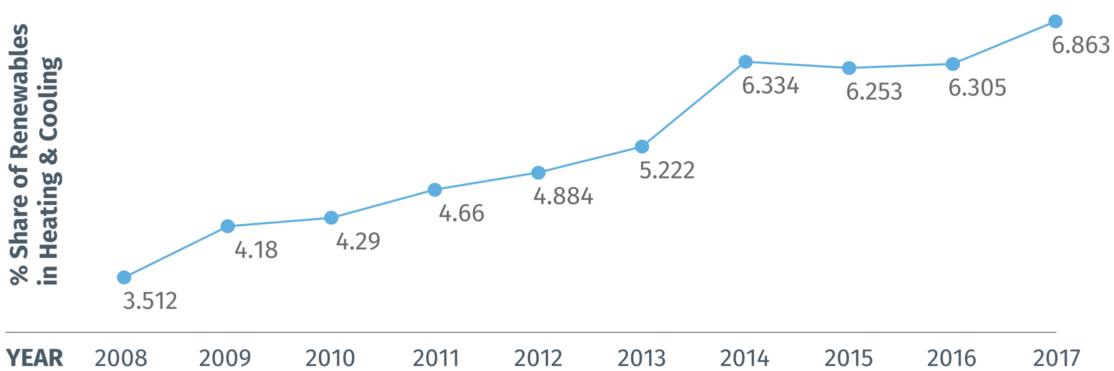



**Figure 3:** *Share of renewables in heating 2008-2017*

4 https://www.seai.ie/home-energy/building-energy-rating-ber/support-for-ber-assessors/domestic-ber-resources/

mandatory performance requirements for heat pumps across Europe under the Ecodesign (2009/125/EC) and Labelling (2010/30/EU) European directives - a legal requirement for heat pumps placed on the market from 26th September 2015. This change allows for a more accurate representation of the heat pumps at high temperatures.

Looking at the share of energy carriers in final residential heat demand in Figure 4 oil is the largest energy carrier with 40%, followed by gas and coal with 25% and 19% respectively [14]. From 2006-2014 there were significant reductions in the amount of emissions from homes, but since 2014 this trend has reversed and carbon dioxide emissions have started to increase. Irish homes emit almost 60% more CO2 than the average EU home, according to SEAI Energy in the Residential Sector 2018 Report. This high CO2 emissions from Irish homes is due to its very high share of heating from fossil fuel sources [17].

There are several factors such as increase in population, urbanisation, physical characteristics of the housing stock, dwelling sizes and building density, type of dwelling, ownership of dwelling, occupancy, floor area, and building insulation quality which effects residential heat demand and which needs to be analysed in detail for prioritising heat pump implementation programmes. A comparative analysis of Ireland's housing stock with other similar temperate climate countries has been recently published by IERC [18].

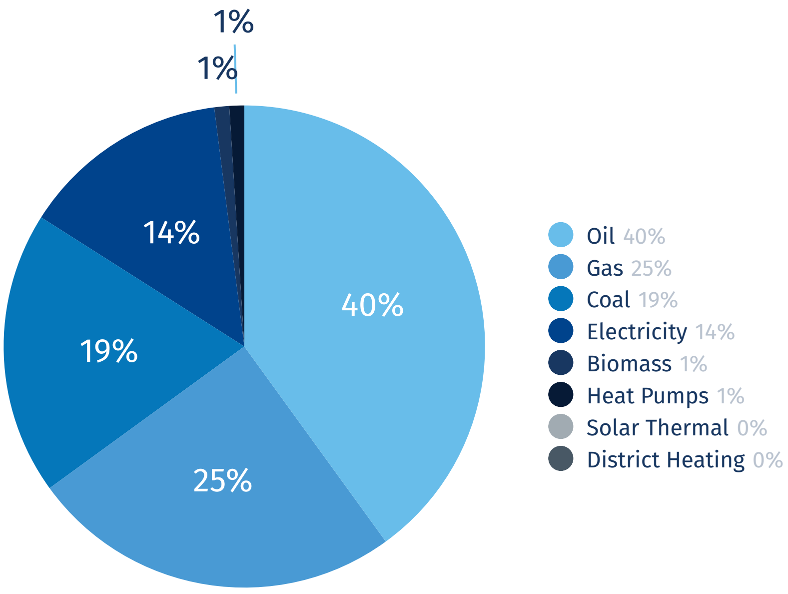



**Figure 4:** *Share of energy carriers for the final residential heat demand*

## 1.2 National vision and strategic roadmaps

**Table 2**: *Ireland's vision and heat strategy*

| National Vision | Year Released | Heat Strategy and Direction |
|---|---|---|
| **White Paper on Delivering a Sustainable Energy Future for Ireland [19]** | March 2007 | The potential of decarbonise heat has been recognised in the paper which mentions achieving a minimum target of 5% market penetration of renewables in the heat market by 2010 and a further target of 12% renewable heat market penetration by 2020. The main focus is on bio heat and combined heat and power. Electrification of heat and heat pumps as a technology was not highlighted. |
| **Ireland National Renewable Energy Action Plan [20]** | July 2010 | Under this plan, the biomass sector along with geothermal resources were prioritised for heating sector decarbonisation. There was no mention of a broader agenda for electrification of heating and relevant technologies. However, the document mentions to "provide financial assistance for boilers fuelled by wood chips and wood pellets, solar thermal collectors, and heat pumps". |
| **Green Paper on Energy Policy in Ireland [21]** | May 2014 | Along with the focus on affordability of heat and electricity, a vision on greater electrification of home heating to lower heating related emissions was revealed in this document. It was also mentioned that large scale heat electrification could require significant additional investment in the electrical grid. The uptake of combined heat and power was the focus but heat pumps and other technologies were not emphasised. |
| **White paper – Ireland's Transition to Low Carbon Energy Future 2015-2030 [22]** | December 2015 | This white paper mentioned that increased decarbonisation of home heating will be vital to Ireland's energy transition and that the government will raise awareness of the benefits to consumers of low carbon electricity heating systems, and develop policies to promote the replacement of domestic boilers with air and ground source heat pumps, which have the lowest running costs of any heating and cooling systems. Heat Pump technologies were strictly considered as part of deep retrofitting package. |
| **Draft NECP (Final version of NECP is due to be submitted by end December 2019) [23]** | December 2018 | There is a clear priority given to prioritise electrification and use of heat pumps in new domestic and commercial buildings driven by building regulations. 170,000 heat pump installations in existing residential building was proposed. District heating as part of a national heat plan is also proposed. |
| **Climate Action Plan [1]** | August 2019 | There is significant focus on low carbon heating and retrofitting of existing buildings with electricity-powered heat pump systems. Government committed to promote the widespread adoption of heat pump or other renewable heating options. 400,000 heat pump installations in existing residential building is planned. Delivering two new district heating systems, and implementing a roadmap for delivering District Heating potential is also stated. |

## 1.3 Heat pumps in Ireland – brief overview

Although the Irish heat pump market saw a comparatively higher growth in the recent years as compared to many other EU countries, it is still significantly behind on key performance indicators for the heat pump market uptake. The EHPA European Heat Pump Market and Statistics Report 2018 recorded a similar trend of the Irish heat pump market in 2017, largely dominated by air to water heat pumps, with small market shares dedicated to ground source and air/air source heat pumps [4]. Ground source heat pumps emerged as the system of choice in Ireland in the early stages of market development but there has not been much attention given to this in later years although shallow ground source geothermal energy can provide a massive heat generation opportunity [24]. In 2018, 4968 units were sold while 17,771 heat pumps were in stock (ready to be sold), resulting in €48.81m turnover [3]. Ireland has around 10.38 units of heat pumps in operation per thousand households, while the leading country Norway had 438.86 units of heat pumps in operation in 2018. In terms of units sold per thousand households, Ireland sells 2.9 units as compared to 33.2 units in Norway. Table 3 below shows the heat pump growth in Ireland in percentage as well as absolute numbers and Table 4 shows sales of different types of heat pumps in Ireland between 2010-2014 [25].

The analysis, made by Passive House Plus based on 2017 and 2018 building energy rating data, discovered that over the 5,080 homes built in 2017 with published final BERs, 36.6% have a heat pump as a heating system, with gas boilers at 52.6%, oil boilers at 4.1%, CHP at 5.8% and LPG at 0.8% [26].

**Table 3**: *Heat pump year on year growth in Ireland in percentage as well as absolute number*

| Year | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|
| Heat Pump growth | 43% (431) | -15% (-209) | 13% (161) | 9% (126) | 54% (811) | 68% (2k) | 27% (1k) |

**Table 4:** *Sales of heat pumps 2010-2014*

| Heat pump type | 2010 | 2011 | 2012 | 2013 | 2014 | 2014 vs 2013 |
|---|---|---|---|---|---|---|
| H-ground/water | 493 | 548 | 479 | 305 | 508 | 66.60% |
| H-air/water | 882 | 660 | 891 | 1172 | 1806 | 54.10% |
| Exhaust air | 90 | 0 | 19 | 21 | 12 | -42.90% |
| Sanitary hot water | 3 | 2 | 5 | 3 | 2 | -33.30% |
| TOTAL | 1468 | 1210 | 1394 | 1501 | 2328 | 55.10% |

# 2. Heat Pump benefits matching with European Legislations

In February 2015, the European Commission launched a new strategy for a resilient Energy Union with a forward-looking climate change policy. The goal of the Energy Union is to give EU consumers - households and businesses - secure, sustainable, competitive and affordable energy. Achieving this goal will require a fundamental transformation of Europe's energy system. The Energy Union Strategy is made up of five closely interrelated and mutually reinforcing dimensions, designed to bring greater energy security, sustainability and competitiveness [27]. The Energy Union has adopted energy efficiency as a primary consideration and has also suggested Member States to leverage this huge untapped potential and specifically tackle this issue in their National Energy & Climate Plan. Implementation of Heat pump technology can provide multiple benefits in different EU policy areas as shown in Figure 5. Some of the key regulations are explained below:

## 2.1 EU Climate Strategies and targets

The EU has set itself targets for reducing its greenhouse gas emissions progressively up to 2050. Key climate and energy targets have been discussed below [28]:

**2020 Climate and Energy Package** [29]: The 2020 package is a set of binding legislation to ensure the EU meets its climate and energy targets for the year 2020. The package sets three key targets which were set by EU leaders in 2007 and enacted in legislation in 2009.

- 20% cut in greenhouse gas emissions (from 1990 levels)
- 20% of EU energy from renewables
- 20% improvement in energy efficiency

**2030 Climate and Energy Framework** [30]: The 2030 climate and energy framework includes EU-wide targets and policy objectives for the period from 2021 to 2030. The framework set three key targets for 2030 which were adopted by the European Council in October 2014. The targets for renewables and energy efficiency were revised upwards in 2018.

- At least 40% cut in greenhouse gas emissions (from 1990 levels)
- At least 32% share for renewable energy
- At least 32.5% improvement in energy efficiency

**2050 Long Term Strategy** [31]: On 28 November 2018, the Commission presented its strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. The strategy shows how Europe can lead the way to climate neutrality by investing into realistic technological solutions, empowering citizens, and aligning action in key areas such as industrial policy, finance, or research – while ensuring social fairness for a just transition. Following invitations by the European Parliament and the European Council, the Commission's vision for a climate-neutral future covers nearly

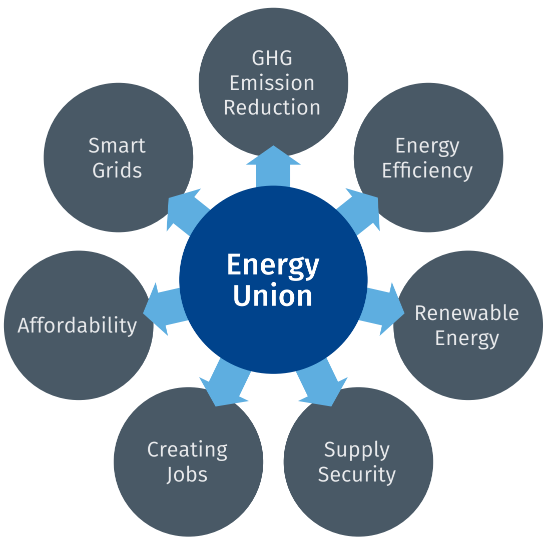



**Figure 5:** *Heat Pump benefits in different policy areas*

all EU policies and is in line with the Paris Agreement [32] objective to keep the global temperature increase to well below 2°C and pursue efforts to keep it to 1.5°C. The Commission's strategic vision is an invitation to all EU institutions, the national parliaments, business sector, non-governmental organisations, cities and communities, as well as citizens and especially the youth, to participate in ensuring the EU can continue to show leadership and encourage other international partners to do the same. To support the long term strategy and become the world's first climate neutral continent by 2050, European Commission also presented the European Green Deal on 11 December 2019 which is the most ambitious package of measures that should enable European citizens and businesses to benefit from sustainable green transition. A €100bn investment has been proposed under this Green Deal and a Just Transition Mechanism has been developed to ensure that the transition towards the climate-neutral economy happens in fair way, leaving no one behind. [5],[6]. The Just Transition Platform aims to assist EU countries and regions to unlock the support available through the Just Transition Mechanism.[7]

## 2.2 Energy Efficiency Directive

The 2012 Energy Efficiency Directive (2012/27/EU) [33] establishes a set of binding measures to help the EU reach its 20% energy efficiency target by 2020. In 2018, as part of the 'Clean energy for all Europeans package', the new amending Directive on Energy Efficiency (2018/2002) was agreed to update the policy framework to 2030 and beyond. The key element of the amended directive is a headline energy efficiency target for 2030 of at least 32.5%. Under the amending directive, EU countries will have to achieve new energy savings of 0.8% each year of final energy consumption for the 2021-2030 period. The directive entered into force in December 2018 and needs to be transposed into national law by Member States by 25 June 2020, except for metering and billing provisions which has a different deadline (25 October 2020).

## 2.3 Renewable Energy Directive

The original Renewable Energy Directive (2009/28/EC) [34] establishes an overall policy for the production and promotion of energy from renewable sources in the EU. It requires the EU to fulfil at least 20% of its total energy needs with renewables by 2020 – to be achieved through the attainment of individual national targets. All EU countries must also ensure that at least 10% of their transport fuels[8] come from renewable sources by 2020. In December 2018, the revised Renewable Energy Directive 2018/2001/EU entered into force, as part of the Clean energy for all Europeans package, aimed at keeping the EU a global leader in renewables and, more broadly, helping the EU to meet its emissions reduction commitments under the Paris Agreement. The new directive establishes a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023. The Directive 2009/28/EC specifies national renewable energy targets for 2020 for each country, taking into account its starting point and overall potential for renewables. These targets range from a low of 10% in Malta to a high of 49% in Sweden. Progress towards national targets is measured every two years when EU countries publish national renewable energy progress reports.

5 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en

6 https://ec.europa.eu/commission/presscorner/detail/en/qanda_19_6690

7 https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/just-transition-mechanism/just-transition-platform_en

8 It would also be interesting to assess how much transportation fossil fuel consumption could be reduced if heat pump were to be adopted on a national scale.

## 2.4 EU Heating and Cooling Strategy

In February 2016, the European Commission presented its newly established Heating and Cooling Strategy [35]. This is the first EU initiative to comprehensively address the energy used for heating and cooling in buildings and industry, which accounts for 50% of the EU's annual energy consumption. The strategy is a key action of the Energy Union Framework Strategy and targets to contribute to improving the EU's energy security and to addressing the post-COP 21 climate agenda. Given the EU's climate goals, the demand for heating and cooling should fall by 42% to 56% by 2050, with a commensurate reduction in $CO_2$ emissions. The EU Heating and Cooling Strategy identifies actions in the following areas: making it easier to renovate buildings; increasing the share of renewables; reuse of energy waste from industry; getting consumers and industries involved [36]. According to the EU, currently the amount of waste heat produced from industrial processes is estimated to be enough to meet the entire heating needs in EU residential and tertiary buildings [37].

## 2.5 Energy Performance of Buildings Directive

The Energy performance of buildings directive (EPBD) [10] is, together with the Energy efficiency directive, the main legislative instruments to promote the energy performance of buildings and to boost renovation within the EU. Both these directives were recently amended as part of the Clean Energy for All Europeans Package. The first version of the EPBD directive 2002/91/EC, was approved on 16 December 2002, entered into force in 2003 and transposed into national law in 2006. This was replaced by the EPBD (2010/31/EU) which has been in force since 2010. It included new provisions to helps consumers to make informed choices [38] allowing them to save both energy and money. It has resulted in a positive change of trends in the energy performance of buildings, following the EPBD introduction of energy efficiency requirements in national building codes [9]. The revised EPBD (2018/844/EU), which amends parts of the 2010 EPBD and introduces a broad range of policies and supportive measures to help national governments boost energy performance of buildings and improve the existing building stock in both a short and long-term perspective. It includes that all new buildings must be nearly zero-energy buildings (NZEB) from 31 December 2020. Since 31 December 2018, all new public buildings already need to be NZEB. The revised directive was adopted on 9 July 2018 and EU countries have until 10 March 2020 to write the new and revised provisions into national law.

9 Ireland introduced Building Regulations Technical Guidance Document (TGD) – Part L in 1991 and later revised in 2002, 2007, 2011, 2017 and 2019. https://www.housing.gov.ie/housing/building-standards/tgd-part-l-conservation-fuel-and-energy/technical-guidance-document-l-2

# 3. Heat pump leading countries: A market development overview

Heat pump technology gained attention in 1970s as a strategy to improve energy efficiency and support energy security. The potential of the technology was significantly recognized during the first oil crisis when most of the countries wanted to reduce their dependency on oil. Compared to several other EU markets, the heat pump market in Ireland is relatively immature. Therefore, it is very important to examine the conditions that led to develop heat pump markets in other countries. On average, uptake of heat pumps has been accelerating over the past decade although it was found that almost all the leading countries have seen several fluctuations in the heat pump market development over the years. The EHPA statistics for 2018 reports installed heat pump stock of 11.8m which contributed 29.8 Mt of carbon emission reduction and 128 TWh to energy generated from renewable sources. It helped reduce 33 Mt of $CO_2$ emissions. The European heat pump market development between 2009-2018 and the number of heat pumps installed in EHAP member countries is shown in Figure 6 and Figure 7 respectively. The market development is largely motivated by energy efficiency and renewable energy ambitions, and underpinned by financial incentives, minimum standards regulation and labelling, multiple-stakeholder partnerships, and progressive build-up of credibility and trust in the technology via effective quality control, information campaigns and independent testing [39].

> France, Italy and Spain are the top 3 heat pump markets in Europe, which are responsible for 50% of all units sold. The top 10 countries, which additionally include Sweden, Germany, Norway, Finland, Denmark, Switzerland and Austria are responsible for 90% of all units sold. In terms of market penetration, Norway, Estonia, and Finland lead sales on a per capita basis [3].

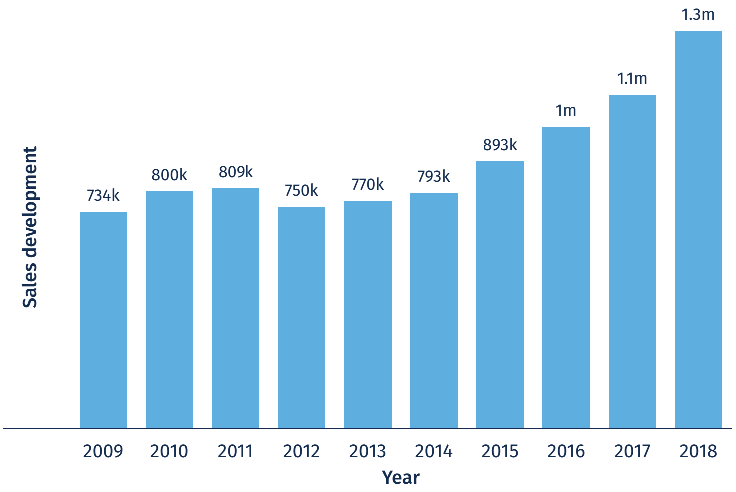



**Figure 6:** *European heat pump market development - 21 EHPA member countries (Source: EHPA [4])*

European countries are very different when it comes to conditions for heat pump market development. It depends on several factors such as geographic location, climate, fossil fuel reserves, renewable share in the electricity mix, variations in building stock, prices of fossil fuel heating, investment into R&D, skills to conduct R&D, technological barriers, political interest etc. The influence of these factors upon the capacity of countries to develop the heat pump market is complex. The collaborative research programmes between publicly and privately funded researchers, authorities and institutions have also provided a very important platform for heat pump market development in two leading countries like Sweden and Switzerland [41].

In terms of energy sources used on this overall heat pump market development, the air source heat pump has been dominating as recent enhanced performance of heat exchangers and compressors made it more cost effective and efficient even when the outside air temperature is very low. The efficiency of geothermal heat pumps based on ground sources is generally high as the ground is warmer than the outdoor air during winter since ground temperatures below the permafrost level, approx. 1m below ground level, remain constant, even in freezing conditions.

In moderate climates almost all types of heat pumps can be applied. Although Germany's climate is a bit different than Ireland (mainly due to Ireland's proximity to the Atlantic and Gulf Stream), it has a moderate climate and a mature heat pump market. It was found that since the

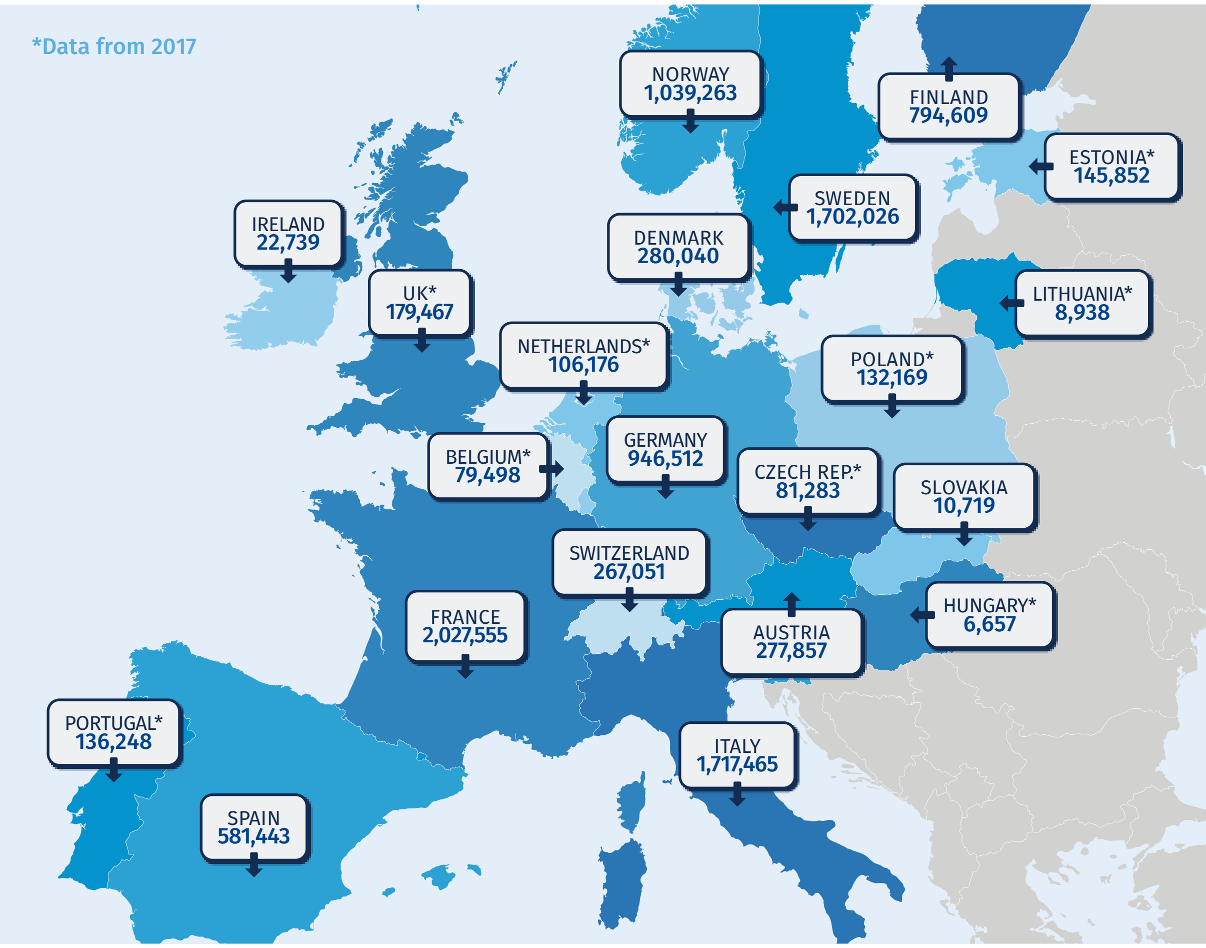



**Figure 7:** *Heat pump installed in EHPA member countries in 2018 (Source: Leonardo Energy White Paper [40])*

mid-90s, the ground coupled (almost only brine/water systems) heat pumps became more popular, mainly since German utilities pushed the development of such systems due to their better seasonal performance factors. During that period, almost 65% of heating heat pumps used ground, 15% used air and 20% used water as the heat source. Later, there was an increased interest in air source heat pumps and in 2012 more than 62% of air source heat pump were sold. The significant decline in the ground sources heat pumps in Germany was due to complicated legal procedures, unnecessary restrictions, and high cost of geothermal drillings mainly in case of vertical bores. Although horizontal geothermal ground loops do not have high drilling cost, there are space constraints with these. Similarly, Austria which has also temperate climate and where the domestic energy production is dominated by hydroelectricity, saw a rapid increase in the installation of heat pumps after the oil shocks and when government introduced a tight building regulation and the subsidies for heat pumps. With the low value of electricity/oil price ratio heat pumps became a very attractive alternative to the oil boilers in Austria. In 2008, Austria had more than 45% share of ground source heat pumps which declined in next years and in 2011 air source heat pump market share reach up to 43% from around 31% in 2008. Likewise, France also saw a downward trend for the geothermal heat pumps which were merely 5% of newly installed devices and the strongest increase over the years was noticed for air-air units. Overall, fuel mix in different countries was also a major factor whether heat pumps are adopted or not.

## 3.1 Market development of selected countries

This section has looked closely to the key incidences that have helped shape the heat pump market development over the years in the EU countries that are leading the market currently. The recorded policy instruments here can provide an overview of how the path of technology, entrepreneurial experimentation, knowledge development and other such initiatives have built trust and confidence in the technology and have brought the end users forward.

**Table 5:** *Policy instruments and major events in selected EU countries [11] [39] [42] [43] [44] [41] [45] [46]*

| Country | Policy Instruments and major events in the development of heat pump market |
|---|---|
| **Austria** | After 1973: After the first oil crisis, demand for thermal protection of buildings increased significantly, mainly to reduce dependency on oil.<br>1970s-1980s: Building standards were improved and subsidies were introduced for complying regulations<br>1980: After second oil shock, governments introduced heat pump support in the form of subsidies based on a tax deduction model. As the electricity/oil price ratio reduced, heat pumps emerged as a very attractive alternative to oil boilers<br>1985: A decrease in oil prices and the removal of government support caused a significant drop in the heat pump market<br>1990: Austrian heat pump association was formed<br>1996: D-A-CH quality seal inaugurated in association with Germany and Switzerland to create a common set of requirements to ensure product and service quality for heat pumps<br>2007: D-A-CH label was transferred to European Heat Pump Association<br>2009: Additional countries – Sweden and Finland joined and new EHPA European Quality Label for heat Pumps (EHPA-Q) with new regulations was introduced [47]<br>2011: Market share increased up to 43% of which about 90% were air/water devices and the remaining 10% were air/air ones.<br>2012: 30% market growth was reported for air/water heat pumps which resulted in them gaining over 50% of the market. Water/water devices showed about 5% growth, while the rest heat pumps market fell by 6% on average. |
| **Germany** | 1974-1988: Federal Ministry funded 72 heat pump R&D projects<br>1979: four-year tax credit scheme was launched<br>1983: tax credit scheme was extended over the next four years<br>1985-1990: Heat pump market collapsed due to low prices of oil and gas, unrealistic savings promised, product quality, insufficient experience of installers<br>1993: German Heat Pump Association (IWP) established<br>1994: Heat pump hand book published<br>1997: Wide information campaign initiated<br>2005: More than 50,000 heat pump units sold<br>2008: Solar system along with heat pumps started to be covered by government subsidy scheme which was suspended in May 2010<br>2009-2010: Sales volume fell due to economic crisis reduction of the main support programme<br>2011: A programme financed around 6000 heat pumps<br>2012: Total of 59,500 heat pump sold<br>2015: Subsidy requirements changed leading to massive increase in heat pump applications |

| | |
|---|---|
| **France** | 1970s: After the oil crisis, French government made the significant change in energy policy<br>1974: “Mesmer Plan” was introduced by the government which entailed the installation of 170 reactors based on the light water system.<br>1980s: French government decided to develop geothermal district heating plants and until 1986 more than 70 networks were installed.<br>1973-2010: During the period share of nuclear energy in total primary energy supply increased from 2% in 1973 to 42% in 2010.<br>1978: French Utility EDF launched the programme “PERCHE” to introduce air/water heat pumps with very specific rules to maintain the quality.<br>1979: 16,000 heat pump units were sold<br>1982: 50,000 units were sold<br>1985: A sharp decline in sales due to the falling price of oil, poor product quality and lack of skilled installers<br>1996: Market went into recession for more than 10 years and in 1996 less than 1000 heat pumps were sold<br>1997-1998: EDF launched new programme “Vivrelec” to promote heat pump through loans and grants. Specific tariff and associated services were introduced. Heat Pump Commission was set up to establish rules for connecting new thermal sources and homes<br>2000: Income tax credit for heat pumps was introduced. Later VAT for heat pumps was reduced from 19.6% to 5.5% and eco-loan at 0% interest loans were introduced<br>2001: Market grew to 15,000 heat pump installations<br>2002-2005: Annual growth rate increased from 2002 to 2005<br>2002: French Heat Pump Association was established<br>2007: Heat Pump Manufacturer can apply for a quality certification mark (NF-PAC) which was based on normalized EN and ISO device testing procedures.<br>2002-2006: A minimum value of COP was also introduced for ensuring effective installations. ”QualiPAC” quality chart was introduced to articulate the requirements regarding cooperation with clients and training procedure for firms.<br>2002-2006: Average annual growth in installations was about 25%. In 2012, sales growth was 112% with total number of installations of 53,510<br>2006: A new tax credit was introduced<br>2007: More than 18,000 geothermal heat pumps were sold for detached single family houses and 80% of them were for new buildings. In 2007, total around 70,000 new heat pumps were installed<br>2008: Around 98,000 heat pumps were in operation<br>2011: By the end of 2011, 106,000 units were in operation where 470,000 were air/air units<br>2012: residential construction sector installed 142,000 heat pumps |
| **Sweden** | 1970s: Heat Pump sales started to rise mainly due to state subsidies and high oil prices. Forms of subsidies changed over the years in cash contributions, interest free loans, income tax reductions<br>1975: Swedish building code stating to install heat recovery system if ventilation heat loss is higher than a certain limit<br>1985-86: Market peaked and then started to drop due to poor reputation of heat pumps, withdrawal of subsidies, decline in oil prices, and stagnation in the construction of new buildings,<br>1993: Launched a programme for development and commercialisation of innovative ground source heat pump technologies, specific requirements for heat pumps were worked out and programme was linked with investment subsidies and informational campaigns<br>1995-1999: Number of heat pump installations grew on average by 56% per year<br>1998: Swan label – an eco-label was introduced for heat pumps<br>2005 – A quality mark (P-label) was introduced<br>2005-10, 2012: Support for heat pump installations in residential buildings was introduced |

| | |
|---|---|
| **Switzerland** | 1970s: Breakthrough came after the first oil crisis and several actions were taken for popularisation of heat pumps<br>1980: First conference on heat pump technology was held. Swiss Heat Pump Association (AWP) was established to include manufacturers and importers<br>1980s: Information campaigns, sharing best practices, quality and certification were carried out<br>1981-82: Start of heat pump system field testing<br>1990: Energy 2000 – A 10-year strategy was launched<br>1993: Swiss Heat Pump Promotion Group was established<br>1993-1995: subsidy for heat pumps for existing buildings was introduced<br>1993-1996: Manuals for better heat pump installations were introduced<br>1997: Subsidy schemes were launched and some of the utilities introduced special energy tariff, standards were introduced that maximum 80% of heat and hot water of new buildings could be covered by non-renewable energies.<br>1998: Swiss Retrofit Heat Pump Competition was launched for promotion and development of efficient heat pumps for heating and hot water<br>2001: "SwissEnergy" was launched to slowdown the growth of electricity demand and integrating renewables<br>2001-2005: FWS ran intensive promotion campaigns for heat pumps<br>2001: DACH label for drilling companies<br>2006: 3-day training programme for installers was introduced<br>2013: Air to water heat pump dominate with a market share of 55-60% followed by ground to water heat pump share diminishing 42-37%. Air to air heat pump market share is only around 2-3%<br>2013: Total installed heating capacity increased from 845 MW in 1990 to 3328 MW in 2013. |

## 3.2 Driving factor for deployment

There are some of the key factors that drives the heat pump implementation widely:

- **Low maintenance and longer lifespan:** Compared to oil and gas boilers, maintenance requirements for heat pumps are minimal and they could potentially have a longer lifespan [48]. A heat pump lifetime is usually more than 15 years which can be extended up to 50 years with a little maintenance of air filters, fan motors, cleaning of the outdoor coil etc. at certain intervals [49]. Usually, there is no need for crucial safety checks with the heat pumps. The annual check can be done by either the owner or the certified installer who can provide the maintenance required and suggest ways to optimise the heating performance.
- **Low carbon technology:** Around 65%to 75% of heat energy is extracted from the natural resources such as air, water, ground which makes it a very low emission technology. The acceptance of electricity as an energy source for heating is a strong driver for heat pump technologies. If renewable based electricity generation is available to run the compressor, a heat pump can be a zero emission technology.
- **Improved supply security:** Ireland's energy import dependency is still very high although reduced from 88% in 2015 to 66% in 2017 which further increased to 67% in 2018 [13]. In the recent World Energy Council's Energy Trilemma Index Ireland scored very low on energy security index ranking 96th out of 128 countries [50]. With increasing renewables in the grid, use of proper building fabric, and the implementation of efficient heat pump technologies, there could be a significant reduction in the fossil fuel consumption, as a result improving the overall national energy security performance.
- **Higher safety prospects:** There is an improved safety aspect as there will be no oil tank or gas pipes will be needed inside home in most cases. In case of any electricity system related fault, the control system comes with different internal protection mechanisms which makes its operation safe. There are no other perceived issues from safety

perspective as long as F-Gases requirements can be addressed, as it could be potentially harmful to the environment in case of any leakage etc.

- **Low running cost:** Most of the heat pumps have a very low running cost once it is installed, as a significant proportion of energy to operate the heat pumps comes through renewable energy sources, such as, air, water, or ground. One unit of driving energy (from the grid or exhaust air from buildings or excess energy from industrial processes) combined with 2-4 units of renewable energy can generate 3-5 units of useful energy. Heat pumps are cost-effective with oil boilers as fuel transportation and chimney and other related cost will not be needed. There could be other significant cost benefit with heat pumps based on electricity tariff and compensation for demand side flexibility. Comparing with direct electric heating, more than 60% savings in operation cost could be achieved by a heat pump with an efficiency of only 2.5 which enables investors to compensate for the higher investment cost over the lifetime of the installation, depending on the price of electricity [40].
- **Reversible operation:** Many heat pumps are able to reverse the heat collection process and can be operated as air conditioner as well which can provide cooling during the summer season. Although it is one of the driving factor for many countries, it is not an appropriate design solution in Irish context. High-efficiency heat pumps can also dehumidify better than standard central air conditioners, resulting in less energy usage and more cooling comfort in summer months [51].

## 3.3 Key barriers to market uptake

Based on literature review and assessing country specific policy challenges, the following key barriers and challenges to heat pump uptake have been identified [39] [52] [53].

**Table 6:** *Key barriers to the heat pump market uptake*

| Type of Barriers | Barriers | Explanation |
|---|---|---|
| **Economic** | **Cost** | Currently, the purchase as well as installation costs (in case of retrofitting) of heat pumps are significantly higher than conventional alternatives such as oil or gas boilers. Heat pump installation may also need an electrical upgrade at the consumer or distribution level which may come at an additional cost. |
| | **Access to finance** | Because of high upfront costs and unavailability of appropriate financial support, majority of consumers have difficulties in purchasing heat pump technologies. |
| | **Uncertainty in fuel and carbon price** | External factors such as fuel prices and carbon prices create uncertainty for the large scale adoption heat pump or renewable heating technologies [54]. |
| | **Lower energy prices** | Low energy prices, which do not fully reflect the external cost of the different energies, are a significant barrier. |

| | | |
|---|---|---|
| **Behavioural** | **Awareness and confidence** | There is a limited awareness around the potential of heat pump technologies among general public and also among the authorities and politicians dealing with energy matters. Due to low awareness and uncertainties around performance, consumers may not have the confidence to invest. |
| | **Space and aesthetics** | Heat pumps and associated heat emitters can take up more space than conventional heating systems and some consumers may have a negative perception of the aesthetics of having a unit on the exterior of their home |
| | **Hidden costs (e.g. time)** | Non-monetary costs such as time taken to research the technology, finding an skilled installer, and hassle associated with installation at the premises can limit uptake |
| | **Landlord-tenant split** | Heat pumps are a long-term investment. The beneficiaries of heating services are often tenants who many only have short tenures whereas the investor is the landlord. This can lead to a mismatch of incentives to invest in beneficial technologies. |
| **Technical** | **Suitability of houses (including noise)** | Heat pumps work effectively in well insulated energy efficient houses and therefore, taking the fabric first approach is really important. Making the homes airtight to reduce heat-loss and infiltration of cold air while, maintaining a good level of planned ventilation to protect homes from damp and mould must be priority [55]. Permitted development limits on noise from heat pumps and objections from local residents can limit uptake, especially installation of air source heat pumps that has outdoor condensing unit with a fan to draw air [56]. |
| | **Regulatory barriers** | Barriers related to lack of technical standards and mandatory policies can limit heat pump uptake. Some regulations may create barriers to uptake. For example, getting permission to install ground water HPs is difficult across the EU and there are several environmental regulations [57] need to be adhered to. |
| | **Installation / operational** | To deliver heating comfort efficiently, there are several technical challenges in installing and operating heat pumps, such as right sizing of heat pumps, installing at the right location, operation at very low temperature, cleaning of air filters regularly in case of air source heat pumps etc. In case of water based system, special radiators in large numbers may be required, if the temperature is lower. Underfloor heating is preferable in this case as they are the most cost-effective solution but, may be cause its own problems, as it is not ideal for retrofitting options. |
| **Supply-side** | **Supply chain capacity** | The capacity of the supply chain could also be a bottleneck in the heat pump market development. It should grow fast enough to match demand. For example, supply of heat pump technologies, testing and certification, number of trained installers, capacity to resolve consumer issues etc. |
| | **Supply chain coordination** | The effectiveness of the heat pump industry to grow may be determined by interdependences along the supply chain (e.g. the development of a spare parts network which matches the needs of installers). EU also recently introduced 'Right to Repair' rules for large domestic appliances and extending this to heat pumps will require manufacturers to ensure longer-lasting product and supply spare parts for up to 10 years. |
| | **Poor perception** | Incompetent vendors and installers can hamper the market growth by not meeting a reasonable efficiency and quality standard, leading to frustrated buyers and a setback in sales in the longer term. |

# 4. International best practices for the deployment of heat pumps

## 4.1 National policy vision

Building a transparent and long-term national policy vision and developing the associated strategies has allowed industries, investors and other key market actors to make informed decisions. Countries where policy frameworks showed a long-term committed strategy and guarantee of support, stakeholders came forward to support and develop the market. It has given confidence to invest in R&D and to develop the optimum products for the market. Manufacturers and suppliers have also developed their strategies accordingly. Utilities have engaged with heat pump technology and explored the innovative business models and revenue streams as a result of having a national policy vision.

Government vision and long term commitment on heat pumps have also given consumers' confidence in the technology. Industry associations came on-board to support policymakers for promotion and implementation of the technology. Sweden and Switzerland are the two leading countries and they set the out their vision in 1970s for the use of heat pumps for residential space and hot water heating. Since then, the number of installed heat pumps in these two countries has been rapidly growing. In these two countries, numerous policy incentives, entrepreneurial initiatives, and knowledge development have helped to develop the heat pump market [41]. These two countries took a more coordinated and strategic policy approach to initiatives in 1990s and 2000s which were flexible and adjusted over time.

National policy vision should support all the three dimensions of policy measures to encourage the heat pump market uptake [39].

- Enabling: Information provision, demonstration, public campaigns
- Incentivising: Economic incentives – supply or demand side
- Mandating: technology standards, installation standards, building regulations

## 4.2 Strategy sequencing and packaging

Appropriate sequencing and packaging of a number of strategies has significantly helped heat pump roll out in countries like Sweden, Austria and Germany. In all these countries, the early deployment of heat pumps took place following the oil crises in 1970s and sales were bolstered by introducing a number of initiatives such as consumer awareness, promotional programme, intensive information campaigns, technical standards, investment grants, low interest loans, and stringent building codes. Forming heat pump associations, introducing installation practices, training for installers and quality assurance initiatives were some of the other key initiatives which were introduced at the right time in the right order to ensure the product quality and best installation practices.

> In Sweden, policy stability has been highest for carbon taxes rather than direct support for heat pumps. The carbon tax in Sweden has sustained over two decades and more than tripled since its introduction in 1991 however, subsidies for heat pumps were available for only discrete periods of one to four years at a time. It has also been argued that uncertainties around subsidies has compromised manufacturers long term investments in heat pump technology [44].

### Strategy sequencing and packaging in Austria

Austrian electricity production is dominated by hydropower which makes heat pump technology a viable low carbon alternative to oil or gas heating. Initial uptake of heat pumps in Austria was mainly driven by the 1970s oil crisis which were further boosted by the introduction of tax breaks for new heat pump installation. In the mid-1980s the heat pump market declined due to falling oil prices, lack of standards and low consumer confidence. In 1990 when the Heat Pump Association was formed in Austria, it initiated an intensive information campaign, training programme for installers, and a labelling programme for heat pump quality assurance in partnership with Germany and Switzerland. In 2001, the Austrian government introduced grants for heat pump installation and a certification programme was introduced for installers by the Austrian Heat Pump Association in the same year, after which the market subsequently recovered [11] [42] [44] [45].

## 4.3 Strong customer proposition

A joint publication by European Heat Pump Association and Delta Energy & Environment suggests that having a compelling customer proposition can mobilise heat pump market growth [42]. Making the technology more affordable for end users in terms of upfront investment as well as running costs is important for a mass market appeal. The provision of government grants, subsidies, and incentives builds the confidence and makes the technology more affordable for end users. Guaranteed government support can also enable private financing to trigger the large scale market growth. In most of the heat pump market leading countries, capital grants covering a proportion of installation costs and tax breaks on labour costs have been two of the most common

### Strategy sequencing and packaging in Switzerland

In 1990 when Switzerland introduced a 10-year vision aiming to increase the use of renewable energy and improving the energy efficiency, the heat pump was considered one of the promising technologies to meet the ambitious goals. During this decade several financial instruments were introduced by the government and also several measures financed by the private sector were launched. These public and private initiatives were introduced in a coordinated manner and they complemented each other. The Swiss Federal Office adjusted the policy measures from time to time and also created a role to coordinate national research, technology transfer and market development of heat pumps. In 1993, Swiss Heat Pump Promotion Group was established which brought heat pump producers, distributors, installers, utilities, some of the local authorities and other stakeholders under one umbrella with a mission to drive the heat pump uptake. In the same year, a test centre was also created for quality control and to boost confidence in the technology. Between 1993-1995, a public subsidy programme was introduced for heat pump installation in the existing buildings which significantly increased sales but when the subsidy ended the sales declined again. In 1996, the first heat pump exhibition took place in the country and later in 1997, a new subsidy programme and special electricity tariffs were launched by some utilities. In 1998, a quality label was introduced for heat pump technologies to support product quality and build customer trust [11] [42] [39] [41] [45] [44].

**Table 7:** *Financial incentives in selected EU countries [44]*

| Country | Instruments type | Support |
|---|---|---|
| **Austria** | Grant | €1000 – €2000; Minimum seasonal COP2 = 4/4.5 |
| **Finland** | Tax reduction | 60% of labour cost; Maximum €3000 |
| **Denmark [58]** | Tax exemption | The amount of tax relief is equal to the tax rate entitled persons are exempt from |
| **France** | Tax reduction | 40% of labour cost; Maximum €8000 |
| **Germany** | Grant | €450 – €1200 for ASHPs, €900 – €2400 GSHPs; SPF>3.7 for ASHPs, SPF>4.2 for GSHPs |
| **Ireland** | Grant | €3500 for all types of heat pumps except air to air €600 ; €200 technical assessment grant |
| **Italy** | Tax reduction | 55% of total cost, deducted in equal maintenance over 5-years; High SPF requirements |
| **Netherlands** | Grant | €500/kWth; Maximum €1000 |
| **Norway** | Grant | €1100; Air-air systems excluded |
| **Sweden** | Tax reduction | 50% of labour costs ; Maximum €5000 |

financial instruments to support heat pump technologies. Table 7 shows the examples of financial incentives in some of the selected EU countries.

In addition to investment subsidies, carbon taxes have also been introduced in several countries in 1990s successfully like Finland, Netherland, Norway, and Sweden which have contributed strongly to adoption of heat pumps.

### Private Financing: Municipal Utilities / ESCO Approach

In Switzerland, heat contracting offered by municipal utilities contributed to the growth of the market. The utility plans, installs and operates heat pumps at their cost at customer sites. This kind of contracting can be very successful for multifamily dwellings. For the end-user this model avoids upfront costs and reduces the risk of uncertain running costs – providing an attractive long term proposition. The ESCO model opens up a suite of opportunities for large installers and other market players to be positioned to offer financing [11] [44] [42].

## 4.4 Key actors and their responsibilities

For an effective and efficient uptake of the heat pump market, a collective effort is required. Countries like Austria, Sweden and Switzerland have included a range of stakeholders which played a critical role either as a lead, or supporting other leading stakeholders depending on the market characteristics and its different stages of development. At the initial stage some of the stakeholders' roles were important in terms of creating a market which can be self-sustaining. Figure 8 describes the key stakeholders and their responsibilities. In these countries, stakeholders collaborated to achieve the objectives of ensuring the product quality and building confidence about the technology among the end users. Many of the leading heat pump markets have found the role of heat pump associations highly effective during the initial stage of technology introduction as well as developing a sustainable heat pump market.

The Austrian Heat Pump Association (LGW), started with a group of manufacturers, was founded in 1990. Later, installers and utilities were also included. After realising the importance of the entity in establishing the heat pump market, Utilities became an important promoter of the Association. While LGW initial focus was creating technology awareness from end-users to politicians, they also took over the tasks of quality management, education & training and dissipation of legal constraints [77].

**Figure 8:** *Key stakeholders and their roles*

| | |
|---|---|
| **HP Manufacturers/Supplier** | Influencing heat policies and strategies and active involvement to roll out the market |
| **HP Certifiers and Installers** | Ensuring product and product instatllation quality and assist in shaping relevant |
| **Standard Developers** | Delivering technical standards to ensure high level of quality and lifetime |
| **National Governments** | Setting national vision and implementation roadmap to build stakeholder confidence |
| **Consumers** | Purchasing the product and communicating the satisfaction to build others' trust |
| **Consumer Associations** | Providing impartial information and advice to consumers |
| **Utility Companies** | Bringing innovative business models and building end-user confidence |
| **Industry Associations** | Assisting in training programmes, quality assurance, promotional campaign etc |
| **Local Government** | Taking initiatives to promote local partnership with installers, utilities and local businesses |

## 4.5 Citizen awareness and technology promotion campaign

All the stakeholders' roles are crucial in raising awareness through carefully designed marketing and promotion strategies for the end users. While policymakers can showcase heat pumps as a key technology as part of their national strategy of energy or emission reduction programmes; utilities, being in direct contact with the end users, can provide direct marketing and provision of information and advice to citizens. Industry associations can also create a positive image of the technology through facilitating promotional events where they can provide information to end users and show some of the trial results to build their trust. Manufacturers and installers can also be key influencers in the adoption of the technology as well as building confidence among consumers. Evaluating the impact of promotion on the heat pump sales development would be very difficult as number of other initiatives such as providing grants, subsidies, technical standards were taken in tandem with promotional and awareness activities in these forefront countries. For example, in Denmark, subsidies, heat pump trials, and promotional campaigns are being considered to achieve 200,000 heat pump installations by 2020.

Some of the key strategies in different jurisdictions are as follows:

- The Swiss Federal Office of Energy (SFOE) designed a heat pump promotion programme and also provided partial funding and some other support to set up a heat pump association (FWS). FWS was finally established in 1993 and tasked with country-wide heat pump promotion and coordination of marketing activity [45]. Subsequently, Swiss Promotion Programme established the Heat Pump Test Facility, WPZ, with SFOE heat pump filed trials in 1996. Independent heat pump performance data from the test centre and field trials were used to raise consumers and installers confidence. Through the Swiss Heat Pump promotion programme, information dissemination took place in each Swiss region through community events involving municipalities, manufacturers and installers, and local communities. Manufacturers also carried out TV advertising campaigns [11].
- German utility RWE has established an online heat pump forum which is basically a portal that provides product information in easy language for the end users and connects them with installers and heat pump products. Installers and manufacturers can pay a small fee to advertise on the portal. From the end users' perspective, product or installer's inclusion on the RWE's portal gives confidence in the product and installer capabilities. NRW (North Rhine-Westphalia) Energy Agency have produced radio adverts, engaged with communities by attending local trade fairs and setting up information sharing events for citizens. This is one of the Germany's most successful regions in terms of heat pump market growth [42] [11].
- In 1989, Sweden also set up the Heat Pump Court (VPN) – An independent complaint board to address any disputes or litigation cases regarding heat pump performance. VPN has the biggest impact in the early stages of the market development as it has significantly built the trust in the technology and encouraged installers to improve the quality of their installations to meet customer expectations. The VPN is run by Swedish Heat Pump Association and allows customers to bring a claim directly against installation companies. Court decisions are made publicly available and offending installers are identified and disciplined. If an installer is found guilty, it must pay back the customer's court fee and fix the problem. A fee of around €150 is charged to raise the case which is refunded if it is successful. VPN has been dealing 40-60 cases per year and about 60% cases won by the customer. In 90% cases, the problem was found to be with the installation rather than the heat pump technology itself. The common causes are under dimensioning of the heat pump, incompatible radiator system and over promising of the heat pump performance by the installer [41] [45].

## 4.6 Technical standards, installation guidelines and installers' capacity building

A comparative review of European heat pump field trials disclosed that heat pump performance is highly sensitive to poor design, installation and operation [59], and therefore, it is very important that the right standards for the technology and guidelines and best practices are communicated to manufacturers and installers.

The establishment of test facilities in Switzerland and Sweden [41] in 1970s and 1980s respectively helped raise the technical standards of heat pumps and providing quality assurance to the product. In Switzerland, installation quality was further bolstered by introducing an installer certification scheme and standardised training for installers provided by FWS. Another element of this quality assurance drive was the creation of the DACH quality label in 1998 (now EHPA quality label), which set minimum standards for Heat Pumps [11].

A number of technical standards have already been introduced by the countries that have led GSHP market, such as Switzerland, Sweden, Germany and Austria. These countries also have the opportunities to introduce 'contractor certifications and quality awards' to reduce the industry risk and build customer trust. In 2012, the EU requested that member states should introduce certification schemes (or equivalent for GSHP installers [60].

The lack of installers and serious quality problems was primarily responsible for the collapse of the heat pump market in mid 80s in Germany. In 1993, the German Heat Pump Association - IWP (a group of seven big utilities and several heat pump manufactures) was also founded which was the first critical step to improve the quality of components and installation techniques. In 1994, a handbook on heat pump technology was published. Further, in 1996 VDI –the German Association of Engineers with support of a group of scientists decided to develop technical guidelines for ground coupled heat pump components and installation techniques [61].

According to Renewable Energy Sources Directive 2009/28/EC, EU member states needed to introduce certification of installers for heat pumps, biomass, solar cells etc. by the end of 2012. According to the Directive the training leading to installer certification or qualification shall include both theoretical and practical parts. At the end of the training, the installer must have the skills required to install the relevant equipment and systems to meet the performance and reliability needs of the customer, ensuring the quality of the installation and comply with all applicable codes and standards. Denmark has a list of certified installers published on DEA website. It has a certification scheme specifically for heat pumps in order to ensure that heat pumps are dimensioned, installed, and maintained correctly. Similarly, Sweden has also introduced a certification scheme for heat pump installers which is valid for five years and a well-designed accreditation programme provides a continuous training of installers and renewal of certificate. Norway and other countries have also adopted similar approach [62].

In 1993, Sweden launched a technology procurement programme for ground source heat pumps, aiming to bridge the gap between buyers and manufacturers. Swedish Agency for Economic and Regional Growth (NUTEK) developed the specification requirement of a heat pump that was 30% more efficient and 30% cheaper than the existing heat pumps on the market. It also specifies the other quality and reliability standards and did not allow products using CFCs and HCFCs. An open invitation was made to manufacturers to enter into the competition who met these requirements and it was guaranteed that at least 2000 units of the winning model would be purchased. The procurement programme was also supported by an independent testing and certification programme (with around 25% of the procurement budget) and a range of information campaigns (with around 50% of the procurement budget) [41].

## 4.7 Stringent building regulations

The heat pump is an economic and environmentally sustainable solution to provide heating and hot water in residential buildings. Having a stringent requirement in building regulations for energy efficiency and renewable energy integration in the heating system can be very effective in stimulating the deployment of heat pumps [39]. Ireland has already seen the impact at some extent by introducing the requirement (Technical Guidance Document Part L 2007[10]) for new homes to incorporate renewables. In Switzerland and Germany renewable energy standards on new buildings have significantly helped drive uptake of heat pumps. In 2009, the German EEWärmeG (renewable energy heat law) set out requirements for 50% of calculated heat load in new residential buildings to be supplied by renewables, of which at least 15% must come from solar energy [45]. A year later the state of Baden-Württemberg introduced an additional requirement that the boiler replacements in existing residential buildings are required to source 10% of heat demand from renewable energy sources [39]. Heat pump installations should also meet the minimum SPF requirement.

Despite the lack of specific incentives, national and regional building energy efficiency regulations have significantly up scaled the GSHP market in new builds in Italy [60]. The current relationship between the price of kWh's electricity and m3 natural gas have become a game changer for the Dutch market for new and renovated buildings. This has led to a wider deployment of the heat pumps on the market [63].

The 1975 Swedish building code (Svensk Bygg Norm - SBN) required that buildings with ventilation heat losses in excess of 50MWh should be fitted with a heat recovery system. Subsequently, the 1980 SBN incorporated an exhaust ASHP as an acceptable solution for residential water heating. Building codes have also favoured certain heat pump technologies over others. The building regulations have mandated higher energy efficiency levels in new buildings, and tighter building envelopes have tended to require controlled ventilation due to greater ventilation losses, leading to the dominance of air-to-air over GSHP heat pump applications [45].

Along with the regulatory obligations and policy support to make residential buildings environment friendly, Norway also implemented an intensive prototype and demonstration facilities for heat pump technologies during 1983-1994. Around sixty prototype and demonstration heat pumps were installed in buildings and industries with extensive measuring equipment, and measurements were examined over several years [45]. In 1996, Swiss Federal Office of Energy also introduced a "Field Analysis of Heat Pump Installations" to document the performance of heat pumps and demonstrate improvement potential. Results were used in the information and dissemination programme [11].

In a report prepared by Frontier Economics [39] for the UK Committee on Climate Change made strong recommendations on two aspects:

- It highlighted the benefit of tightening carbon emission standards on new builds to 6 $kgCO_2/m_2/year$ from 2020.
- Introducing a minimum carbon emission standard on heating system replacement, subject to suitability requirements for alternatives to the existing system being met.

Carbon standard regulation for new homes is a highly effective means to tackle behavioural and suitability barriers to heat pump uptake. This kind of policy also retains the flexibility to explore and allow other options to reduce emissions that may be more cost-effective in certain circumstances or different scenarios. Policies can also be introduced to encourage the uptake of heat pumps in off-gas homes even before 2025 when the Irish government is planning to ban gas boilers. It is also important to note that suitable criterion or measures (such as those required by SEAI for approving heat pump grants) would be needed to ensure heat pumps or other low carbon heating technologies are not being installed in homes that are not properly insulated.

> In 1997, Zurich introduced a requirement that maximum 80% of useful energy demand per m2 could be from non-renewable energies for heating and hot water purposes and the rest 20% could be met by either installing insulations or using technologies like heat pumps. This was a strong policy incentive for the deployment of heat pumps in the region [41] [44].

10 https://www.housing.gov.ie/sites/default/files/migrated-files/en/Publications/DevelopmentandHousing/BuildingStandards/FileDownLoad%2C19069%2Cen.pdf

**Figure 9:** *Outdoor heat pump unit*

# Annex: Heat pump: Technological understanding for policymakers

## A1.1 What is heat pump?

Heat pump is a technology that extracts thermal energy from a heat source/place, upgrades it to a higher temperature and transfers the energy to another source/place. It is not a new technology; refrigerators and air conditioners are both common examples of this technology, where warm air is extracted from inside these appliances and vented outward. Heat pumps can be used in cooling (during summer) as well as heating (during winter) mode. During the winter, heat pumps operate like an air conditioner in reverse. Heat pumps transfer heat by circulating a substance called a refrigerant through a cycle of evaporation and condensation. A compressor pumps the refrigerant between two heat exchanger coils. In one coil, the refrigerant is evaporated at low pressure and absorbs heat from its surroundings. The refrigerant is then compressed along the way to the other coil, where it condenses at high pressure. At this point, it releases the heat it absorbed earlier in the cycle. The process is shown in Figure 10.

There are two parts to a heat pump system: the heat source (from where heat is to be captured), for example, the ground, air or water; and the heat sink (where the heat is to be sent and to be used). In very simple terms, the heat pump is the mechanism which drives this heat flow cycle of heat pooling and releasing. As an electric motor is needed to drive the compressor, heat pumps need electrical energy to operate. As a small amount of energy is required to run the compressor's motor, the overall efficiency of heat pumps is very high. The energy needed to heat one building with direct electricity is sufficient to heat 3-4 buildings with heat pump technology. Similarly, the amount of energy needed to heat one house with a gas boiler is sufficient to heat 2-3 houses with heat pump technology. Figure 11 and Figure 12 shows a comparison of energy input required to provide one unit of useful heat and the comparison of $CO_2$ equivalent emissions of different heating systems. An air source heat pump typically captures around 3 kW thermal energy per kW of electrical energy consumed that gives an effective efficiency of 300%. According to thermodynamics theory, it is impossible to have an efficiency of more than 100% and therefore, the heat pump performance is always expressed as a

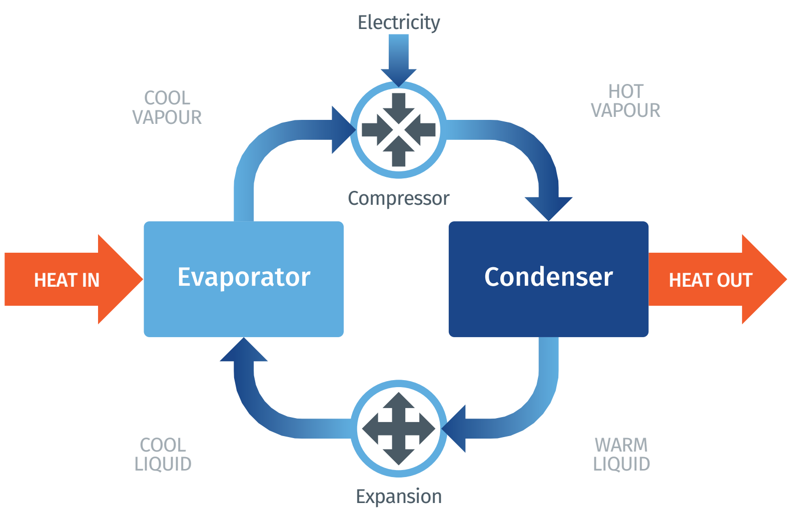



*Figure 10: Operating principle of heat pump*

The temperature of the ground or air being used by the heat pump also plays a key role in the system's efficiency. The seasonal performance factor (SPF) takes into account how well the pump works at both low and high temperatures, and is a much better indicator of how efficient the pump will be than the COP. Usually, the efficiency of HP is inversely proportional to the temperature difference between the heated space and the environment. In case of Ireland, as the daily average temperature rarely falls below freezing point, the climatic condition is ideal for the effective operation of heat pumps.

Coefficient of Performance (COP) rather than an efficiency. In this case, we can say that ASHP has COP of 3 [64]. It is also important to highlight that heat pump performance for space heating and hot water heating is strongly linked with the outside air temperature due to seasonal fluctuations. Additionally, there are varying performances for space heating and water heating at low temperature, and even if the space heating demand can be covered by lower temperature networks, the hot water temperature requirement cannot be avoided. As houses become more insulated/air tight in future, hot water demand will form the majority of the heating load.

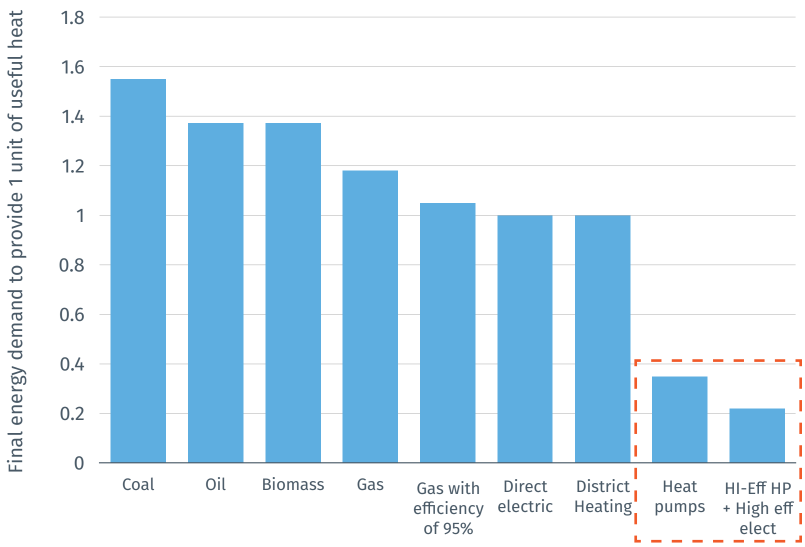



**Figure 11:** *Comparison of final energy demand of different heating systems (Source: EHPA, 2018 [40])*

## Types of Heat Pumps

Heat pump technologies are primarily used for the purpose of space and water heating. The three main types of heat pump systems based on heat sources are:

1. Air Source - energy is taken out from the outside air.
2. Ground Source - energy is extracted from the ground. It can be either heat extraction from horizontal pipes laid flat in the soil or heat extraction from pipes laid vertically in boreholes.
3. Water Source - energy is extracted directly from the nearby water source (Like wells, rivers, ponds or water streams).

Ground source heat pumps are typically installed in new, detached dwellings whereas air source is generally more suitable for retrofitted buildings [65]. Beside these, technological advancements and economic growth have also enabled geothermal source and solar assisted heat pump technologies which are being installed in many countries.

An air source heat pump (ASHP) takes lower surrounding heat from the air, and raises its temperature to higher level so that it can be used for building heating or any other heating purpose. Air-Water HP benefits from wet heating distribution system, and distributes the heat to the heat sink, while the Air-Air HP generates warmer air at heat sink, which can be circulated through the fans. ASHP usually finds its applications in domestic heating which could be either space heating or water supply

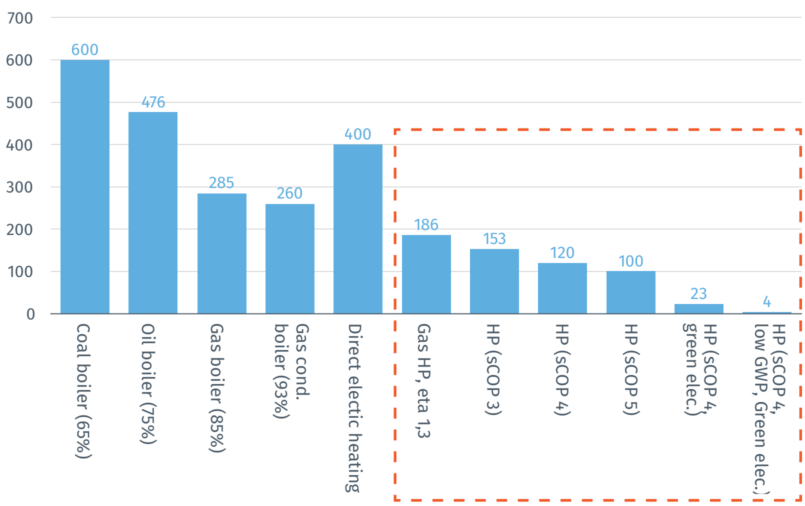



**Figure 12:** *Comparison of $CO_2$ equivalent emissions of different heating system (Per kWh) (Source: EHPA, 2018 [40])*

**Table 8:** *Common heat pump technologies*

| Source | Sink | Heat Transfer |
|---|---|---|
| Air | Water | This is called 'AIR-WATER HP'. This heat pump captures heat from air, and transfers it to the water. |
| Air | Air | This is called 'AIR-AIR HP'. This heat pump captures heat from air, and transfers it to the air. |
| Water | Water | This is called 'WATER-WATER HP'. This heat pump captures heat from the water (from lakes, ponds or rivers) and gives it off to the hot water circuit. |
| Water | Air | This is called 'WATER-AIR HP'. This heat pump captures heat from water (from lakes, ponds or rivers) and gives it off to the air. |

Air continues to be the main energy source (more than 85%) used in the EU heat pump market [25].

heating. However, the efficiency of these heat pumps very much depends on the seasonal changes. Furthermore, there is also a growing recognition of Exhaust Air Heat Pumps (ESHPs) which extracts heat from the exhaust air leaving of a building, and uses it to for space heating purposes or to provide hot water. Exhaust air heat pumps are widely used in conjunction with underfloor heating systems and it can help prevent condensation and improve air quality [11],[12] .

Water source heat pumps (WSHPs) make use of water bodies such as lakes, ponds, underground aquafers or rivers, etc. as heat sources. This HP makes use of smaller amount of heat from water and converts it to the higher temperature heat, which can be considered for domestic heating. Compared to ASHP, the WSHP is more environment friendly as WSHP generates less $CO_2$ emissions. Ambient temperature does not strongly impact the efficiency of WSHP. This is because a waterbody has enough heat to make WSHP work even during wintry weather. Hence, WSHP operates with higher efficiency as compared to ASHP, but availability of waterbodies or water storage near heat sink makes their applications to be limited [3].

Ground source heat pumps (GSHP) and Geothermal HP use natural heat energy which is stored inside the ground as the heat source. Although the functioning process for both HP systems are similar, a key difference exists between the technologies. GSHP extract heat from shallow ground (usually from 1m and 200m depth), as compared to Geothermal HP which traces the heat from deeper ground (usually from 500-2500m). They both are different as per their application as well. GSHP is mostly applicable in domestic heating and small commercial space and water heating applications, whereas, geothermal HP is suitable for larger industries. Studies on GSHP suggests that the system is useful in cold and hot climatic situations and provides substantial energy saving [4]. Further, a pre-heated water to water heat pump technology is also gaining some recent application to overcome the limitation of a typical geothermal heat pumps which cannot provide enough temperature for water heating purposes. A preheated incoming liquid is used as the water source and depending on the source temperature, this technology can have a coefficient of performance (COP) of between 2.5 and 6.5 [13].

Ground source and geothermal heat pump technologies are characterised with higher efficiency because they have no dependency on ambient temperature. Hence these heat pumps are popular and deployed worldwide.

Further, based on the variation in thermodynamic cycle, HPs can be categorised as Adsorption heat pump and Absorption heat pump. Altogether

11 https://www.designingbuildings.co.uk/wiki/Exhaust_air_heat_pump

12 https://www.seai.ie/publications/HPAI%20Heat%20Pump%20Code%20of%20Practice

13 https://www.nordicghp.com/2015/03/how-our-high-temperature-water-to-water-geothermal-heat-pump-works/

these HPs are known as Sorption HPs. These HPs use the thermal energy of industrial waste heat as their heat source. Adsorption heat pumps find its application in industrial sites, where it can utilise waste heat, whereas Absorption HPs utilises liquid refrigerants as heat transfer fluid and hence these HPs might face many problems related to refrigerant heat transfer fluid like refrigerant crystallization, system corrosion and efficiency loss [5].

Solar Assisted Heat Pumps (SAHP) use solar energy or solar heat as a heat source for HP. Performance of Solar assisted heat pumps are affected due to the intermittency of the available solar energy. However, dual heating sources can be used to resolve this problem. For example, solar assisted GSHP can use both solar and ground source heat as the heat source. This HP finds their application in domestic space heating and domestic hot water supply [66].

> SAHP heating system, which combines HP technology with solar heating, can solve intermittency problem of solar energy. It can be highly effective if its requirements are taken into consideration during design process.

Further categorisation appears as Hybrid heat pumps. Combination of conventional heating systems with heat pump technologies are one of these examples, such as, heat pumps with gas boilers is used to manage peak load. Heat pumps can also be integrated with biomass boilers or solar thermal collectors or may be with direct electric back up. Hybrid system HPs can be ideal for efficient supply demand for domestic space heating and domestic hot water requirement.

Table 9 depicts the environmental impacts, and pros and cons for different heat pump technologies as published by researchers from Economic and Social Research Institute in [52].

**Table 9:** *Pros and cons of different heat pump technologies*

| Technology | Environmental Impacts | Pros | Cons |
|---|---|---|---|
| **Air Source Heat Pump** | • Highest environmental impact in cold regions<br>• Leakage of refrigerant can cause pollution<br>• Causes noise pollution | • Less or no pollution concerns<br>• Simple operation<br>• Low Maintenance Cost<br>• High efficiency<br>• Low primary energy consumption | • Frost formation on outer units<br>• Efficiency varies with ambient temperature<br>• Requires more space |
| **Water Source Heat Pump** | • Can cause water pollution stratum settlement and trigger geological disasters | • Highly efficient<br>• Not affected by ambient conditions<br>• Can utilise waste heat from rivers and lakes | • Requires water bodies or storage tanks in vicinity<br>• Needs regulatory permission for installation |
| **Ground Source Heat Pump** | • Unchecked heat transfer fluids are hazardous<br>• Surface water can enter borehole<br>• Can perturb groundwater temperature | • Highly efficient and shows great energy saving potential<br>• Very reliable source of heat<br>• Can operate in regions with extreme winters | • Needs careful assessment of local geology and requirements<br>• Efficiency may decrease over heating season due to saturation of soil temperature |
| **Geothermal Heat Pump** | • Reduces emissions with low payback period | • High efficiency<br>• utilises vast source of heat<br>• Most suitable for large industrial applications & district heating | • May need supplemental heat system for better performance |
| **Sorption Heat Pump** | • Working fluids do not cause ozone depletion | • Waste heat utilisation from sewage and brine | • Low efficiency |
| **Solar Assisted Heat Pump** | • Significant environmental benefits<br>• Can reduce emissions by 50% | • Financially and energetically viable solution<br>• Solar helps HPs in achieving higher efficiency<br>• Lowers grid electricity consumption | • Needs additional control mechanism for optimal operation<br>• Highly location and application specific |

## A1.2 Heat pump integration: Issues and considerations

With the increased uptake of renewable energy sources in the electric grid, the future electrical power network will have supply or demand imbalances, as well as increased congestion. Solar photovoltaics and wind sources are known to cause high imbalances to the grid, as the amount of energy they produce is highly variable, uncontrollable and the generation happens at variable times. It is anticipated that allowing end-users active participation in clean energy trading, in periods of high demand or available cheap supply, can create a positive impact on reducing these imbalances. However, in most European countries, the electric grid (specially the low voltage distribution network) is not well equipped yet with capabilities of having bidirectional energy flow. Therefore, it is very important for the governments to invest in upgrading the electricity network, adapting innovative two-way communication technologies and bringing supportive regulations.

Furthermore, there is concern regarding the impact of introducing large amounts of heat pumps on the electricity grid, especially in countries where gas equipment is to be replaced by electric heat pumps. While the gas demand will decrease, the electricity demand will increase, causing extra stress on the electric grid, and possibly leading to power outages. From the consumer point of view, depending on the size (rating) of heat pump, there could be additional connection charge implemented if they cross the limit. From the distribution network point of view, each transformer has their maximum rating and overloading capacity. Depending on the transformer rating, the maximum allowable capacity of heat pump should be considered for each branch of the distribution line and, in that case, no additional cost would be required. Vice versa, if we want to install heat pump in each houses under a network and the capacity goes high, then we may have to increase the capacity of branch and transformer with additional cost, otherwise intelligent control with demand side management will be must. This extra load to the electricity network can be managed by demand response control. The new approach to grid stabilisation requires a focus on adjusting demand to the given supply, and this system flexibility can be ensured by introducing decentralised energy storage systems, increasing demand elasticity using demand response policies, and introducing automatic control strategies to manage electricity demand of the device in response to price signals from the grid [40]. High number of installation of heat pumps could also impact the power quality of the network and therefore, some active power filtering or grid stabilising devices may also be required in future.

> The use of heat pumps will increase sudden demand for electricity for heating and may create both capacity and power quality issues. To mitigate these impacts there should be a strong consideration towards improving building fabric energy efficiency, introducing demand side management programmes and exploring green gases as a possible solution for use in hybrid heat pump systems.

The National Grid, a British multinational electric and gas utility company, has modelled the impact to the grid as a result of the uptake of heat pumps (2 to 20 million units) by 2050 [67]. The study concluded that the demand for electricity for heating increased, as it was expected. However, in some scenarios, with increased use of energy storage technologies and time of use tariffs, as well as an increase in energy efficiency of other sectors, the overall demand for electricity decreased. Another series of studies [68] [69] have found that heat pumps could have an impact on the market capacity, depending on how many will be deployed, but also on the power quality, depending on how many will be deployed in a specific region. As an example, a typical 10 kW heat pump usually have a 2.5 kW compressor motor. Even with a soft-starter, the starting current will be around twice the normal running current. If several such HPs are connected to the low voltage network, there will be even more possibility of voltage collapse/power failure. A Belgian study has also concluded that high heat pump penetration rates can create overloading (20 to 30% depending on the cable) and voltage stability problems in existing feeders [70]. A study conducted by Oxford researchers shows that the increases in peak demand are considerably greater than those for average demand and that could be a key challenge presented by the implementation of residential heat pumps technologies [71]. Another study by UKERC suggests that very high electrification of space heating in UK might result in an electricity demand space heating load of 75TWh per year, an increase winter peak to 40GW, requiring generation investment costs of around £2,600 per household [72]. None of these studies have been done for Ireland. As such there are no assessments or analysis available, analysing how the HP implementation plan would impact on Ireland's smart grid decarbonisation target by 2050. It is therefore very important to carefully study the short-term and long-term impacts of the installation of a large number of heat pumps in Ireland. Extensive research is needed to understand the impact of mass deployment of heat pumps on local distribution network as well as overall electricity system, including an understanding of total electricity demand and peak demand in different scenarios and how variation in future temperatures (maybe due to climate change) can vary the electricity demand. This research should be commissioned with the earliest possibility to help develop relevant regulations, guidelines and standards in the near future for a successful deployment of our heat pump ambitions. Also, long term distribution and transmission planning will be needed considering the future penetration of heat pump technologies while there will also be a significant growth towards electric vehicles.

> The high economic and environmental cost of increased peak capacity and power fluctuation in the distribution network could delay or prevent electrification of the heating system.

## A1.3 Heat pump and demand response

### A1.3.1 Demand response

Demand response provides an opportunity for consumers to play an important role in the operation of the electricity grid by shifting or shedding their electricity usage during peak periods in response to time based tariffs or other form of financial incentives. Figure 13 shows how the heat pump induced flexibility can help to manage the electricity demand. By paying consumers, like households and businesses of any size, to reduce energy consumption, generators and utility commissions can effectively create a new energy source that has the added bonus of negative carbon emissions. Demand response participants are seen as generators, or producers of electricity, because by reducing energy consumption, they are effectively increasing the available supply of electricity. The demand response programmes can also help to reduce the problems caused by the intermittent distributed generation from renewable energy sources and to stabilize both the physical electric grid and the electricity market. Further, the application of smart appliances or smart homes, together with storage capacity and self-generation can significantly empower citizens to effectually respond to financial incentives in the energy market.

> Demand response (DR) and demand side Management (DSM) are not the same, even though they are often used interchangeably. DR refers to programmes that encourages the end user to be more energy efficient by taking longer term or permanent energy efficiency measures. In a way, DR falls under the category of DSM [91].

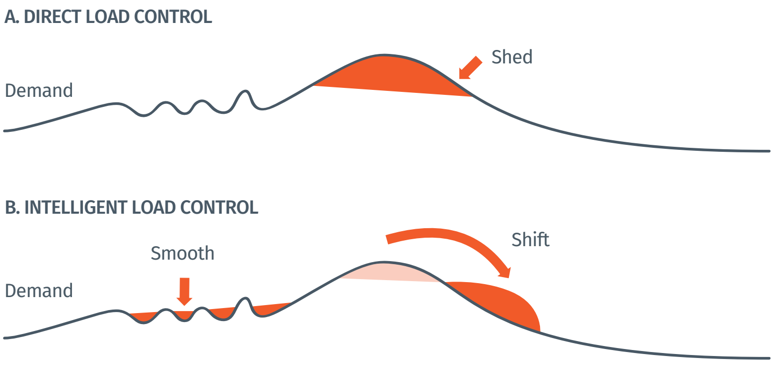



**Figure 13:** *Effect of heat pump induced flexibility on the electricity demand curve (Source: Integrated Analytics Inc. and EHPA 2018 [40])*

### A1.3.2 Benefits of using heat pumps for demand response

With most European countries setting new sustainability goals for the future, integrating more intermittent renewables to the grid is inevitable. Depending on outdoor conditions, high fluctuations in energy supply reduces the reliability of the grid to answer to all the energy demand. The trend in the near future will involve any user who can reduce their electric demand at specific times to give this flexibility to the grid in order to reduce the electric load of the network. At the same time, flexible resources are needed to provide the grid ancillary services. Heat pumps can be successfully used to provide these services through the demand response technique due to following reasons:

- For the heating & cooling purposes heat pumps are considered as the most matured, environment friendly and easy to install technology and therefore, the penetration rates of a range of heat pump technologies are drastically increasing (as compared to other technologies) in most countries.

> For the heat pump demand response, dynamic price thresholds should be used instead of fixed price thresholds which can help achieve significant peak reduction and provide up to 25% cost savings without significant thermal comfort losses [73].

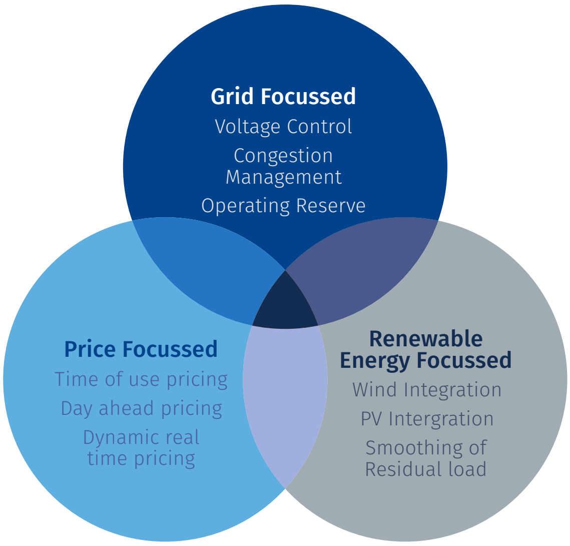



**Figure 14:** *Application of heat pump in a smart grid context (Source: D. Fischer Doctoral Thesis [75])*

- Smart meter rollout in number of countries are making it easier to realise the full potential of heat pump technologies for demand response. During periods of low demand, the extra thermal energy can be stored and subsequently released during periods of high demand, therefore shifting the load on the power grid [73].
- Smart operation of heat pumps and other assets such as energy or thermal storage can provide a reliable solution to help balance electricity generation and demand [74]. Thermal storage can help decouple electricity demand of the heat pump from the heat demand of the building which will enable shifting the electricity demand. The use of heat pumps for three main area of applications in a smart grid context are shown in Figure 14.
- Advancements in remote controlled capabilities and the communication system is providing the opportunity to switch off heat pumps or thermostat set point adjustments without any manual intervention. After the end user gives their approval, the heat pumps can be controlled directly by the aggregators or the utility company, when the need arises.
- Heat pumps can be controlled in a similar way as conventional technologies by customers without compromising any comfort
- Demand response needs also fits well with the high use of heat pumps either for cooling in summer peak or heating in winter peak situations. Local peaks at network level can be managed by providing attractive incentives to consumers.

**Utilities offering heat pump tariffs**

The tariff is a reduction in the electricity rate from the Distribution Network Operator, which customers receive in exchange for an agreement that their heat pump can be switched off for a certain period per day at peak times. For example, Germany has a heat pump tariff which can give end users up to 20% reduction in their electricity rotes. In Switzerland, more than 80% of the ~900 local network operators offer a heat pump tariff which provides the customer a significantly cheaper electricity rate (up to 40% cheaper than the standard rate). This kind of mechanism was designed to solve the congestion problems which heat pumps can cause on the grid [11] [42].

#### A1.3.3 Barriers to using heat pumps for demand response

There are some obstacles to fully utilise the advantage of heat pumps for the demand response purpose:

- There is almost very little experience on using heat pumps for demand response and developing relevant technical and regulatory solutions could take a long time.
- Slow implementation of smart meter roll out could also act as barrier in experimenting and developing mature technical solutions
- Lack of standardization in the field of Home Area Networks (HAN) could be a significant barrier for heat pump based demand response programmes
- Starting current of heat pumps could be very high and it effects the stability of low voltage distribution networks, hence the operation and management strategy of the network should be improved.
- Lack of public knowledge on heat pump technology and how to respond to relevant DR programmes could also be a barrier.
- Lack of clarity on how public can avail of the services of aggregators and how the energy, finances and information is then transferred on to the different stakeholders.
- Widespread adoption of heat pumps will certainly increase peak electricity demand for certain periods of time, which could lead to overloading the network and thus voltage instability issues will arise.
- Limited capacity and communication capabilities of the current electric grid could also limit the implementation of heat pump demand response programmes.

**A1.4 Refrigerant issue with heat pumps**

The heat pump operating principle is based on a circulating refrigerant, which transfer heat while changing different phases. The heat pump characteristics allow heat pumps to operate and to use renewable energy in generating useful heat and cold. The refrigerants used in this process can be toxic, flammable or even explosive or they can act as greenhouse gases. This issue is not severe if a high quality design and manufacturing has been considered to keep the refrigerants inside the unit. In case it is released due to some leakage or unskilled maintenance handling, it can release emissions with a certain global warming potential into the atmosphere. The commonly used refrigerants are basically Fluorinated gases (F-gases) which are man-made gases that can stay into the atmosphere for centuries and can result in the form of global warming. There are four types: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3). The common refrigerants used in heat pumps today is listed in the Table 10 [40] [76]. For air-air heat pumps R410A, R407C and for air-water heat pumps R134A, R407C, R410A, R290, R744 are frequently used refrigerants [77]. The majority of residential units deployed today use HFCs while in large/industrial size heat pumps the use of natural refrigerants, for example, Ammonia, Propane, $CO_2$ is more common.

**Table 10:** *Commonly used refrigerants in heat pumps (Source, EHPA White Paper 2018 [40])*

| Name | Group | Flammability | GWP (AR4) |
|---|---|---|---|
| **R32** | HFC | Mild | 675 |
| **R125** | HFC | No | 3500 |
| **R134A** | HFC | No | 1430 |
| **R152A** | HFC | Yes | 124 |
| **R245FA** | HFC | | 1030 |
| **R404A** | HFC | No | 3922 |
| **R407C** | HFC | No | 1774 |
| **R410A** | HFC | No | 2088 |
| **R1234YF** | HFO | Yes | 4 |
| **R1234ZE** | HFO | Yes | 7 |
| **R448A** | HFO | No | 1387 |
| **R449A** | HFO | No | 1397 |
| **R290 Propane** | Hydrocarbon | High | 3 |
| **R600** | Hydrocarbon | High | 3 |
| **R717** | Ammonia | No | 0 |
| **R744** | Carbon-di-oxide | No | 1 |

EU Commission is taking regulatory action to control F-gases as the emission of F-gases in the EU have risen by 60% since 1990 [78]. F-gases do not damage the atmospheric ozone layer and therefore, they are often used as substitute for ozone depleting substances. However, F-gases have around 23,000 times greater global warming effect as compared to $CO_2$ emission. EU Commission introduced a new F-gas regulation, in force from 1 January 2015 which has introduced following changes [79]:

- Limiting the total amount of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030. This will be the main driver of the move towards more climate-friendly technologies;
- Banning the use of F-gases in many new types of equipment where less harmful alternatives are widely available, such as fridges in homes or supermarkets, air conditioning and foams and aerosols;
- Preventing emissions of F-gases from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.

Since the 1st January 2017 any refrigeration, air conditioning or heat pump equipment charged with HFCs cannot be placed on the EU market unless the HFCs within the equipment are accounted for within the EU HFC quota system [80] [81]. This phase down implementation will reduce the availability of F-gases continuously until 2030.

The largest share of emissions from any heating/cooling system results from the fuel used to operate the unit. Figure 15 shows a comparison of the lifetime emissions of different heating solutions as taken from EHPA report published in 2018. For simplicity of this graph, heat pumps have been assumed to use only one refrigerant (R410A), with the exception of the last column, where the future scenario of a heat pump with a new low GWP refrigerant is used considering the ongoing greening of the electricity mix and the phase down of the current refrigerants [40]. It can be seen from the Figure that reduction of electricity related emissions can have a bigger impact on the life cycle emissions of heat pumps as compared to deploying a low GWP refrigerants. It suggests that from an environmental perspective, already the use of existing refrigerants - if handled properly - contributes to a reduction of greenhouse gas emissions which is accelerated by every reduction step of emissions from electricity. Therefore, developing high quality products and processes to keep the refrigerant leakage to minimum and developing trained installers with a knowledge of handling refrigerants [82] will be critical. For example, in Sweden only refrigerant technicians have the right to repair some parts of the heat pump which avoids unskilled handling and ensure that only the broken parts are replaced instead of whole component, that leads to unnecessary costs for insurance companies [83].

Total Equivalent Warming Impact (TEWI) is a measure beside global warming potential measure which is defined as sum of direct emission from (chemicals) and indirect emissions (energy) of greenhouse gases from production, operation and recycling. The environmental impact from the operation of heat pumps can be split in emissions from energy use and $CO_2$ equivalent emissions from the use of refrigerants [90].

Apart from exploring the use of low GWP refrigerants in the mid-term, one of the other options is the careful specification of products as suggested by a blog author from waste and Sustainability Places [84]. It mentions that water-based systems such as air-water heat pumps can be preferred as it contains refrigerant which is hermetically sealed (completely airtight) within the compressor (through the creation of permanent connections by welding or brazing) and factory tested. As during the heat distribution system only water is used, the volume of refrigerant in the system is minimal and the risk of leakage is greatly reduced.

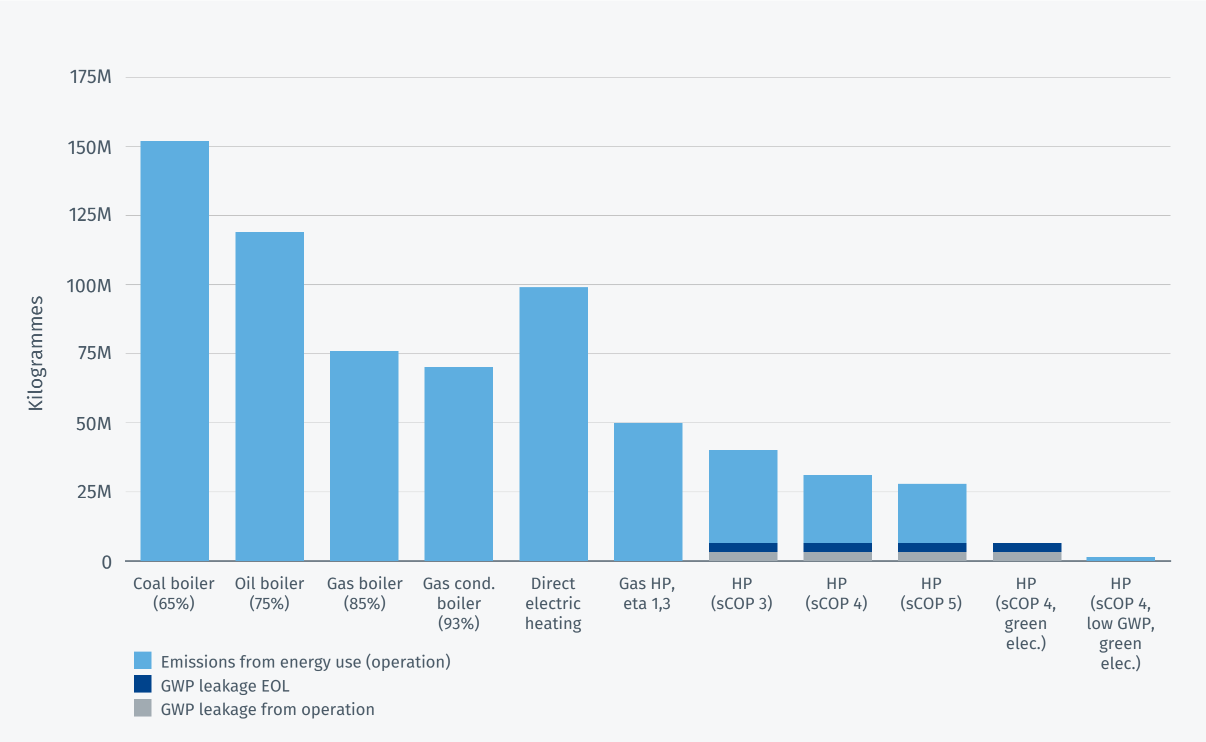



**Figure 15:** *Comparison of lifetime emissions of different heating solutions (Source: EHPA White Paper [40])*

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