



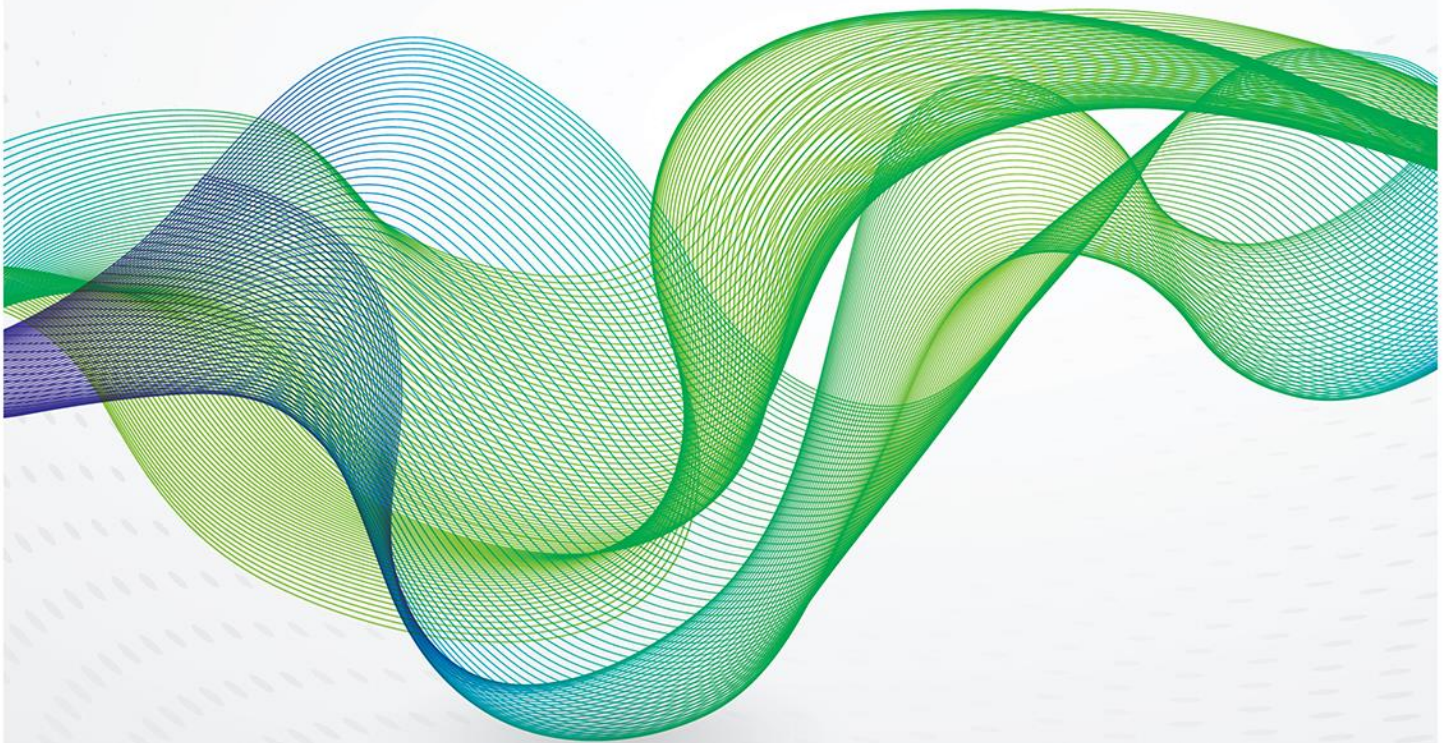
THE OXFORD  
INSTITUTE  
FOR ENERGY  
STUDIES

A RECOGNIZED INDEPENDENT CENTRE OF THE UNIVERSITY OF OXFORD



May 2018

# Decarbonisation of heat in Europe: implications for natural gas demand





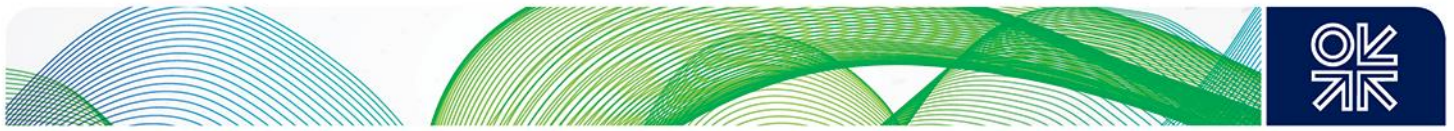
The contents of this paper are the author's sole responsibility. They do not necessarily represent the views of the Oxford Institute for Energy Studies or any of its members.

Copyright © 2018  
***Oxford Institute for Energy Studies***  
(Registered Charity, No. 286084)

This publication may be reproduced in part for educational or non-profit purposes without special permission from the copyright holder, provided acknowledgment of the source is made. No use of this publication may be made for resale or for any other commercial purpose whatsoever without prior permission in writing from the Oxford Institute for Energy Studies.

ISBN 978-1-78467-110-5

DOI: <https://doi.org/10.26889/9781784671105>



## Acknowledgements

My grateful thanks to my colleagues at the *Oxford Institute for Energy Studies (OIES)* for their support, and in particular Jonathan Stern and James Henserson for their helpful comments. A big thank you to all the sponsors of the *Natural Gas Research Programme (OIES)* for their constructive observations during our meetings. A special thank you to Liz Henderson for her careful reading and final editing of the paper. Last but certainly not least, many thanks to Kate Teasdale who made all the arrangements for the production of this paper.

The contents of this paper do not necessarily represent the views of the *OIES*, of the sponsors of the *Natural Gas Research Programme* or of the people I have thanked in these acknowledgments.

All the opinions expressed and any remaining errors are my sole responsibility.

Anouk Honoré  
Senior Research Fellow, Natural Gas Programme  
Oxford Institute for Energy Studies  
Oxford, May 2018



## Preface

Decarbonisation of energy systems has become a key topic in Europe as both the European Union and member states attempt to achieve goals set out at the COP21 meeting in Paris to limit the impact of the human race on global climate change. The initial focus has been on the power generation sector, where the rise of renewable energy sources such as wind and solar has already had a significant impact on gas demand. For the time being the gas sector appears to have come to terms with the changes that are taking place, with coal-to-gas switching and the reduction in the use of nuclear energy leaving room for gas demand to rebound from its 2014 lows in Europe. Indeed, researchers in the *OIES Natural Gas Programme* foresee a relatively bright future for gas in the region out to 2030 as these trends continue to play out.

However, if Europe is to meet its longer term environmental targets, not only will gas' place in the power sector be threatened post-2030 if it fails to develop a decarbonisation strategy, but its role in the heating and cooling sector will also come under threat. This paper by Anouk Honoré, which has been written in tandem with a paper on the UK heat sector by Malcolm Key<sup>1</sup> aims to address this key long-term issue by providing a framework to analyse the heat sector in Europe. As Honoré shows, the heat sector is the largest gas consuming sector, but it is relatively poorly defined, and as a result she goes into some detail exploring its various constituent parts and identifying the key trends within them. Her overarching conclusion, though, which fits into the Institute's overall view of the future of gas in Europe, is that if the gas industry in its current form is to have a long-term future beyond the end of the next decade then it needs to develop a strategy not only for the power sector but also for potential changes in the heat sector as well. Interaction and collaboration with electricity may be one answer, while developments such as the use of hydrogen and biogas may be another, but in either case the industry needs to start thinking about the key issues soon as key strategic decisions, for example about the future of gas networks, will need to be made sooner rather than later.

This paper aims to provide a solid foundation for this strategic thinking, which the Natural Gas Programme at OIES will be pursuing over the coming years.

James Henderson  
Director, Natural Gas Programme  
Oxford Institute for Energy Studies  
Oxford, May 2018

---

<sup>1</sup><https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/05/Decarbonisation-of-heat-and-the-role-of-green-gas%E2%80%99-in-the-United-Kingdom-NG-128.pdf>





## Abstract

This paper forms part of a joint research carried on by the *OIES Natural Gas Programme* and the *OIES Electricity Programme* focussing on the impacts of decarbonisation of energy systems and it goes together with a second paper written by Malcolm Keay, which focuses on the UK market and the potential role of hydrogen in the decarbonisation strategy.<sup>2</sup>

The EU is committed to reducing greenhouse gas (GHG) emissions to 80-95 per cent below 1990 levels by 2050. So far, the electricity sector has been the main focus of low-carbon policies, but if Europe is to meet its objectives, decarbonisation efforts will need to expand to other sectors, including the heating and cooling sector. This sector is the largest single energy user in Europe. It covers half of the final energy demand of which 42 per cent comes from natural gas alone. If the lessons of the decarbonisation of the electricity sector are to be learnt, then the gas industry may want to pay particular attention to the effects that it will have on gas demand. One problem however is that the role of the heating sector in natural gas demand is not very well understood, which is essentially due to a lack of a specific definition and available data in most energy balances. The objective of this paper is to set the scene and provide a framework to study the heating (and cooling) sector in Europe, with a special focus on the implications for the natural gas industry, and especially for natural gas demand.

---

<sup>2</sup> <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/05/Decarbonisation-of-heat-and-the-role-of-green-gas%E2%80%99-in-the-United-Kingdom-NG-128.pdf>



## Contents

<b>ACKNOWLEDGEMENTS.....</b>	<b>3</b>
<b>PREFACE .....</b>	<b>4</b>
<b>ABSTRACT.....</b>	<b>5</b>
<b>CONTENTS.....</b>	<b>6</b>
LIST OF FIGURES .....	7
LIST OF TABLES.....	8
<b>INTRODUCTION.....</b>	<b>9</b>
<b>I. DEFINITION OF THE HEATING (AND COOLING) SECTOR AND STATISTICAL LIMITATIONS</b>	<b>10</b>
<b>II. HOW MUCH (AND WHAT SORT OF) ENERGY IS USED FOR HEATING AND COOLING IN EUROPE? .....</b>	<b>12</b>
2.1. PRIMARY ENERGY .....	12
2.2. CENTRALISED HEAT GENERATION (TRANSFORMATION SECTOR) .....	13
2.3. FINAL ENERGY DEMAND.....	15
2.3.1. <i>Energy carriers</i> .....	16
2.3.2. <i>End-uses and analysis by sector</i> .....	18
<b>III. THE ROLE OF THE HEATING SECTOR IN NATURAL GAS DEMAND .....</b>	<b>23</b>
3.1. BY COUNTRY .....	23
3.2. BY SECTOR .....	24
3.2.1. <i>Derived heat</i> .....	25
3.2.2. <i>Final consumption</i> .....	25
<b>IV. DECARBONISING THE HEATING AND COOLING SECTOR: MAIN POLICIES AND REGULATION .....</b>	<b>27</b>
4.1. EU TARGETS FOR 2020, 2030, AND 2050.....	27
4.2. THE EU EMISSIONS TRADING SYSTEM (EU ETS).....	28
4.3. EFFICIENCY AND ENERGY SAVINGS .....	29
4.4. RENEWABLE ENERGY .....	31
4.5. THE HEATING AND COOLING STRATEGY.....	32
<b>V. OVERVIEW OF EXISTING TECHNOLOGIES.....</b>	<b>33</b>
<b>VI. OPTIONS TO DECARBONISE THE HEATING AND COOLING SECTOR .....</b>	<b>39</b>
6.1. IMPROVING EFFICIENCY AND ENERGY SAVINGS .....	39
6.1.1. <i>Upgrade boilers</i> .....	39
6.1.2. <i>Develop micro CHP (mCHP) and fuel cells technology</i> .....	39
6.1.3. <i>Switch to other forms of heating and cooling systems</i> .....	40
6.2. INCREASING THE SHARE OF RENEWABLES .....	41
6.2.1. <i>Replacing fossil fuels with renewables</i> .....	41
6.2.2. <i>Hybrid systems</i> .....	41
6.2.3. <i>Repurpose the gas network for green gas</i> .....	43



6.3. ELECTRIFICATION OF THE HEATING SECTOR .....	43
6.4. EXPAND HEAT NETWORKS .....	45
<b>VII. MAIN CHALLENGES TO DECARBONISING BUILDINGS AND PROCESS HEAT.....</b>	<b>45</b>
7.1. DIVERSITY AND NUMBER OF STAKEHOLDERS INVOLVED.....	46
7.2. CONSUMERS' INVESTMENT CYCLE AND DISRUPTION.....	46
7.3. DECARBONISING HEAT WILL COME AT A COST .....	46
7.4. HOW TO CHOOSE A HEATING (COOLING) SYSTEM? .....	48
7.4.1. No "one size fits all" option.....	48
7.4.2. Renovation of the existing building stock.....	48
7.4.3. Process heat in industry: limited options for renewables?.....	49
<b>VIII. CONSEQUENCES FOR FUTURE NATURAL GAS DEMAND.....</b>	<b>51</b>
8.1. UP TO 2030: LIMITED CHANGES FOR NATURAL GAS DEMAND .....	51
8.2. AFTER 2030: A WIDE RANGE OF POSSIBILITIES .....	53
<b>SUMMARY AND CONCLUSIONS .....</b>	<b>57</b>
<b>BIBLIOGRAPHY .....</b>	<b>61</b>

## List of Figures

Figure 1: Simple schematic overview of the heating and cooling sector .....	11
Figure 2: Primary energy for heating and cooling per energy carrier in the EU, 2012 (%).....	12
Figure 3: Gross derived heat production by fuel in the EU, 1990-2015 (TJ) .....	13
Figure 4: District heating final consumption in the EU, 2012 (TWh) .....	14
Figure 5: Sources for energy for heat sales from district heating in the EU, 2012 (%).....	15
Figure 6: Final energy demand per country in the EU, 2015 (TWh) .....	15
Figure 7: Final energy demand for heating and cooling by fuel source in the EU, 2015 (%) .....	16
Figure 8: Final energy demand for heating and cooling from renewable energies by source in the EU, 2004-2015 (Mtoe).....	17
Figure 9: Final energy demand for heating and cooling per country and per energy carrier in the EU, 2015 (% and TWh) .....	17
Figure 10: Final energy demand for heating and cooling in the EU by end-use in 2015 (%) .....	18
Figure 11: Final energy demand for heating and cooling in the EU, per country per end-use, 2015 (TWh) .....	19
Figure 12: Final energy demand for heating and cooling in the EU by sector and end-uses, 2015 (TWh) .....	19
Figure 13: Final energy demand for heating and cooling in the residential sector by fuel in the EU, 2015 (TWh) .....	20
Figure 14: Final energy demand for heating and cooling in the industrial sector by fuel in the EU, 2015 (TWh) .....	21
Figure 15: Final energy demand for heating and cooling in the service sector by fuel in the EU, 2015 (TWh) .....	21
Figure 16: Natural gas for heating and cooling by end-uses and by sector in the EU, 2015 (bcm) .....	22
Figure 17: Natural gas demand for heating by EU country, 2015 (%).....	23
Figure 18: Role of the heating sector in natural gas demand per EU country, 2015 (%) .....	24
Figure 19: Role of the heating sector in natural gas demand by sub-sectors and by EU country, 2015 (bcm).....	24
Figure 20: Production of derived heat by EU country, 2015 (Mtoe).....	25
Figure 21: Natural gas demand for heating in the residential sector, by EU country, 2015 (bcm) .....	25
Figure 22: Natural gas demand for heating in the industrial sector, by EU country, 2015 (bcm) .....	26
Figure 23: Natural gas demand for heating in the commercial sector, by EU country, 2015 (bcm) .....	26
Figure 24: Shares of renewables in gross final energy demand in the EU, by sector (%) .....	32



Figure 25: Main options to generate heating in buildings by fuel and operating system .....	34
Figure 26: Share of heating technologies and total installed capacity by country in the EU, 2012 (%).....	34
Figure 27: Installed capacity of natural gas, oil and coal boilers by EU country, 2012 (MWth).....	35
Figure 28: Age distribution of installed boilers in the EU, 2012 (%) .....	36
Figure 29: District heating: installed thermal capacity and trench length in the EU, 2012 (MWth and km) .....	38
Figure 30: Share of heating technologies (units and capacity) and demand related to final energy carriers in the EU, 2012 (%).....	38
Figure 30: CO <sub>2</sub> emissions avoided due to fuel-oil to natural gas conversions in France (mt) .....	41
Figure 31: Heating technologies and available options for partnerships .....	42
Figure 33: Heating asset profile (heat pump/boiler) vs temperature (kW) .....	42
Figure 33: Thermo-sensitivity of electricity generation in France by end-use, July 2015-June 2016 (GW).....	44
Figure 34: Thermo-sensitivity of electricity generation in selected EU countries, July 2015-June 2016 (GW).....	44
Figure 36: Low carbon heating options: decarbonisation potential vs costs .....	47
Figure 37: Heat temperature requirements for several industrial sectors (not including space heating and water heating) (%).....	50
Figure 38: Process heat and available fuel sources (°C).....	50
Figure 39: Current policy scenario for final energy demand for heating and cooling by sector and energy carrier in 2012, 2020 and 2030 in the EU (TWh) .....	52
Figure 40: Current policy scenario for final energy demand for heating and cooling by energy carrier mix by EU country in 2012 and 2030 (TWh).....	52
Figure 41: Current policy scenario for natural gas demand for heating in the residential sector by EU country in 2012, 2020 and 2030 (bcm) .....	53
Figure 42: WEO scenarios for final energy demand in the building sector by energy carrier for the EU, 2015-2040 (Mtoe).....	54
Figure 43: Delta Energy and Environment scenarios for energy demand for heating in the UK residential sector, by energy carrier, 2012-2045, (%) .....	55
Figure 44: National Grid scenarios for natural gas demand in the UK residential sector, 2005-2050 (TWh) .....	56

## List of Tables

Table 1: Summary of energy and natural gas demand for heating and cooling in the EU, 2015 .....	22
Table 2: Summary of natural gas demand for heating in the EU, by sector, 2015 .....	27
Table 3: Average conversion efficiencies in local boilers and electrical appliances.....	40





## Introduction

The EU is committed to reducing greenhouse gas (GHG) emissions to 80-95 per cent below 1990 levels by 2050. So far, the electricity sector has been the main focus of low-carbon policies. Electricity generation is one of the largest sources of carbon dioxide (CO<sub>2</sub>) emissions and it is technologically feasible to produce electricity in centralised power plants from a wide range of sources, including low-carbon ones. It was the obvious first area for the European Union (EU) to translate its commitments to decarbonise the economy into concrete actions. However, if Europe is to meet its objectives of reducing emissions by 80 per cent by 2050, the next focus of effort will need to be the expansion of decarbonisation to other sectors, including the transport sector and the heating and cooling sector.

The transport sector will be one of the cornerstones for limiting GHG emissions, but it is not the most significant for natural gas demand. Oil products account for most of the energy consumed in this sector, which only represented about 1 per cent of natural gas consumption in 2015.<sup>3</sup> On the other hand, natural gas has a prominent role in heat generation in Europe and if the lessons of the decarbonisation of the electricity sector are to be learnt, then the gas industry may want to pay particular attention to the effects that it will have on gas demand.

This is part of the thesis developed by Professor Stern in his paper “The Future of Gas in Decarbonising European Energy Markets: the need for a new approach” published in 2017.<sup>4</sup> In his paper, Stern wrote that “*European countries need to have substantially decarbonised their power sectors by 2030 and their heat sectors by 2050*”<sup>5</sup> in order to meet their environmental targets and both of these measures will have an impact on the gas industry. Stern’s paper laid the foundation for future research by the OIES Natural Gas Programme on issues which relate to the future of gas in a decarbonising world, and this paper is a logical follow up focusing on the heating sector.

The role of the heating sector in natural gas demand is not very well understood, which is essentially due to a lack of a specific definition and available data in most energy balances. But in order to analyse the consequences of transitioning to a low carbon system in the future, it is important to understand the main characteristics of the sector in the present. The objective of this paper is therefore to set the scene and provide a framework to study the heating and cooling sector in Europe. It focuses on the implications for the natural gas industry, and especially for natural gas demand.

How will the decarbonisation of the heating and cooling sector impact natural gas consumption in Europe? In order to answer this question, the paper is structured in eight sections: the first one provides a definition of the heating (and cooling) sector; the second focuses on how much (and what sort of) energy is consumed by the sector and differences between countries; the third examines more specifically how much natural gas demand is used for heating purposes and the differences across Europe. The fourth section examines the decarbonisation process and the policies/measures in place. The fifth section provides a brief overview of the heating and cooling systems in Europe and section six looks at the possible technological options to put this sector on the path to a low-carbon future. The seventh section focuses on some of the main challenges that are to be expected, especially in the buildings and process heat sectors. The penultimate section analyses the possible consequences for future natural gas demand and the final section draws together some conclusions.

This paper forms part of a joint research carried on by the OIES Natural Gas Programme and the OIES Electricity Programme focussing on the impacts of decarbonisation and it goes together with a second paper written by Malcolm Keay, which focuses on the UK market and the potential role of hydrogen in the decarbonisation strategy.<sup>6</sup>

---

<sup>3</sup> Data for OECD Europe. Source: IEA (2017A), p.III.16

<sup>4</sup> Stern J. (2017)

<sup>5</sup> Stern J. (2017), p.4

<sup>6</sup> <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/05/Decarbonisation-of-heat-and-the-role-of-green-gas%E2%80%99-in-the-United-Kingdom-NG-128.pdf>



## I. Definition of the heating (and cooling) sector and statistical limitations

What may seem like a trivial introduction is, in effect, important as there appears to be a certain level of confusion over what people consider to be the heating and cooling sector. A broad definition covers all the energy inputs used to generate thermal energy. Heat (and cooling) can be produced in a centralised way in combined heat and power plants (CHPs) and in heat plants, but it is also produced in a decentralised way at the end-user level (industries, households). Studies of the sector traditionally focus on one area of heating and cooling (district heating, heat pumps or buildings for instance) and give it a general term of 'heating sector' or 'cooling sector', which adds to the confusion. The reason for focusing on specific parts of the heating and cooling sector individually and not looking the whole picture is due to its wide diversity. This is not in essence a problem, but it makes understanding the whole picture a lot more complex.<sup>7</sup>

One of the major problems is that in most statistical databases,<sup>8</sup> there is no specific breakdown of heat (and cooling) consumption. Fuel input used for heating and cooling is part of total energy use by sector and it cannot be found in - or derived from - most existing energy balances. Any analysis of the sector will be limited by the available statistical data as much more complex analysis needs to take place before any information on energy inputs and end-uses in the heating and cooling sector can emerge.<sup>9</sup>

Figure 1 below shows a simplified schematic overview of the heating and cooling sector with energy inputs used to produce thermal energy and the sectors of consumption where these energy inputs will be included as represented in traditional energy balances. Note that in order to keep the definition simple, Figure 1 only shows the main uses and end-uses, but the list is not exhaustive.<sup>10</sup>

- In the transformation sector:
  - Heat production: energy balances report the primary energy used for the production of *derived heat (or cooling)*, which is the portion of heating (or cooling) that is sold on the

---

<sup>7</sup> For instance, the EC defined the heating sector as 'a catch-all term for energy consumption that is neither for transport nor in the form of electricity' in its 2011 Energy Roadmap 2050. As a result, this definition would apply to final energy demand for heating and cooling but exclude the thermal energy generated in the transformation sector.

<sup>8</sup> Such as the IEA or Eurostat for instance

<sup>9</sup> The EC gives these examples for the two biggest consumers, which are final energy demand for heating and cooling in space heating in buildings and process heat in the industry:

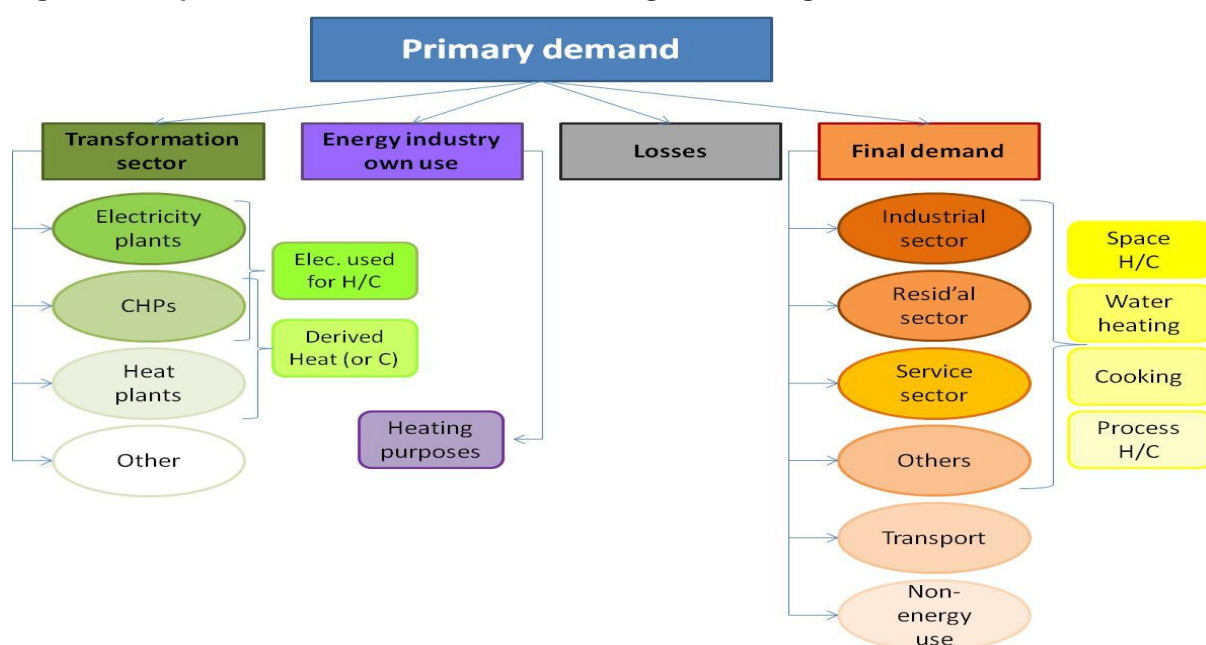
- In order to get data on final energy demand for heating and cooling and the fuel mix used to heating and cooling in buildings, estimations need to be made using a combination of EU, international and national energy statistics. A number of factors also need to be taken into account such as conversion efficiencies for fuels used in final energy demand, estimation of how much electricity is used for heating and cooling purposes, the heated floor area, the building thermal integrity (quality of its insulation and control instruments such as meters, meter displays and thermostatic valves), its size and type, climatic conditions (outside temperatures in winter and in summer), usage patterns (consumers' behaviour and end-users preferences), the number of inhabitants (m<sup>2</sup>/person) and the age of the building. This list is not exhaustive. Source: European Commission (2016), part 1, p.8
- Similarly, the industrial sector's primary, final and useful heating and cooling consumption is also not directly available and must be derived from primary demand (conventional and renewable energy sources) and final energy demand (fuels, derived heat, renewable energies, electricity). Additional factors to be included in the analysis cover the efficiencies of specific conversion technologies and industrial processes, which may differ not just sector by sector but also from one plant to another, and the knowledge of the cross-cutting technologies (for instance steam systems (large boilers) generate process steam in a wide range of industrial processes). A wide disparity across industrial sectors is to be expected as the sector is far from being heterogeneous and that impacts on its heating and cooling production and needs. Source: European Commission (2016), part 1, p.15

<sup>10</sup> For instance, the industrial and service sectors will use heat for a much wider range of purposes, such as washing, cooking, sterilizing, drying, preheating of boiler feed water, and process heating. Another example not covered is the production of waste heat (and cold) from industrial sites (supermarkets for instance) and infrastructure (such as the metro), which can be used to heat/cool buildings nearby. A third example shows that other sectors could be included in feed for heating and cooling such as agriculture which needs to generate heat for drying crops. In 2007, a report suggested that 'around 37 per cent of direct energy use in agriculture is for heating, and 61 per cent of this is expended in the protected crops sector for greenhouse heating and humidity control'. Source: Warwick HRI (2007)



- market (from CHPs or heat plants). This is usually the only separate data available for the production of thermal energy, but it is also far from being satisfactory.<sup>11</sup>
  - Electricity generation: A considerable amount of electricity may be used for space heating and cooling in buildings, but this is not separately monitored and reported and is part of the total energy used.<sup>12</sup>
- In the energy industry own use sector:
  - Energy used by energy industries for heating purposes and for operation of their equipment.
- In the final consumption sector:
  - Energy inputs used for space heating and cooling, water heating, cooking, and process heating and cooling are not reported separately and are part of the total energy used.

**Figure 1: Simple schematic overview of the heating and cooling sector**



Source: Author

Some countries provide end-use balances for the residential sector, which include the energy use for heating and cooling (fourteen countries provide data for space heating and hot water), some for the tertiary sector (six for space heating) and very few for the industrial sector (only three provide information for space heating and process heating and cooling).<sup>13</sup> This data gives some information on a national situation but due to differences in definitions and methodology used to compile the data, it cannot be used to give a regional picture or compare one country to another.

Designing a methodology to calculate adequate heating and cooling data at a European level is outside the scope of this paper, but readers interested in the subject can look at various attempts and methodologies which can be found in reports such as 'The EU strategy for heating and cooling',<sup>14</sup>

<sup>11</sup> For instance, there is traditionally no detail regarding the use made of derived heat, which can be directed at industrial processes or be distributed via district heating networks. Additionally regarding district heating, data sometimes shows the input to district heating plants and sometimes it shows the output of the plant.

<sup>12</sup> These plants can be owned by main producers or auto producers. The IEA describes the 'main activity producers' of electricity plants as 'plants whose primary purpose is to produce, transmit or distribute electricity' and 'auto producers' of electricity plants as 'an enterprise which, in addition to its main activities, generates electricity wholly or partly for its own use (e.g. industrial establishments, railways, refineries, etc).' Source: IEA (2017A), p.I.4

<sup>13</sup> For the residential sector, only about half of the countries base their data on empirical analysis, while the others base their stats on models or other approaches. For more information, see European Commission (2016b), p.9

<sup>14</sup> European Commission (2011a)





'Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)',<sup>15</sup> 'Heat roadmap Europe'<sup>16</sup> or the Stratego reports<sup>17</sup> for instance. The EU is also trying to improve data in the building sector thanks to the EU building stock observatory,<sup>18</sup> which monitors the energy performance of buildings across Europe. Most of the data presented in this paper draws from their analysis. Note that complete series of data are not available. Most recent data is available for 2015, but others are only available for 2012 or even 2010. The source of each statistic is given in footnotes if not in the text. Due to various sources, some discrepancies may happen as a result of different methodologies and estimations.

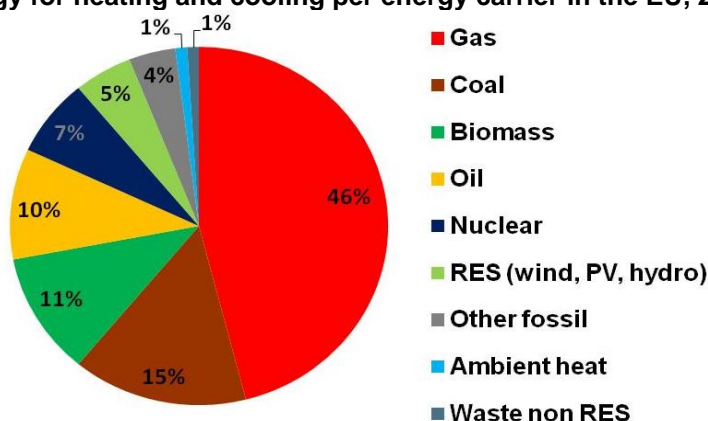
## II. How much (and what sort of) energy is used for heating and cooling in Europe?

Thermal energy can be generated from a wide range of sources which include fossil fuels (coal, oil, natural gas), renewable energies (solar, biomass, others) and electricity (which can be generated from fossil fuels and renewables, but also from thermal energy itself). The following paragraphs present an overview of the type of energy used for heating and cooling and highlight the differences across Europe.

### 2.1. Primary energy

Primary energy<sup>19</sup> used for heating and cooling reached 684 Mtoe in 2012,<sup>20</sup> or about 40 per cent of total primary energy in the EU at the time.<sup>21</sup> As seen in Figure 2, it mostly came from fossil fuels (75 per cent), while renewables accounted for 18 per cent. The most remarkable feature was that natural gas alone covered 46 per cent of the requirement and was the most relevant individual energy carrier.

**Figure 2: Primary energy for heating and cooling per energy carrier in the EU, 2012 (%)**



Source: European Commission (2016b), p.81

<sup>15</sup> European Commission (2016b)

<sup>16</sup> Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>17</sup> Stratego, Enhanced heating and cooling plans (2015)

<sup>18</sup> <https://ec.europa.eu/energy/en/eubuildings>

<sup>19</sup> In traditional energy balances, primary energy supply is calculated by adding production and imports, by subtracting exports and by adding or subtracting stock changes. However, in order to calculate the primary energy input for heating and cooling purposes, the calculation needs to be done backward. It starts with energy inputs for final consumption to produce heat (and cooling) plus energy inputs in the transformation sector used to produce derived heat and to generate electricity that will be used for heating and cooling purposes.

<sup>20</sup> Calculated from European Commission (2016b), p.81. Conversion: 1 TWh = 0.08598 Mtoe, <https://www.iea.org/statistics/resources/unitconverter/>

<sup>21</sup> Calculated from Eurostat data

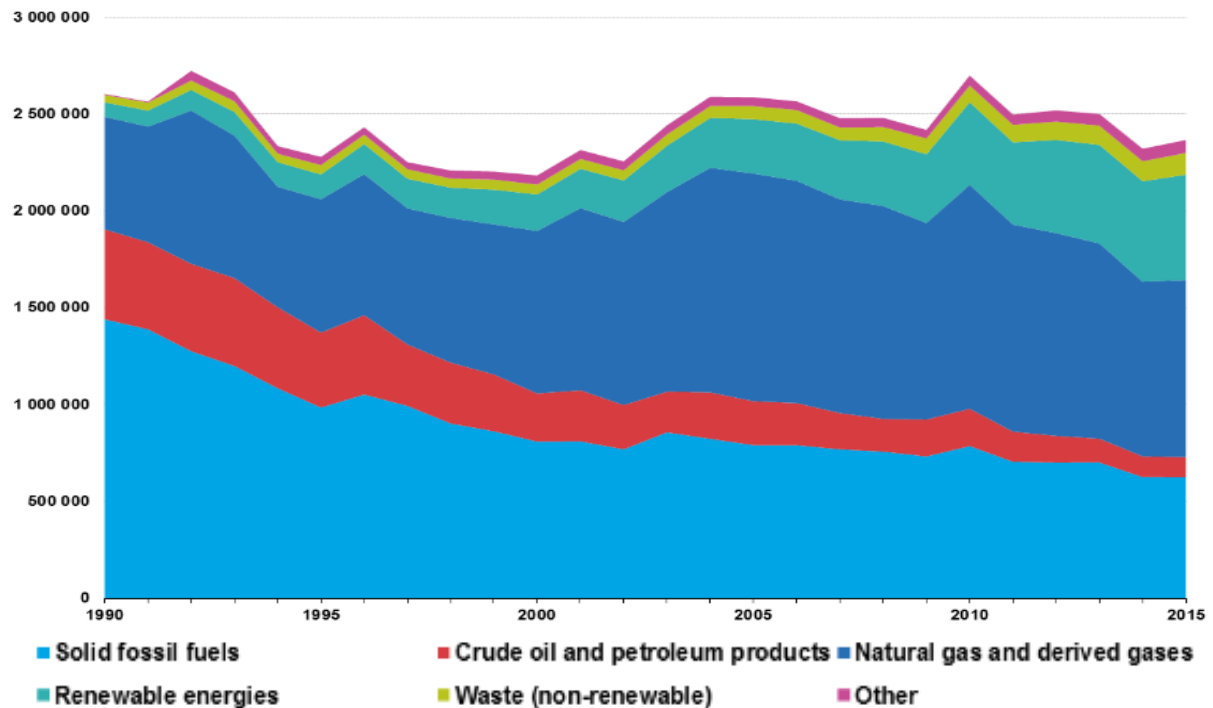




## 2.2. Centralised heat generation (transformation sector)

In 2015, in the transformation sector,<sup>22</sup> the total gross production of derived heat reached 2.37 million TJ<sup>23</sup> (about 57 Mtoe<sup>24</sup>), of which the largest share (about 37 per cent) came from natural gas as seen in Figure 3.<sup>25</sup> Fossil fuels represented 77 per cent of the total and while renewables only contributed to 23 per cent, but they seemed to be following a long term increasing trend.<sup>26</sup>

**Figure 3: Gross derived heat production by fuel in the EU, 1990-2015 (TJ)**



Source: Eurostat<sup>27</sup>

Part of the derived heat is used in the industry (process heat) and part is distributed via district heating systems. Note that the following paragraphs focus on thermal energy in district heating systems rather than in district cooling systems, which are not widespread in the EU (essentially in Sweden and France) and represented less than 0.5% of the total in 2012.<sup>28</sup>

<sup>22</sup> Energy input in the transformation sector for heating and cooling is derived from the electricity and district heating (and cooling) generation mix with estimated conversion efficiencies for each energy carrier to account for transformation and heat losses in district heating (and cooling) network.

<sup>23</sup> Eurostat data, [http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity\\_and\\_heat\\_statistics#Derived\\_heat\\_production](http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_and_heat_statistics#Derived_heat_production)

<sup>24</sup> Conversion: 1 million TJ = 23.885 Mtoe. Source: <https://www.iea.org/statistics/resources/unitconverter/>

<sup>25</sup> Note on Figure 3: The figure shows a 'natural gas and derived gases' category, which includes natural gas used in CHP plants and heat plants to produce heat and additionally natural gas which is used as a feedstock in gas works, coke ovens, blast furnaces, and other recovered gases. Of the total in this category, natural gas used for CHP plants and heat plants represented about 95.6 per cent of the total, therefore the whole category is still representative of the importance of natural gas in heat production in the transformation sector.

<sup>26</sup> Eurostat data, [http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity\\_and\\_heat\\_statistics](http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_and_heat_statistics)

<sup>27</sup> [http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Gross\\_derived\\_heat\\_production\\_by\\_fuel\\_TJ\\_EU-28\\_1990-2015\\_new.png](http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Gross_derived_heat_production_by_fuel_TJ_EU-28_1990-2015_new.png)

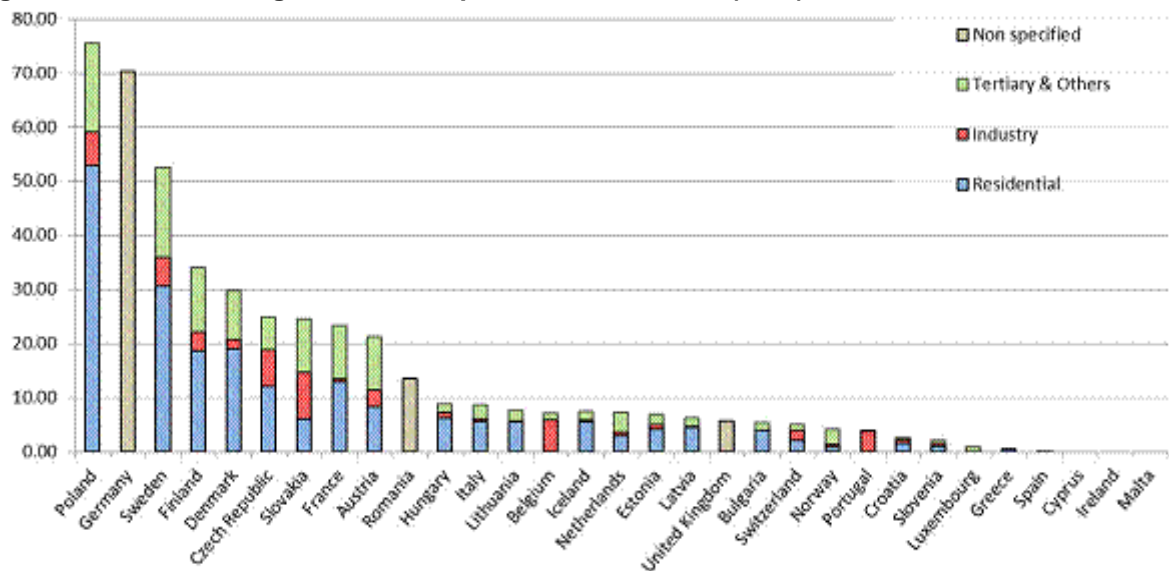
<sup>28</sup> Less than 3 TWh for thermal energy was distributed via cooling systems but 606.3 TWh was distributed via heating systems. Source: European Commission (2016b), pp116-118



District heating represented 606.3 TWh in 2012 (about 52 Mtoe<sup>29</sup>). It was by far the largest consumer of derived heat (87 per cent of the total<sup>30</sup>), and was mainly used in the residential sector (45 per cent), followed by the tertiary sector (24 per cent) and the industrial sector (11 per cent).<sup>31</sup>

There were wide differences by country as seen in Figure 4. The main markets for district heating were Poland, Germany, Sweden, and Finland, and these four countries represented about 50 per cent of the total in the EU. There is an important difference between Scandinavian and Baltic countries where a high proportion of the population is covered by district heating while the percentages are much lower in warmer climates of Southern Europe.<sup>32</sup>

**Figure 4: District heating final consumption in the EU, 2012 (TWh)**



Source: European Commission (2016b), p.115

Energy for district heating is essentially produced from natural gas, coal and biomass as seen in Figure 5. Natural gas is the main single source and accounted for 35 per cent of the total mix in the EU in 2012.<sup>33</sup>

However, the energy supply composition for district heating is very country-specific and influenced by a number of factors such as the availability of energy sources. A number of countries had much higher shares of gas in their energy mix. For instance, it was above 80 per cent in Bulgaria, Croatia, Hungary, and the Netherlands. In Lithuania, Italy, and Romania, the share of natural gas was between 50 - 70 per cent. In Spain, Germany, and France, the share of natural gas in district heating was in the 40-50 per cent range.

Coal was a close second with a share of 31.6 per cent. The main markets were Poland (74 per cent of its district heating) and Czech Republic (71 per cent), while Germany used coal for 40 per cent of district heating needs. Biomass had a 16 per cent share at an EU level and it had a prominent role in Sweden (49 per cent) as well as in Austria (41 per cent) and Estonia (35 per cent). In contrast, solar thermal and heat pumps play only a minimal role in district heat production. It should be noted that there was no individual data for Greece, Luxembourg, Portugal or the UK.

<sup>29</sup> Conversion: 1 TWh = 0.08598 Mtoe. Source: <https://www.iea.org/statistics/resources/unitconverter/>

<sup>30</sup> Author's calculations from Eurostat data, [http://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity\\_and\\_heat\\_statistics](http://ec.europa.eu/eurostat/statistics-explained/index.php?title=Electricity_and_heat_statistics)

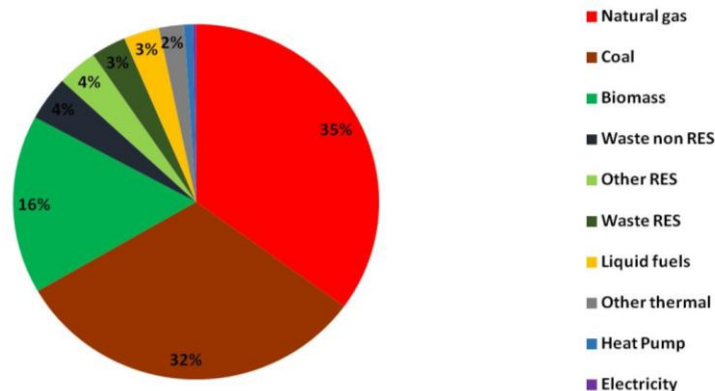
<sup>31</sup> About 20 per cent of final consumption was used in non-specified sectors in 2012.

<sup>32</sup> European Commission (2016b), p.115

<sup>33</sup> European Commission (2016b)



**Figure 5: Sources for energy for heat sales from district heating in the EU, 2012 (%)**



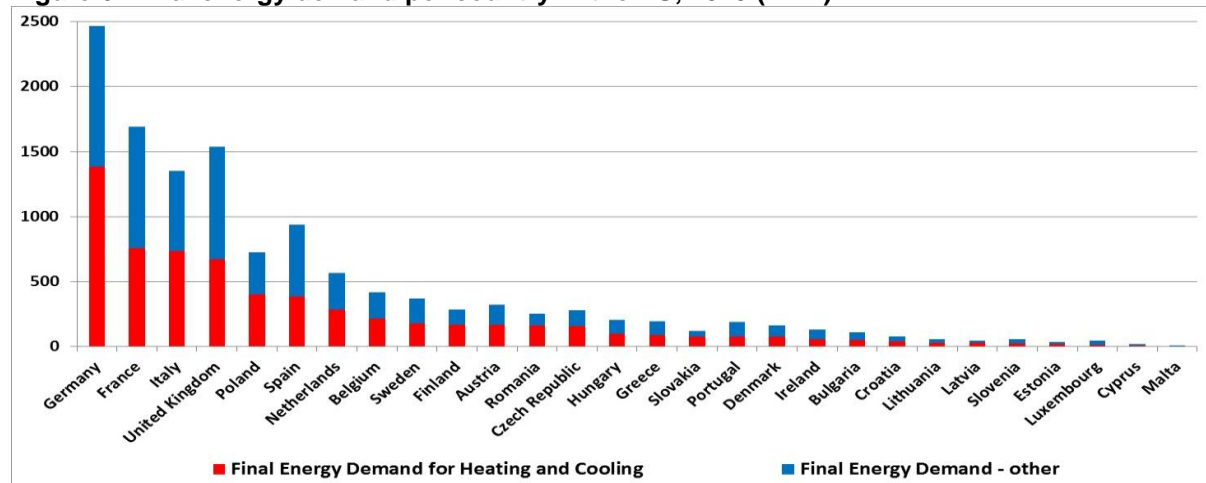
Source: European Commission (2016b), p.122

### 2.3. Final energy demand

In 2015, about 50 per cent of the final energy demand in the EU28 was used for heating and cooling (about 546 Mtoe).<sup>34</sup> The rest was consumed by transport (32 per cent) and electricity (18 per cent).<sup>35</sup>

Heating (and cooling) systems have been influenced by, amongst other things, demographics, the efficiency of the building stock, energy availability, energy policies, economic structure (for example, the share of energy intensive industries), and climate considerations. As a result, Final Energy Demand for heating or cooling varies a lot across Europe as seen in Figure 6. It covered more than half of total final energy demand in eleven countries. It was especially important in Slovakia, Romania, Latvia, and Finland (>60 per cent), but on the contrary represented less than 45 per cent in seven countries with the lowest shares in Malta (29 per cent) and Luxembourg (33 per cent).<sup>36</sup>

**Figure 6: Final energy demand per country in the EU, 2015 (TWh)**



Source: Author's calculations from Eurostat data and data from Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>34</sup> Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>35</sup> The split for transport and electricity is for 2012. Source: EurActiv, 15 April 2016, Infographic: The EU's new Heating and Cooling Strategy, <https://www.euractiv.com/section/energy/infographic/the-eus-new-heating-and-cooling-strategy/>

<sup>36</sup> Author's calculations from Eurostat and Heat roadmap Europe data

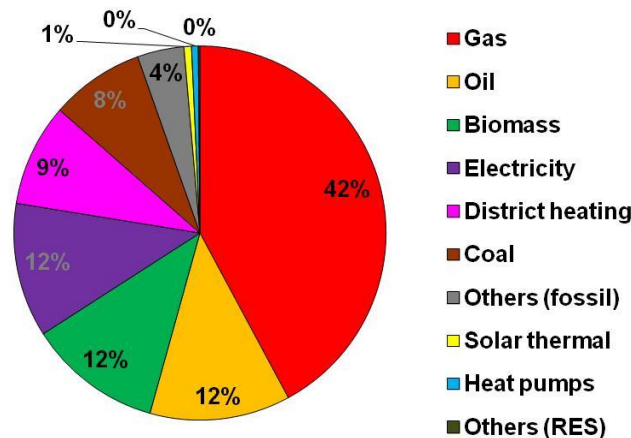


The largest consumer by far is Germany, which alone accounted for about 22 per cent. It was followed by France (12 per cent), Italy (11.5 per cent), and the UK (10.5 per cent). These four markets accounted for more than half of the total energy used in final energy demand for heating and cooling (56 per cent).<sup>37</sup>

### 2.3.1. Energy carriers

Although the heating and cooling sector is moving towards low carbon energy, about 66 per cent of final energy demand still came from the direct combustion of fossil fuels (oil, coal, or natural gas) in 2015. About 42 per cent came from natural gas alone as seen in Figure 7. Heat generated through oil appliances was still important at about 12 per cent, mostly used by houses not connected to the gas grid. Electricity and district heating accounted for 21 per cent, and may or may not have been generated from natural gas depending on the location. Renewable sources represented only 13 per cent of the energy used for final consumption, and biomass represented the lion's share (12 per cent).

**Figure 7: Final energy demand for heating and cooling by fuel source in the EU, 2015 (%)**



Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

The fairly low share of renewables in final energy demand for heating and cooling nonetheless hides a rising trend as seen in Figure 8. The 2017 Renewable Energy Progress report<sup>38</sup> even showed that the renewables share reached 18.6 per cent in 2015, well above its aggregated National Renewable Energy Action Plans (NREAP) trajectory for heating and cooling.<sup>39</sup> Solid biomass remained the most widely used renewable energy for heating and cooling throughout the EU (78 per cent), followed by heat pumps (11 per cent), renewable waste (3.4 per cent), biogas (3.2 per cent), solar thermal (2.2 per cent) and geothermal (0.7 per cent).<sup>40</sup>

<sup>37</sup> Eurostat and Heat roadmap Europe data

<sup>38</sup> European Commission (2017a)

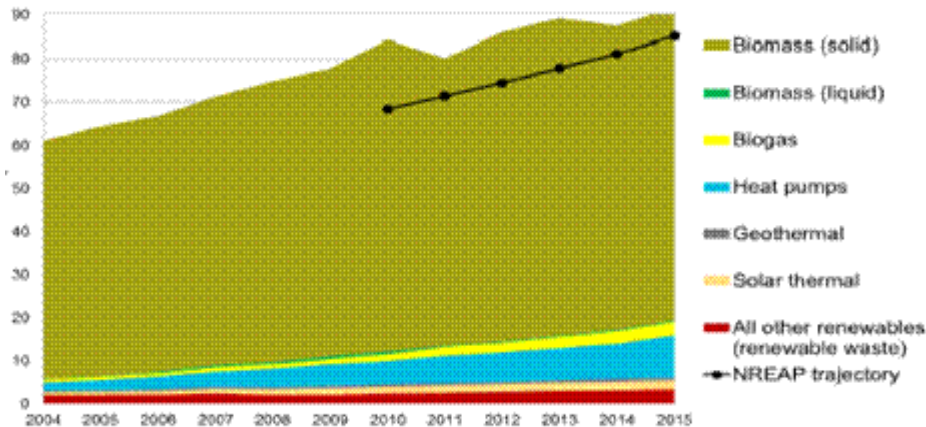
<sup>39</sup> NREAP aggregation indicates an expected share of 15 per cent and 16 per cent respectively in 2014 and 2015.

<sup>40</sup> Based on PRIMES EUCO30 scenario





**Figure 8: Final energy demand for heating and cooling from renewable energies by source in the EU, 2004-2015 (Mtoe)**

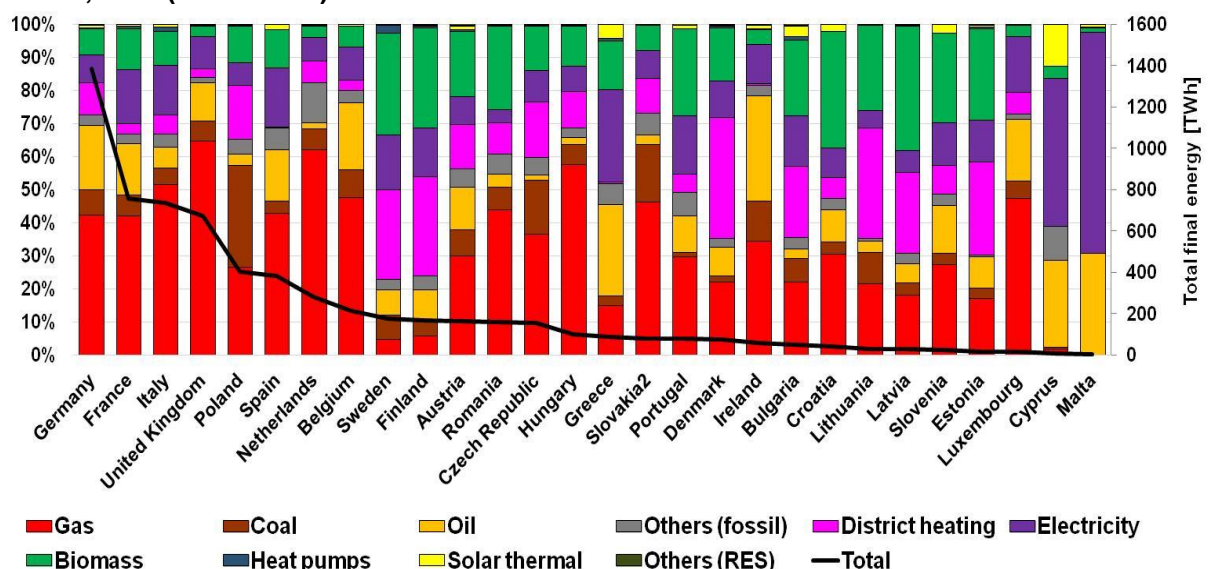


Source: European Commission (2017), p.5

At the national level, the use of natural gas was fairly widespread across Europe and accounted for a substantial share in several countries, essentially located in North and West Europe in addition to some central European countries as seen in Figure 9. Natural gas even accounted for more than half of final energy demand for heating and cooling in Italy, the Netherlands, and Hungary; while on the contrary, it had a very low share in Finland and Sweden (and none in Cyprus and Malta due to lack of available gas supply).

The use of coal was more limited and was essentially concentrated in Poland and a few other countries such as the UK, Czech Republic, Sweden, and Slovakia. The use of oil products was still quite pronounced in some countries such as Greece, Cyprus, Ireland, the UK, Belgium, and Germany. Thermal energy sourced from electricity was very important in Malta and Cyprus and to a lesser extent in Spain, Greece, Portugal, Bulgaria, and Luxembourg. District heating accounted for marginal heat market shares in Western and Southern Europe, while countries located in Northern and Eastern Europe relied on it more heavily due to colder climates, especially Denmark, Lithuania, Finland, Estonia, Slovakia, Bulgaria, and Latvia. Renewable energy sources share was highest in Baltic and Nordic Member States (ranging from 43 per cent in Estonia to 67 per cent in Sweden).

**Figure 9: Final energy demand for heating and cooling per country and per energy carrier in the EU, 2015 (% and TWh)**



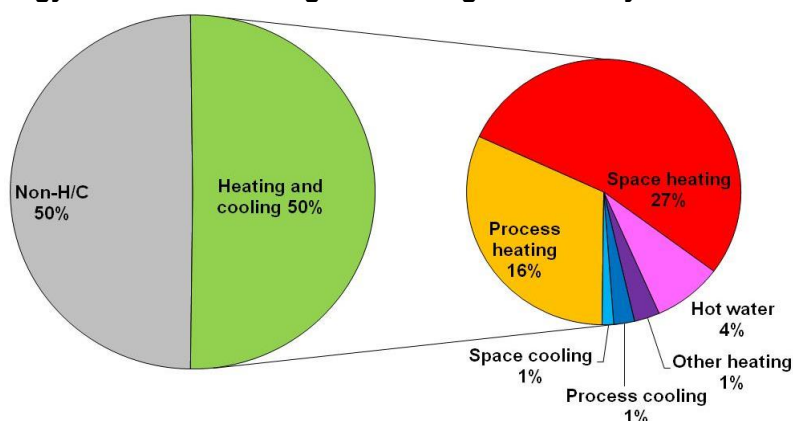
Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)



### 2.3.2. End-uses and analysis by sector

There are six main final energy demand sectors for heating and cooling end-uses: space heating, space cooling, water heating, process heating, process cooling, and cooking. As seen in Figure 10, heating accounts for by far the biggest area of consumption, representing about 96 per cent of final energy demand for heating and cooling in 2015 (6,110 TWh or 525 Mtoe<sup>41</sup>) while the cooling sector was much smaller with a 4 per cent share (242 TWh or 21 Mtoe).<sup>42</sup>

**Figure 10: Final energy demand for heating and cooling in the EU by end-use in 2015 (%)**



Other heating: cooking in residential buildings

Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

In 2015, more than 85 per cent of final energy demand for heating and cooling was used in buildings for space heating (54 per cent) and in the industry for process heating (32 per cent). Although all countries in Europe need some sort of space heating during the year, the length of time when heating is needed varies considerably, ranging from year-long heating seasons in the North to a few days a year in the South. But while outside temperatures influence building heat demands, it is important to note that building insulation also plays its part, with northern cities usually having a much higher level of insulation than southern cities. This explains the fact that heat demand is not only concentrated in the northern states, but is also important in central and, to some extent, southern Europe as well.<sup>43</sup> As a result, the share of space heating in household energy demand is above 80 per cent in colder climates and still represents about 50 per cent in warmer climates as seen in Figure 11.<sup>44</sup> Space (and process) cooling is essentially concentrated in the warmer climates of southern Europe, but even here it is limited.<sup>45</sup>

<sup>41</sup> Conversion: 1 TWh = 0.08598 Mtoe. Source: <https://www.iea.org/statistics/resources/unitconverter/>

<sup>42</sup> Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

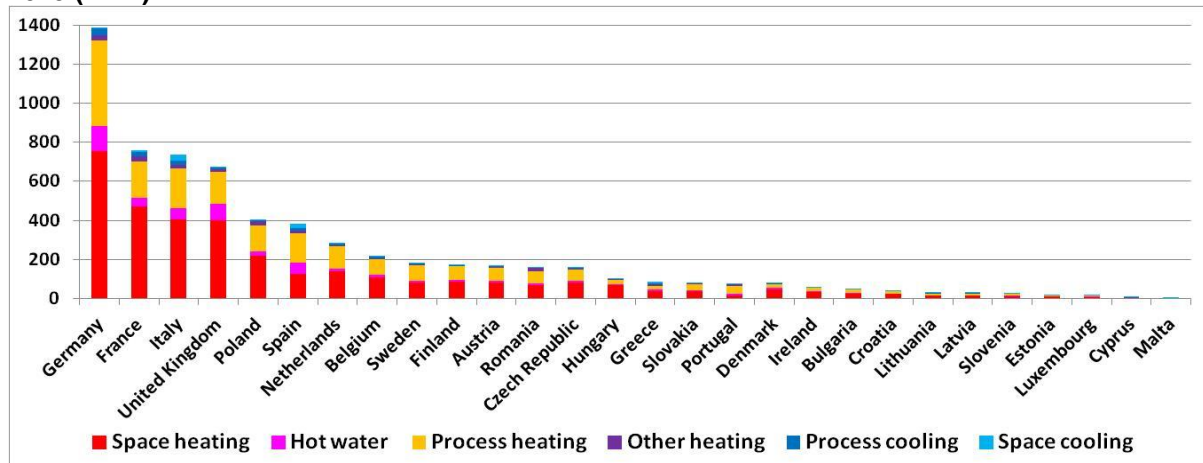
<sup>43</sup> Stratego, Enhanced heating and cooling plans (2015), p.4

<sup>44</sup> European Commission (2016b)

<sup>45</sup> Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)



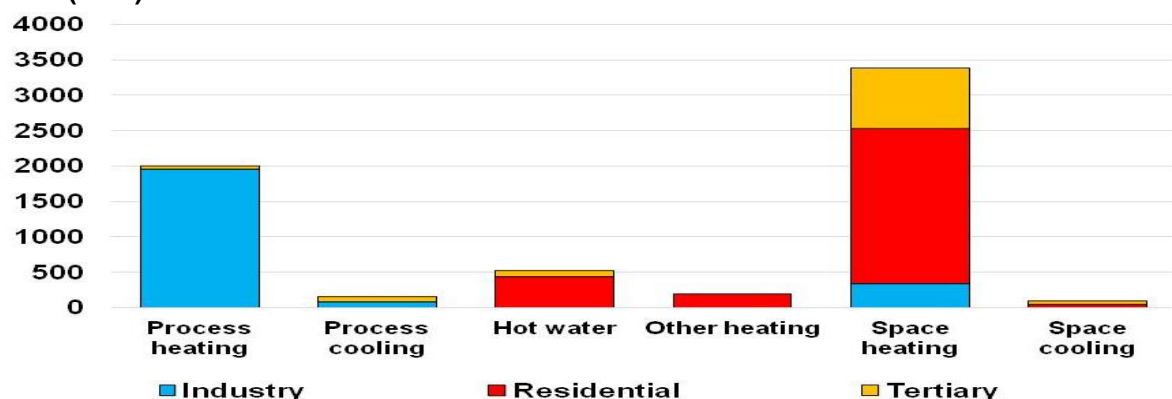
**Figure 11: Final energy demand for heating and cooling in the EU, per country per end-use, 2015 (TWh)**



Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

As seen in Figure 12, space heating was largely used in the residential sector (65 per cent), but the shares of the commercial and industrial sectors were also relatively important. On the contrary, process heating was almost exclusively used in the industrial sector.

**Figure 12: Final energy demand for heating and cooling in the EU by sector and end-uses, 2015 (TWh)**



Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

In 2015, the residential sector was the largest consumer of final energy demand for heating and cooling (45 per cent), followed by the industrial sector (38 per cent) and the commercial sector (18 per cent).<sup>46</sup> The following paragraphs provide some details on the levels of demand and on the energy used in each sector.

### Residential sector

In 2015, the residential sector accounted for about 25 per cent of total final energy demand in the EU<sup>47</sup> but for 45 per cent of final energy demand used specifically for heating and cooling.<sup>48</sup>

- About 77 per cent of the energy consumed by households was used for heating and cooling, mainly for space heating (65 per cent), but also for water heating (14 per cent) and for cooking (6 per cent). Energy used for lighting and electrical appliances accounted for 14 per cent.<sup>49</sup>

<sup>46</sup> Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>47</sup> Calculated from Eurostat, data for 2015

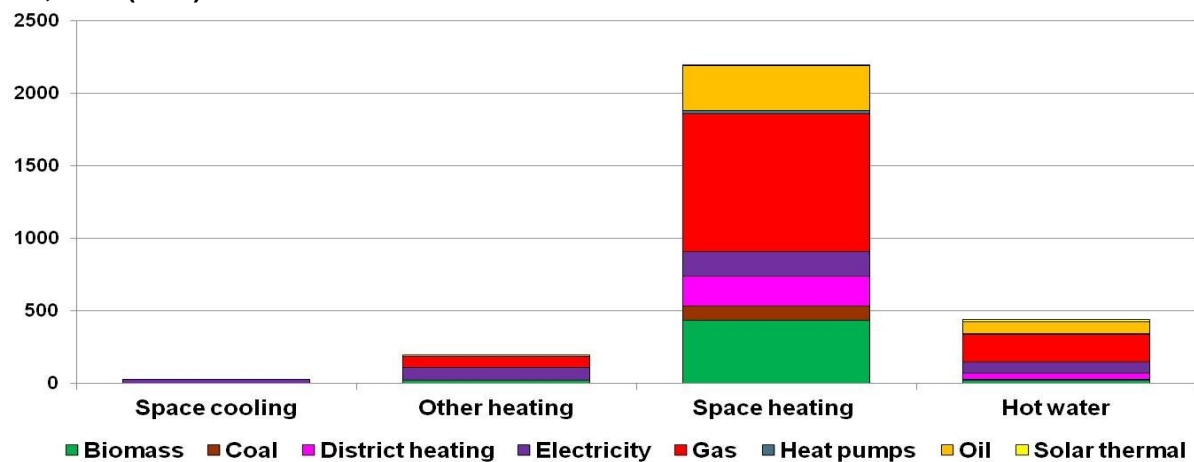
<sup>48</sup> European Commission (2016b), p.83





- Cooling demand is usually included in the electricity demand of a building (and not measured separately) but it was estimated to be a fairly small share of energy consumed (around 1 per cent).<sup>50</sup>
- Space heating came largely from natural gas (43 per cent), but biomass (20 per cent) and oil (14 per cent) also accounted for a large share as seen in Figure 13.

**Figure 13: Final energy demand for heating and cooling in the residential sector by fuel in the EU, 2015 (TWh)**



Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

### Industrial sector

In 2015, the industrial sector accounted for about 25 per cent of total final energy demand in the EU but for 37 per cent of final energy demand used specifically for heating and cooling.<sup>51</sup>

- About 73 per cent of the energy consumed by the sector was used for heating and cooling in 2012,<sup>52</sup> while the rest was directed to mechanical applications driven by electricity.
- For heating and cooling, the largest end-use was process heating (81 per cent in 2015), while process cooling only accounted for less than 4 per cent. The share of space heating reached 14 per cent and space cooling less than 1 per cent.
- Deeper analysis of the industrial sector shows that process heating above 500°C accounted for 42 per cent of its final energy demand for heating and cooling, process heating between 200 and 500°C for 9 per cent, process heating between 100 and 200°C for 21 per cent and process heating under 100°C for 9 per cent as seen in Figure 14. This is an important detail because depending on the end-use and the temperature needed to be achieved, not all fuel sources will be adequate. Coal is essentially burnt for high-temperature process heating uses, while natural gas is more widely used for heating purposes, except for low temperature processes (under 100°C) where district heating held the largest share. Renewable energy came essentially from biomass and it is mostly used for steam in the 100-200° process heating range.
- Natural gas accounted for 39 per cent of total energy used in the industry sector (space heating and process heat).

<sup>49</sup> Eurostat data for 2015. Source: <http://ec.europa.eu/eurostat/web/products-eurostat-news/-/DDN-20170328-1>

<sup>50</sup> European Commission (2016a), p.12

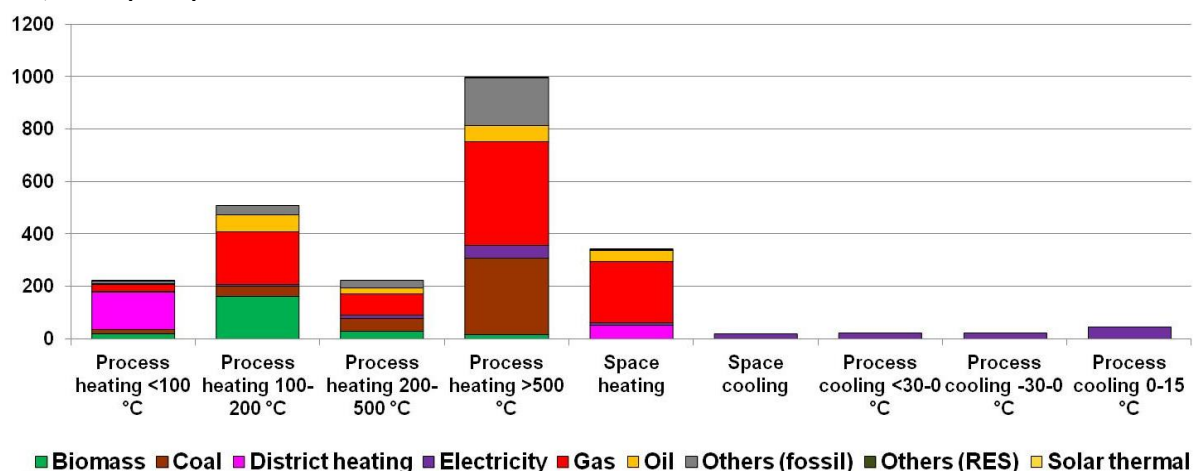
<sup>51</sup> Calculated from Eurostat, data for 2015

<sup>52</sup> European Commission (2016a), p.15





**Figure 14: Final energy demand for heating and cooling in the industrial sector by fuel in the EU, 2015 (TWh)**



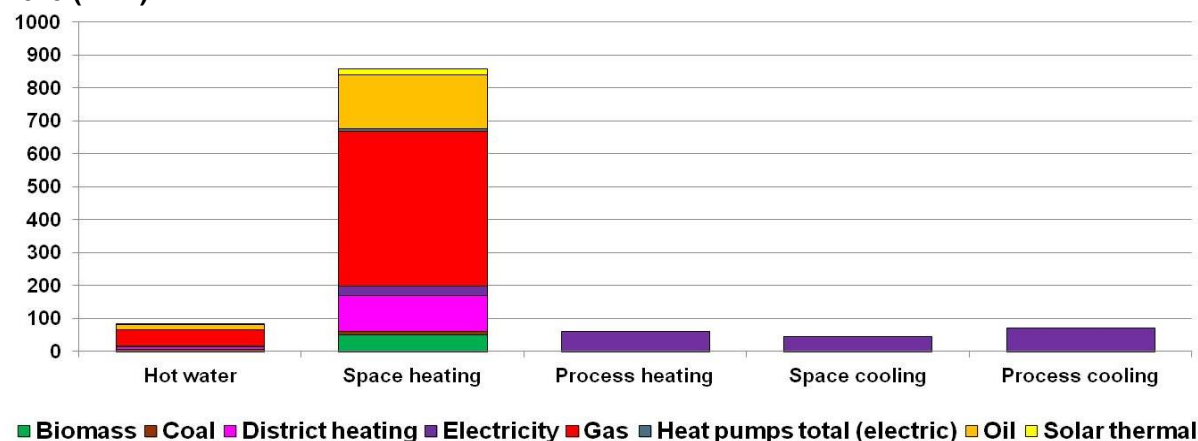
Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

### Service sector

In 2015, the service sector accounted for 14 per cent of total final energy demand in the EU and for 18 per cent of final energy demand used specifically for heating and cooling.<sup>53</sup>

- About 63 per cent of the energy consumed by the sector was used for heating and cooling.<sup>54</sup>
- Energy consumption was very diverse depending on the subsector, but space heating in buildings accounted for the biggest share (77 per cent), which largely came from natural gas (55 per cent).
- Energy was also used for water heating (7.5 per cent), process heating (5 per cent) while cooling purposes accounted for 10.5 per cent, especially from businesses such as the food industry [Figure 15].

**Figure 15: Final energy demand for heating and cooling in the service sector by fuel in the EU, 2015 (TWh)**



Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>53</sup> Calculated from Eurostat, data for 2015

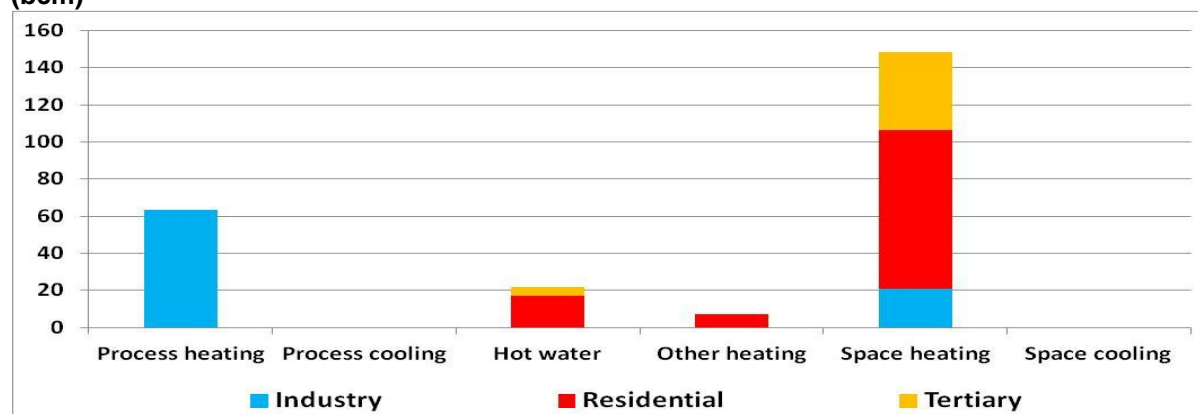
<sup>54</sup> European Commission (2016a), p.21



## Building sector

Natural gas used in buildings represented about 143 bcm in 2015. Most of it (57 per cent) came from the residential sector, 28 per cent in the service sector, and the remaining share in the industry as seen in Figure 16. Note that the amount of gas used to heat buildings is subject to large variations from one year to another depending on ambient temperature and its impact on space heating demand. For natural gas itself, the range of variations for total demand due to cold or warm winters is about 30 bcm.<sup>55</sup>

**Figure 16: Natural gas for heating and cooling by end-uses and by sector in the EU, 2015 (bcm)**



Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

To conclude, available data show that the heating and cooling sector is the largest single energy sector in the EU, representing 40 per cent of primary energy and 50 per cent of final energy demand, and natural gas is the most relevant individual energy carrier in most sectors as seen in Table 1.

**Table 1: Summary of energy and natural gas demand for heating and cooling in the EU, 2015**

	Energy demand for heating or cooling (Mtoe)	Share of gas (%)
Primary energy	684*	46*
Transformation (derived heat)	57	37
District heating	52*	35*
<b>Final energy demand</b>	<b>546</b>	<b>42</b>
Heating	524	43*
Cooling	22	0*
<b>Final energy demand</b>	<b>546</b>	<b>42</b>
Buildings - space heating	295	48*
Industry - process heat	175	34*
<b>Final energy demand</b>	<b>546</b>	<b>42</b>
Residential	246	43*
Industry	207	39*
Commercial	98	46*

Note: \* data for 2012

Source: Author's calculations

<sup>55</sup> Author's calculations of weather corrected natural gas demand based on IEA data for OECD Europe.



### III. The role of the heating sector in natural gas demand

Natural gas is the main energy source used for heating in Europe, both in the transformation sector and for final consumption. And while it does not provide energy for cooling directly, it is worth noting that most of the cooling demand is served by electricity, of which natural gas accounted for 16.4 per cent of the mix in 2015. As a result, any changes in the heating and cooling sector due to decarbonisation efforts are likely to have an impact on natural gas demand.

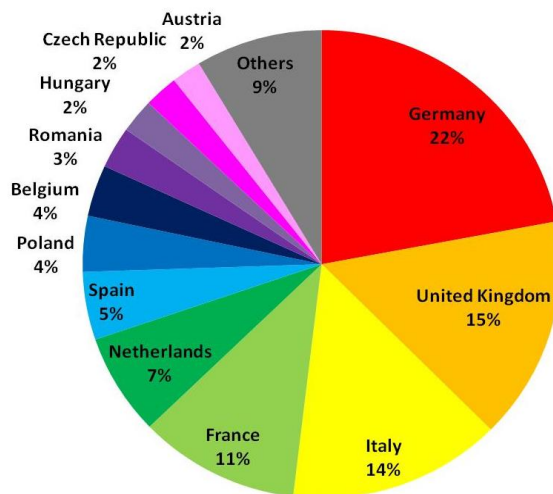
As already mentioned, there is no readily available data series on natural gas demand for heating.<sup>56</sup> The paragraphs below provide a rough picture of natural gas used for heating in Europe; however, the statistics are best estimates and therefore need to be taken with precaution.

#### 3.1. By country

In 2015, natural gas demand reached 433 bcm in the EU.<sup>57</sup> Six countries accounted for 75 per cent of the demand: Germany (81 bcm), the UK (72 bcm), Italy (67.5 bcm), the Netherlands (40 bcm), France (38 bcm) and Spain (27 bcm).

The heating sector was responsible for 64 per cent of the gas used or about 275 bcm. The same key countries dominated the split and accounted for about 74 per cent of the demand: Germany (22 per cent or about 58 bcm), the UK (15 per cent, 41 bcm), Italy (14 per cent, 38 bcm), France (11 per cent, 29 bcm), Netherlands (7 per cent, 18 bcm) and Spain (5 per cent, 12 bcm) as seen in Figure 17.<sup>58</sup>

**Figure 17: Natural gas demand for heating by EU country, 2015 (%)**



Source: Author's calculations

Any changes in gas demand in these countries as a result of decarbonisation policies will have an important impact on regional demand. However, at a national level, decarbonisation policies could also dramatically change the picture in countries such as Sweden (90 per cent) and Estonia, Slovenia, Czech Republic, Luxembourg, France and Germany, all of which have a share of natural gas used for heating above 70 per cent of total gas demand as seen in Figure 18. On the contrary,

<sup>56</sup> Natural gas demand is traditionally represented as the primary energy supply available to one market, which is then split by sectors: transformation sector, energy own use, losses, final consumption, and non-energy use.

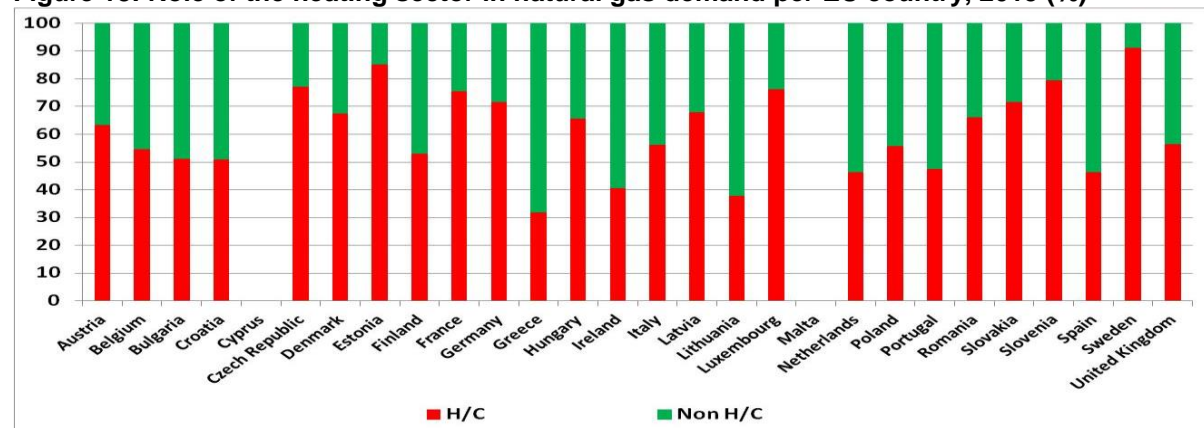
<sup>57</sup> IEA (2017A)

<sup>58</sup> Author's calculations



gas used for heating in Greece, Ireland, and Lithuania represented a much smaller sharer of total demand in 2015, albeit still above 30 per cent.<sup>59</sup>

**Figure 18: Role of the heating sector in natural gas demand per EU country, 2015 (%)**



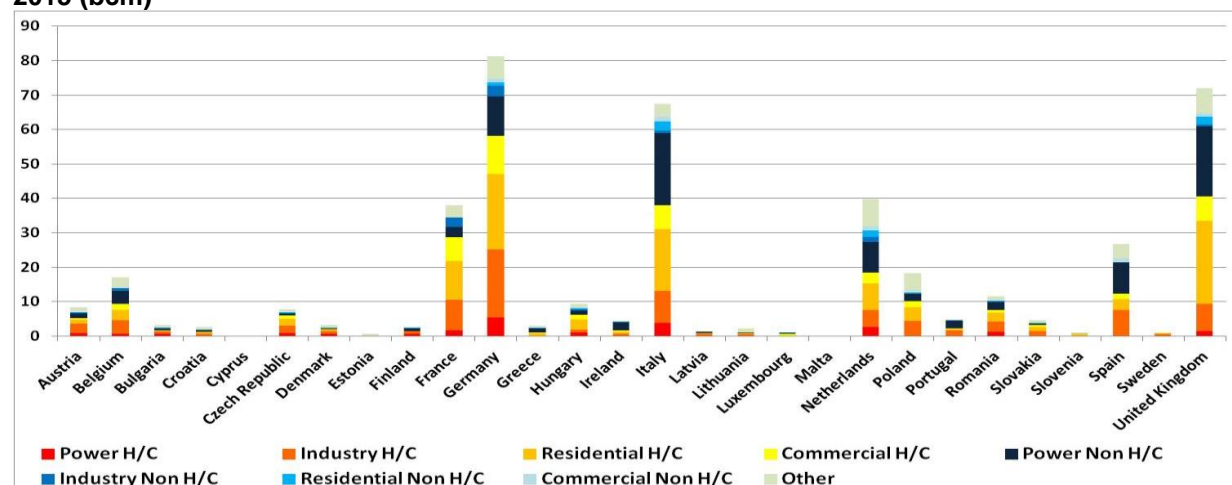
Source: Author's calculations

### 3.2. By sector

Figure 19 below shows the share of natural gas used for heating purposes for each of the main sectors (power, industry, residential and commercial)<sup>60</sup> in each country, defined by 'warm' colours such as red, orange, and yellow.

The chart shows that most of the non-heating uses were in the power (transformation) sector, but the data available in the public domain only shows derived heat produced in CHPs and heat plants and does not account for the share of electricity generation that is used for heating and cooling. As a result, the total share of natural gas used for heating (and cooling) in the transformation sector should actually be higher if it accounted for the use of electricity.

**Figure 19: Role of the heating sector in natural gas demand by sub-sectors and by EU country, 2015 (bcm)**



Source: Author's calculations

<sup>59</sup> Author's calculations

<sup>60</sup> In 2015, gas demand was used for power (27.2 per cent), residential (26.6 per cent), industry (21.5 per cent), commercial (12.1 per cent) and others (12.7 per cent) in the EU28. Source: IEA (2017A)

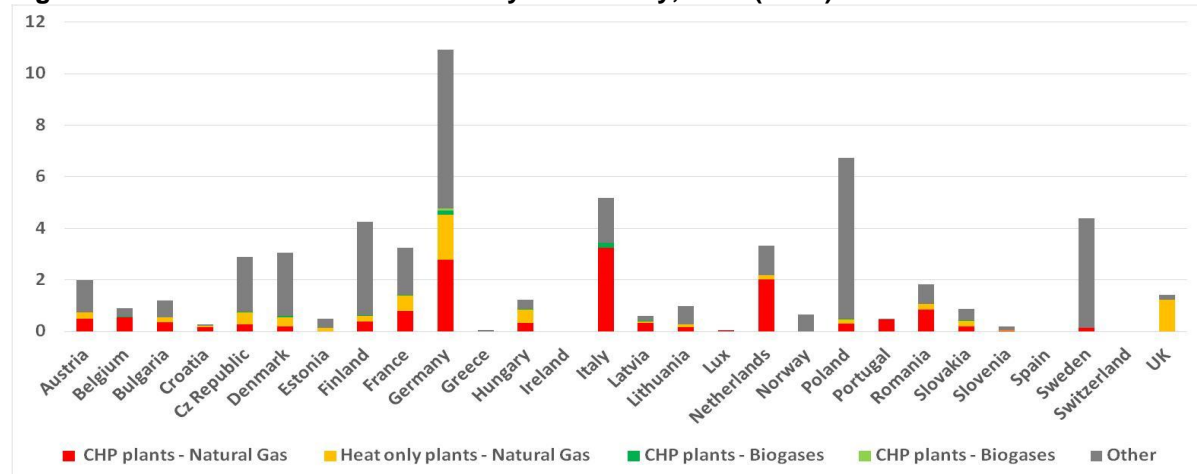




### 3.2.1. Derived heat

In 2015, the production of derived heat represented about 25.4 bcm of natural gas (17.1 bcm in CHPs [as the share of natural gas consumed by CHPs used to produce heat] and 8.3 bcm in heat plants). The largest amount of natural gas used as a primary source in CHPs and heat plant was in Germany, followed by Italy, the Netherlands, the UK, and France as seen in Figure 20. Eurostat data provides additional information on the use of biogases in CHPs and heat plants, but it is still very limited.

**Figure 20: Production of derived heat by EU country, 2015 (Mtoe)**

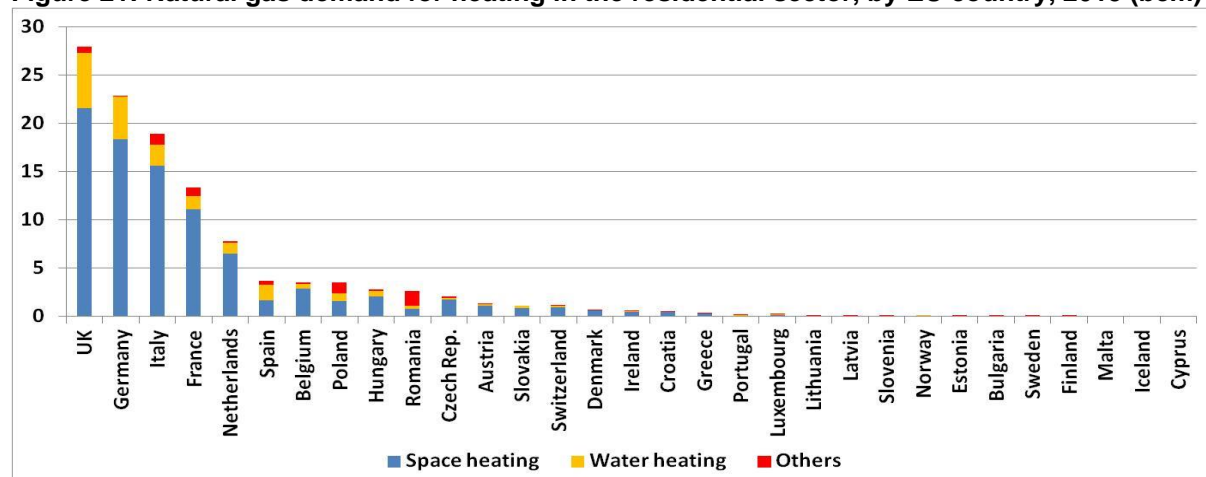


Source: Author's calculations from Eurostat data

### 3.2.2. Final consumption

The residential sector was the largest user of natural gas in the heating sector, accounting for 116 bcm in 2015. The largest end-use was space heating (77 per cent), followed by water heating (17 per cent). As for the total market, the largest consumer was the UK (24 per cent), followed by Germany (20 per cent), Italy (16 per cent), France (12 per cent) and the Netherlands (7 per cent). These five countries alone represented close to 80 per cent of the demand for gas to generate heat in the residential sector as seen in Figure 21.<sup>61</sup>

**Figure 21: Natural gas demand for heating in the residential sector, by EU country, 2015 (bcm)**



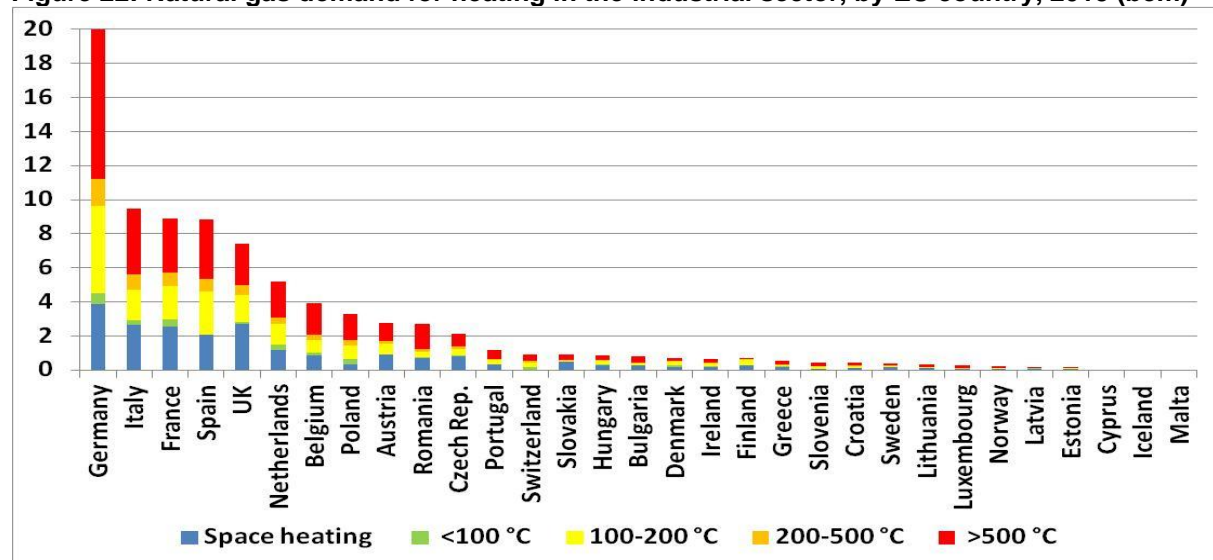
Source: Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>61</sup> Author's calculations from Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)



In the industrial sector, about 84 bcm was used to generate heat in 2015. The main source of demand was for temperatures above 500 degrees (40 per cent), followed by space heating (25 per cent) and demand for heat between 100 and 200 degrees (22 per cent). The main consumer by far was Germany (23 per cent), followed by Italy, France, Spain (all at about 11 per cent), and the UK (9 per cent) as seen in Figure 22.<sup>62</sup>

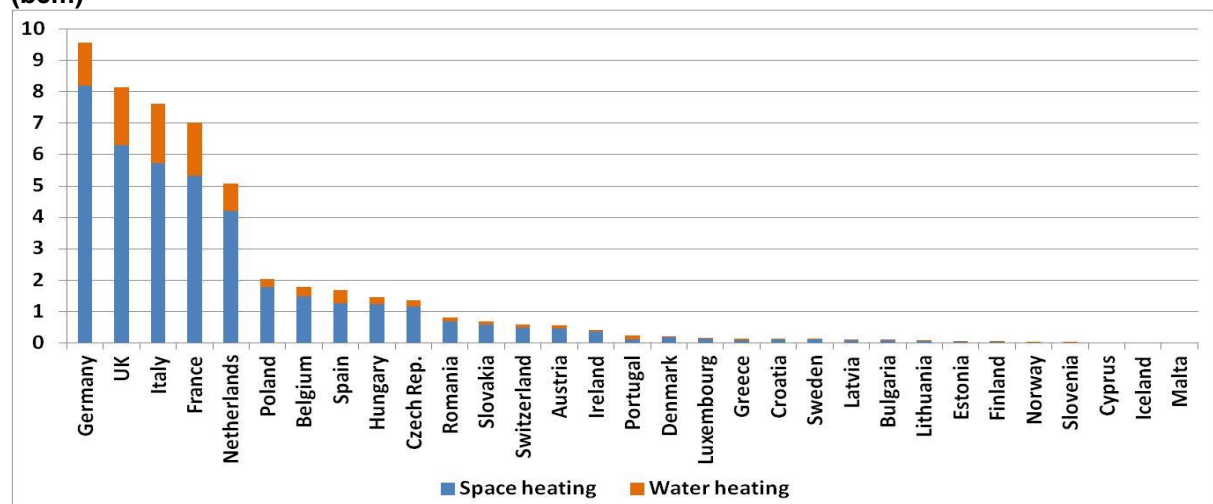
**Figure 22: Natural gas demand for heating in the industrial sector, by EU country, 2015 (bcm)**



Source: calculated from Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

In the commercial sector, 80 per cent of the 50 bcm of gas demand used for heating was directed to space heating and 20 per cent to water heating. The largest markets were almost the same as in the previous sector, with Germany as the main consumer (19 per cent), followed by the UK (16 per cent), Italy (15 per cent), France (14 per cent), and the Netherlands (10 per cent) as seen in Figure 23.<sup>63</sup>

**Figure 23: Natural gas demand for heating in the commercial sector, by EU country, 2015 (bcm)**



Source: calculated from Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>62</sup> Author's calculations from Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>63</sup> Author's calculations from Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)



To conclude, the heating sector is the main market for natural gas in Europe. It represents 64 per cent of total gas demand. In the residential, industrial and commercial sectors, the role of heating is even higher as seen in Table 2.

**Table 2: Summary of natural gas demand for heating in the EU, by sector, 2015**

	Total natural gas demand (bcm)	Share of gas used for heating (%)
Total	433	64
Transformation	117	21*
Final energy demand	288	87
Residential	117	99
Industry	93	90
Commercial	53	94

Source: Author's calculations

Any policies to decarbonise heating in buildings and process heating in industry will have important consequences for natural gas demand in the future, but neither the impacts nor the timeframes are likely to be uniform across Europe.

## IV. Decarbonising the heating and cooling sector: main policies and regulation

The main focus of EU decarbonisation policies for heating and cooling production so far has been on two main categories of measures: energy efficiency and the promotion of renewables, essentially for final energy demand although some work is also being done on district heating systems. The following paragraphs present an overview of the main measures at the EU level.

### 4.1. EU targets for 2020, 2030, and 2050

The climate change targets for 2020, 2030 and 2050<sup>64</sup> set the framework for the decarbonisation of the economy in the EU. In order to ensure 'energy consumption to be sustainable, through the lowering of GHG emissions, pollution, and fossil fuel dependence,'<sup>65</sup> the long term strategy covers three main timeframes.

- The '2020 climate and energy package' defines the EU's energy priorities between 2010 and 2020. These include a reduction of GHG emissions by at least 20 per cent, an increase in the share of renewable energy to at least 20 per cent of gross final consumption (which includes the heating and cooling sector, but there is no renewable target for heating by 2020<sup>66</sup>), and to improve energy efficiency by at least 20 per cent compared to previous estimates.<sup>67</sup>
- The '2030 climate and energy framework' defines the objectives for the period 2021-2030. These include a binding EU target of at least a 40 per cent reduction in GHGs emissions by 2030 across all sectors of the economy compared to 1990 levels; a binding target of at least 27 per cent of renewable energy in the EU and an energy efficiency increase of at least 27

<sup>64</sup> European Commission website, 2020 climate and energy package, [https://ec.europa.eu/clima/policies/strategies/2020\\_en](https://ec.europa.eu/clima/policies/strategies/2020_en); 2030 climate and energy framework, [https://ec.europa.eu/clima/policies/strategies/2030\\_en](https://ec.europa.eu/clima/policies/strategies/2030_en)

<sup>65</sup> European Commission website, Energy strategy and energy union, Secure, competitive, and sustainable energy, <https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union>

<sup>66</sup> EC (2011), p.12

<sup>67</sup> The EU seems to be on track to meet these commitments, at least at the regional level. Source: European Commission website, Energy strategy and energy union, Secure, competitive, and sustainable energy, <https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union>



per cent (with the possibility to be raised to 30 per cent after a review in 2020).<sup>68</sup> In order to reach the 40 per cent reduction target of GHG emissions, the industrial and power sectors covered by the EU emissions trading system (ETS) should reduce emissions by 43 per cent by 2030 compared to 2005 and other sectors of the economy (the non-ETS sectors<sup>69</sup>) should reduce emissions by 30 per cent by 2030 compared to 2005.<sup>70</sup>

- The Energy Roadmap 2050, published in 2012, sets out a series of scenarios on how to meet an 80 -95 per cent reduction in GHG emissions compared to 1990 levels by 2050. The main points include a central role for electricity in achieving a low carbon economy with the intention of partially replacing fossil fuels in the heating and cooling sector (as well as in transport). In the building sector, the focus is on the deployment of low carbon electricity (heat pumps, storage heaters, electricity from renewables), renewables (solar, biogas, and biomass) and district heating, as well as improved insulation to reduce energy demand.<sup>71</sup>

## 4.2. The EU emissions trading system (EU ETS)

One the main measures to decarbonise the economy is the EU ETS.<sup>72</sup> This cap and trade system covers more than 11,000 heavy energy-using installations including power stations and industrial plants operating between 31 countries.<sup>73</sup> The CO<sub>2</sub> emissions from power, CHP, heat plants, and district heating in general are regulated under the EU ETS (those with a rated thermal input exceeding 20 MW although some smaller installations have been included, for example in Finland and Sweden). However, individual heating systems such as boilers in households, are not covered. As a result, only about 25 per cent of total heat supply is covered by the EU ETS (essentially derived heat produced in the transformation sector), while 64 per cent is not (final energy demand). The rest already comes from renewables.<sup>74</sup>

In the November 2017 agreement about Phase 4 of the EU ETS (2021-2030), coal-fired generators will effectively not be eligible for free EU ETS allowances from the new modernisation fund under post-2020 reforms except for the coal-fired district heating networks in Romania and Bulgaria.

According to the EC in its 2016 Strategy for Heating and Cooling, putting a price on carbon emissions via the EU ETS has helped the decline registered in the EU's energy intensity since the early 2000s. The EC argues that putting a cost on energy has provided an incentive to use low carbon fuels and to invest in energy efficiency.<sup>75</sup> The effect of the EU ETS may indeed have complemented national measures to favour renewables, but regarding the generation mix, one can argue that a high enough carbon price may tend to favour gas over coal in power generation (at least while coal plants are kept in the mix), but in the heating and cooling sector, it will mostly favour renewables over natural gas as the role of coal is minimal. The only exception will be for high-temperature heat production in the industrial sector where coal is still important (essentially in the iron and steel sector where coal covered about half of the final energy demand for heating and cooling needs in 2015 and to a much lesser extent in non-metallic minerals where coal's share was less than 15 per cent).<sup>76</sup> In these sectors, natural gas but also eventually green gas will tend to be favoured over coal which has a higher CO<sub>2</sub> price.

---

<sup>68</sup> The framework also stipulates the completion of the internal energy market with an electricity interconnection target of 15 per cent between EU countries by 2030

<sup>69</sup> These sectors include buildings, agriculture, waste management, and transport and accounted for almost 60 per cent of total EU emissions in 2014. [Source: European Commission - Fact Sheet \(2016\)](#)

<sup>70</sup> European Commission - Fact Sheet (2016)

<sup>71</sup> European Commission (2011a), p.11

<sup>72</sup> See additional info: [European Commission website, EU Emissions Trading System \(EU ETS\), https://ec.europa.eu/clima/policies/ets\\_en](https://ec.europa.eu/clima/policies/ets_en)

<sup>73</sup> All 28 EU countries plus Iceland, Liechtenstein, and Norway

<sup>74</sup> Seppänen S. and Magnusson R. (2015)

<sup>75</sup> European Commission (2016e), p.7

<sup>76</sup> Data from Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)





### 4.3. Efficiency and energy savings

Lower heating and cooling demand but also lower volumes of energy needed are the first logical step toward decarbonisation as these are the easiest and most cost effective ways to reduce emissions. For instance, the deployment of condensing boilers in the mid-2000s to replace the less efficient traditional boilers in the UK<sup>77</sup> was an illustration of how regulation can affect energy demand, even in the decentralised residential sector.<sup>78</sup>

Some of the efficiency legislation relates directly to the heating and cooling sector, especially targeting the space heating (and cooling) demand. These include:

- The Eco-Design Directive,<sup>79</sup> published in 2009, requires manufacturers to decrease the energy consumption of their products by establishing minimum energy efficiency standards. The Directive sets minimum performance levels for energy-using appliances (including household appliances) and minimum requirements for products affecting energy consumed (for instance windows and insulation). The Energy Labelling Regulation (2010 and its latest version in 2017)<sup>80</sup> complemented the Eco-Design requirements with mandatory labelling and incentives for products such as heaters to aim at the highest performance levels. Ecodesign and energy labelling requirements for space and water heaters were applied in 2015, in effect banning the sale of inefficient boilers. The EC expects that these measures will incur annual energy savings of 600 TWh (which represented 18 per cent of total space heating energy demand in 2015<sup>81</sup>), CO<sub>2</sub> emission reductions of 135 mt, and a reduction of air pollutants emissions by 2030.<sup>82</sup>
- The Energy Performance of Buildings Directive (EPBD),<sup>83</sup> which dates back to 2010, sets out minimum energy efficiency performance levels for existing buildings undergoing major renovation. It also requires new buildings to consume nearly-zero energy from 31 December 2020 (public buildings from 31 December 2018). In effect, the EPBD created a framework to improve the energy efficiency of buildings, which was a first for many EU Member States. The proposed energy performance requirements are expected to gradually reduce energy demand and increase supply from renewable sources; however it will take time to see major progress due to low renovation rates.<sup>84</sup> An additional proposal was published in November 2016 aimed at accelerating the renovation of existing buildings, requiring the development of long-term renovation strategies and the transition of EU buildings to become 'smart' by 2030.<sup>85</sup>
- The Energy Efficiency Directive (EED)<sup>86</sup> followed in 2012 and set an overall target for the EU to reduce its energy consumption by 20 per cent by 2020 compared with levels projected for 2020 in the EC's Energy Baseline Scenario.<sup>87</sup> The EED also sets out energy savings requirements for EU countries' buildings. Article 4 requires that Member States '*establish a long-term strategy beyond 2020 for mobilising investment in the renovation of residential and commercial buildings with a view to improving the energy performance of the building stock*'. For instance, an annual renovation rate of at least 3 per cent should be reached for buildings owned by public governments (art.5). In order to transpose the Directive and to increase the rates and depth of building renovation, Member States had to draw National Energy Efficiency

---

<sup>77</sup> Since 2005, all new gas central-heating boilers fitted in England and Wales have had to be high-efficient condensing boilers (unless exceptional circumstances). The same regulations applied to oil-fired boilers from April 2007.

<sup>78</sup> The stocks of condensing gas boilers compared to the whole market reached about 58 per cent in 2012. Source: European Commission (2016c), p.16

<sup>79</sup> European Union (2009a)

<sup>80</sup> European Union (2017)

<sup>81</sup> Based on Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>82</sup> European Commission (2016e), p.6

<sup>83</sup> European Union (2010)

<sup>84</sup> In a 2016 assessment of strategies for building renovations, the EC concludes that 23 out of 31 Member States met the requirements of establishing a long-term strategy beyond 2020 to mobilise investment in energy efficiency renovations for commercial and residential buildings. Source: European Commission – JRC Science for Policy Report (2016)

<sup>85</sup> European Commission (2016f)

<sup>86</sup> European Union (2012)

<sup>87</sup> European Commission (2008)



Action Plans setting out actions to reduce demand for heating and cooling, to renovate the overall building stock and make comprehensive assessments of the potential for high-efficiency cogeneration and district heating. These 'National Building Renovation Strategies' form part of individual Member States 'National Energy Efficiency Action Plans' (NEEAPs).<sup>88</sup> Member States should also aim to encourage deep renovations of buildings leading to significant (typically more than 60 per cent) efficiency improvements.<sup>89</sup> Article 14 encourages the identification of cost effective potential for delivering energy efficiency, principally through the use of cogeneration, efficient district heating and cooling, and the recovery of industrial waste heat<sup>90</sup> or, when these are not cost effective, through other efficient heating and cooling supply options.

These three Directives are technology-neutral. Consumers are encouraged to use high-efficient technology but there is no obligation to use any specific technologies in new or renovated buildings. This is to accommodate the decentralised and much diversified nature of the heating and cooling market as no 'one size fits all' option exists, but any higher-efficiency technologies will effectively lower energy demand for heating and cooling in Europe and as a result, emissions as well.

The EU has identified the existing building stock as a priority sector as it consumes approximately 40 per cent of primary energy, about 31 per cent of the final energy demand -mostly for space heating and hot water<sup>91</sup>- and it represents about 36 per cent of CO<sub>2</sub> emissions.<sup>92</sup> In some parts of Europe, up to three quarters of outdoor fine particulate matter pollution are attributable to household heating with solid fuels (including coal and biomass).<sup>93</sup> However, policies promoting energy efficiency in buildings are fairly recent, and essentially started in the early 2010s. The effects of these policies will take time to materialise in the European market where buildings are old and waste energy: about 75 per cent of the building stock was still considered energy inefficient in 2015. With only about 0.4-1.2 per cent of the stock being renovated each year, depending on the Member States,<sup>94</sup> reducing the amount of heat loss due to inefficient building stocks and improving the energy efficiency of heating equipment and appliances will be a long process. Standards for new buildings are also being developed but the impacts will be limited compared to the potential of refurbishing the existing stock.

At the EU level, the 2017 EEA report shows that the EU's primary energy consumption<sup>95</sup> and final energy demand in 2015 were on track to meet the 2020 target. Between 2005 and 2015, energy demand in the residential sector decreased by 11 per cent thanks to improvements in energy intensity but also warmer winters which led to lower energy use for heating.<sup>96</sup> At a country level, each Member States has its own national energy efficiency targets, which are non-binding targets for primary and final energy consumption for 2020.<sup>97</sup> Member States can revise their targets and projections upwards or downwards at any point and as a result, there is no formal trajectory set for each country, which would allow monitoring progress towards these targets. As a result, giving an estimation of how much the efficiency targets will affect primary energy demand for heating and cooling and also how much heating and cooling consumption will be reduced is complex. However, the EED request that each

---

<sup>88</sup> European Commission website, National Energy Efficiency Action Plans and Annual Reports, <https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plans>

<sup>89</sup> European Commission (2013)

<sup>90</sup> Article 14(4) then requires Member States to take adequate measures to ensure these are developed if there is cost-effective potential. Source: European Commission (2013b)

<sup>91</sup> Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

<sup>92</sup> European Commission website, Buildings, <https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings>

<sup>93</sup> European Commission (2016e), p.6

<sup>94</sup> European Commission (2016f)

<sup>95</sup> The EU's 2020 target expressed in terms of primary energy consumption is equivalent to a 13.4 per cent reduction from 2005 levels. Source: European Environment Agency (2017)

<sup>96</sup> European Environment Agency website, Final energy consumption by sector and fuel, <https://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-9/assessment-1>

<sup>97</sup> They can be based on absolute primary or final energy consumption, absolute or relative primary or final energy savings, or on energy intensity, but need to be expressed in absolute levels of primary and final energy consumption in 2020. For primary energy consumption, targets range from a 19.4 per cent reduction (UK) to a 20.4 per cent increase (Estonia) compared with 2005 levels. For final energy consumption, targets range from a 21.0 per cent per cent reduction to a 65.8 per cent increase compared with 2005 levels.



country publishes NEEAPs every three years. NEEAPs submitted in 2017<sup>98</sup> indicate that “some Member States seem to have lowered their ambition with regard to their 2020 primary and final energy consumption target levels.<sup>99</sup> Despite the good progress achieved overall since 2005, this is casting a doubt on whether the 20 per cent regional target will be met as “the sum of all individual 2020 targets for primary energy consumption add up to 1 540 Mtoe, which is 3.8 per cent higher than the EU target (1 483 Mtoe) while the sum of Member States 2020 targets for final energy demand adds up to 1 091 Mtoe, 0.4 per cent higher than the EU target (1 086 Mtoe).<sup>100</sup>

Given that the EU gross domestic product (GDP) may increase threefold between 1990 and 2050, higher energy demand may be expected for services such as heating, but also lighting, cooking, and process energy as part of increasing welfare. There is an important potential for rising demand for cooling in the future both for comfort in buildings (including in other more northerly regions) and via process cooling for various industries (food, pharmaceutical, and internet data services to name but a few). If the EU wants to meet its 80 per cent GHG reductions objective by 2050, energy consumption will need to decrease substantially.<sup>101</sup> In addition to limiting energy demand, energy efficiency measures will also encourage primary sources that can be used with small losses in the final energy uses such as many renewables or even natural/green gas and decarbonised electricity.<sup>102</sup>

#### 4.4. Renewable energy

Together with demand reduction, the fuel used to generate heating and cooling is also important and renewable heat provides some alternatives to fossil fuels in order to decarbonise the sector.

The Renewable Energy Directive (RED),<sup>103</sup> published in 2009, establishes an overall policy for use of renewable energy in the EU. The target is set at minimum 20 per cent of gross final consumption by 2020 and eventually 27 per cent by 2030.<sup>104</sup>

Legally binding national targets for 2020 are included in the RED, ranging from 10 per cent for Malta to 49 per cent for Sweden, reflecting differing national circumstances and starting points. To monitor progress towards these 2020 targets, the RED sets out indicative trajectories for the period from 2011 to 2020. Member States also submitted National Renewables Action Plans (NREAPs) in mid-2010 which describe their own main estimated trajectory to 2020 in addition to estimated trajectories for electricity, heating and cooling, and transport.<sup>105</sup>

According to the 2017 EEA report, renewables represented 16.7 per cent of gross final consumption in 2015 and the EU was on track to meet its 2020 target.<sup>106</sup> The objective in the NREAPs was to

---

<sup>98</sup> European Commission website, National Energy Efficiency Action Plans and Annual Reports,

<https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plans>

<sup>99</sup> According to the 2017 EEA report, in 2015, ‘23 Member States had reduced or limited the increase in their primary energy consumption to below that of their linear trajectories between 2005 levels and the 2020 targets. Five Member States (Bulgaria, Estonia, France, Germany, and the Netherlands) had not achieved sufficient savings in primary energy consumption to stay below the linear trajectory level in that year. According to preliminary data from the EEA, three additional countries (Austria, Belgium, and Cyprus) would exceed their linear trajectory threshold in 2016. For final energy consumption, only 19 Member States were on or below their estimated target paths in 2015. Austria, Belgium, Bulgaria, France, Germany, Hungary, Lithuania, Malta, and Slovakia had not sufficiently reduced their final energy consumption to stay below their final energy trajectories.’

Source: European Environment Agency (2017)

<sup>100</sup> European Environment Agency (2017b), chapter 7

<sup>101</sup> European Commission (2011b), p.12

<sup>102</sup> European Commission (2011b), p.16

<sup>103</sup> European Commission (2009b)

<sup>104</sup> In November 2016, a proposal was published for a revised RED with a 27 per cent target in final energy consumption in the EU by 2030. Source: European Commission (2017b)

<sup>105</sup> European Commission website, Energy Action Plans, <https://ec.europa.eu/energy/node/71>

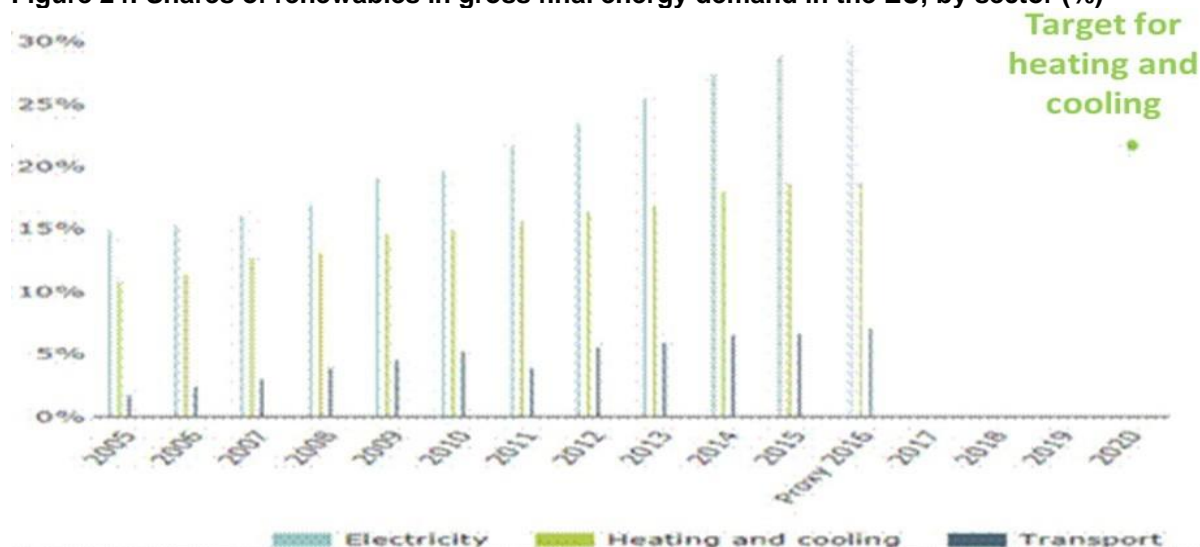
<sup>106</sup> In 2015, renewables represented 16.7 per cent of gross final consumption in 2015. All MS except three (France, Luxembourg, and the Netherlands) exceeded their indicative trajectory set in the RED for the period 2015-2016 and 11 MS exceeded their national targets for 2020 set under the RED (Bulgaria, Croatia, the Czech Republic, Denmark, Estonia, Finland, Hungary, Italy, Lithuania, Romania, and Sweden). Source: European Environment Agency (2017b), chapter 4





generate nearly 21 per cent of heating and cooling from renewables by 2020.<sup>107</sup> The RES share in heating and cooling reached 18.6 per cent in 2015. This is higher than the general share but hides more limited progress which was concentrated in the electricity sector (Figure 24). According to the EEA, the compound annual growth rate of renewables in the heating and cooling sector was 3 per cent per year between 2005 and 2014, but would need to be 4 per cent per year until 2020 in order to realise the trajectories set in the NREAPs.<sup>108</sup>

**Figure 24: Shares of renewables in gross final energy demand in the EU, by sector (%)**



Source: European Environment Agency (2017b), chapter 4

Thanks to the RED, the EU is the largest regional consumer of renewable heat in the world, which was boosted by the replacement of fossil fuel boilers with efficient renewable heating and by increasing the deployment of renewable energy in district heating and CHP, according to the IEA.<sup>109</sup> Continued growth in renewables in heating and cooling is expected across the EU, but it will not progress as fast as in the electricity sector. According to the RED, renewable energy needs to be integrated in all new or renovated buildings and the EPBD also mentions the role of renewables in the transition toward near-zero energy building (NZEB) energy performance by stating that ‘the very low amount of energy in a NZEB should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby’. From 2021 to 2030, utilities will also need to increase the renewable energy share in their energy usage for heating and cooling sales by 1 per cent per year, which is expected to sustain growth in renewable energy use in the residential (and industrial) heating.

## 4.5. The Heating and Cooling Strategy

The EPBD, the EED, and RED are part the European clean energy objective. They created a framework of policies and measures that will impact the decarbonisation of the heating and cooling sector, without focusing on it specifically. In February 2016, the heating and cooling sector became the focus of increased attention in its own right with the publication of the first EU ‘Heating and Cooling Strategy’.<sup>110</sup> The objective of this Strategy was to highlight the importance of this sector in the energy transition and the first sentence of it speaks volume: ‘Heating and cooling consume half of the

<sup>107</sup> European Commission website, National Renewable Energy Action Plans (NREAPs), <https://iet.jrc.ec.europa.eu/remea/national-renewable-energy-action-plans-nreaps>

<sup>108</sup> European Environment Agency (2017a), p.6

<sup>109</sup> IEA (2017b)

<sup>110</sup> European Commission (2016e)





EU's energy and much of it is wasted'. The strategy acknowledges that the decarbonisation of the economy and deliverance of its GHG reduction targets and commitment under the climate agreement reached at the COP21 climate conference in Paris will not happen without action on the heating and cooling sector to reduce (sharply) its energy consumption and to cut its use of fossil fuels.

The strategy covers five main areas: renovating buildings faster than just 1 per cent of the stock per year; integrating electricity systems with heating and cooling systems; increasing the share of renewables; reusing energy waste from industries; and getting consumers and industries involved via the promotion of smart systems. The decarbonisation strategy 'entails renovating the existing building stock, along with intensified efforts in energy efficiency and renewable energy, supported by decarbonised electricity and district heating'. The strategy adds an element into the mix with its support of the synergies between the heating and cooling sector and the electricity system and its encouragement to link the two sectors in the path to decarbonise the building sector. The strategy also mentions the industrial sector, which could move in the same direction of better efficiency and more renewable energy. However, it notes that 'some fossil fuel demand can be expected for very high temperature processes' which cannot be met by renewable heat alone.

According to the strategy, the technology for a more sustainable heating and cooling sector is available, and measures can be taken 'rapidly, without prior investment in new infrastructure (...), provided that (household) consumers can afford to invest or have access to the finance needed to do so.' This may be an overly optimistic vision in regard to the complexity of the market, but the strategy has the benefit of highlighting the need to focus more genuinely on the heating and cooling sector to reach 2050 targets.

## V. Overview of existing technologies

Heat is generated by converting an energy input (for instance, natural gas) to a thermal output (for instance hot water). This generation of thermal energy is done through a range of technologies from large centralised generation units such as electricity plants, CHPs and heat plants to feed district heating networks in the transformation sector, to large-scale industrial boilers and furnaces in the industrial sector and to small decentralised appliances such as boilers, heat pumps, or micro CHPS in several sectors for final energy consumption. Similarly, cooling can be produced in large chillers and heat pumps but also small decentralised technologies such as households air-conditioning units. The capacity of the heating and cooling systems ranges from several hundred MW units to 1 kW or even less.

Heat can be produced by a wide range of technologies, and for the end-user, there are many options to choose from for their heating systems, both in terms of fuel type (energy input) and the operating principle (appliances), although not all these options have the same efficiencies and not all will be available or desirable for all buildings. Figure 25 offers a summarised schematic overview of the technological options available for heating in the final energy demand sector.<sup>111 & 112</sup>

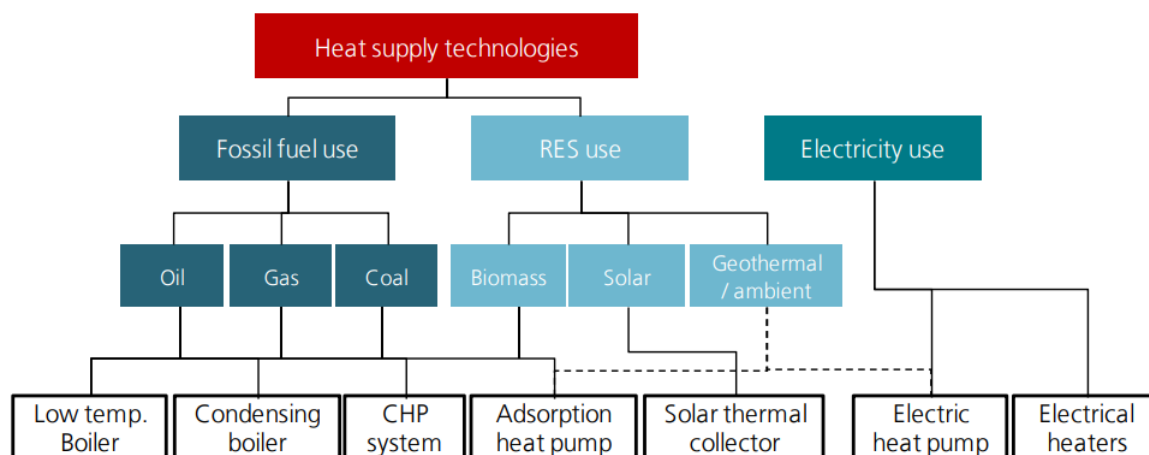
---

<sup>111</sup> For additional information, see the Association of the European Heating Industry (EHI) website, <http://www.ehi.eu/>

<sup>112</sup> As for the space cooling demand in the residential and service sectors, it is largely met by individual electrical appliances, such as air conditioners, and ventilation units or large electric chillers (heat pumps). District cooling systems also exist, especially in dense urban areas but it is very limited in Europe. Natural gas can also be used for cooling purposes via gas-fired absorption chillers and renewable options include solar absorption chilling, for example. Source: Stratego (2015).



**Figure 25: Main options to generate heating in buildings by fuel and operating system**

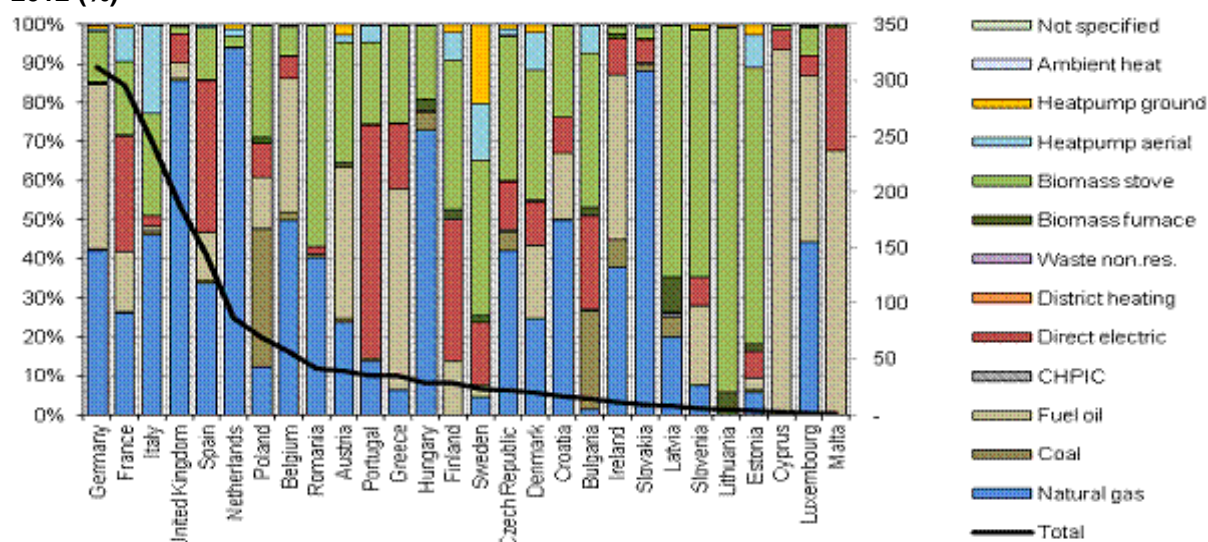


Source: European Commission (2016c), p.8

The following paragraphs focus on the technologies available for space heating in buildings, especially in the residential and service sectors.

Natural gas technologies accounted for the lion's share of installed heating capacity in Europe with 42 per cent (and 40 per cent of all installed units in buildings). The other main technologies were based on biomass (19 per cent), fuel oil (17 per cent) and direct electricity (13 per cent), while heat pumps accounted for about 6 per cent of total capacity, coal for 2 per cent and ground heat pumps for 1 per cent.<sup>113</sup> The split by country shows a wide diversity across Europe: Germany is highly dependent on natural gas and fuel oil; France relies on electric heating, natural gas, fuel oil and biomass; in Italy, natural gas technologies account for over 45 per cent of the fleet, but there is also a large share for biomass and heat pumps; the UK is highly reliant on natural gas for more than 85 per cent of its capacity and Spain use direct electricity for the largest share followed by natural gas technologies, and to a lesser extent fuel oil and biomass (Figure 26)

**Figure 26: Share of heating technologies and total installed capacity by country in the EU, 2012 (%)**



Source: European Commission (2016c), p.179

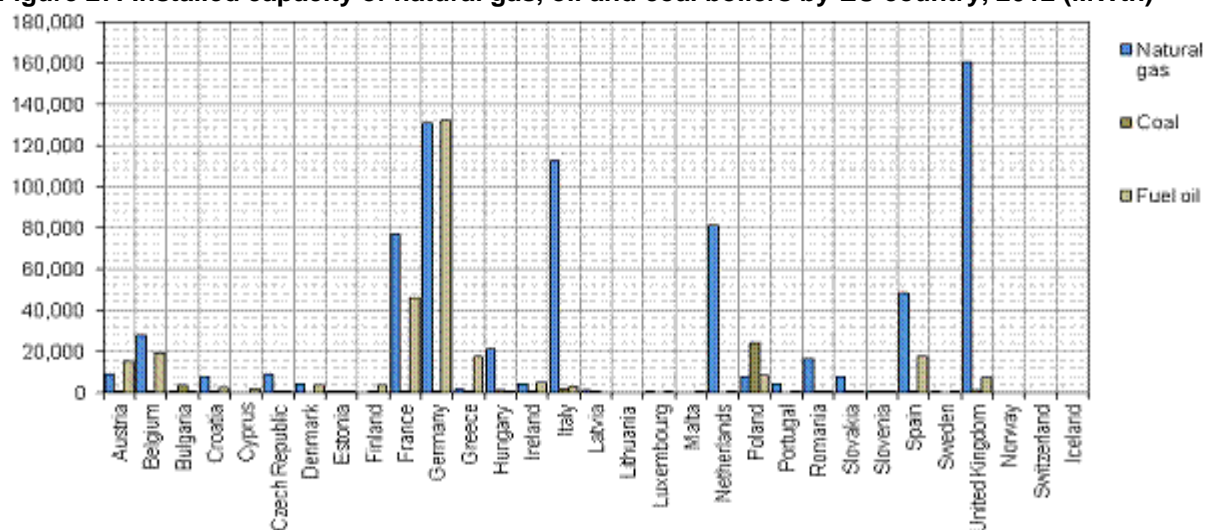
<sup>113</sup> European Commission (2016c), p.178



Total fossil fuel technologies accounted for about 61 per cent of the installed thermal capacity in 2012 and for about half of all the installed heating units.

- The UK had the largest stock of natural gas boilers in the EU (23 million) as seen in Figure 27, of which 58 per cent were high efficiency condensing boilers<sup>114</sup> and most of them (96 per cent) were small boilers below 25 kW.<sup>115</sup> The other major markets for gas boilers were Italy (16.5 million), Germany (13.1 million), and France (9.4 million). Logically, natural gas producing countries had the largest proportion of gas heating systems with about 86 per cent of installed capacity in the UK and 94 per cent in the Netherlands.
- The countries with the largest number of installed oil boilers were Germany and France (6 million or about 32 per cent of the EU, and 4.2 million or about 23 per cent).
- Coal fired boilers have largely been replaced in most European countries with the exception of Poland, which was the country with by far the largest number of coal fired boilers (2 million, or about 60 per cent of total coal boilers and a share of 36 per cent of Polish installed heating capacity).
- There are also countries using very low proportions of fossil fuel fired technologies for heating, for instance Sweden, Estonia, and Finland which have shares of installed gas, oil and coal fired technologies of 7 per cent, 10 per cent and 13 per cent respectively.<sup>116</sup>

**Figure 27: Installed capacity of natural gas, oil and coal boilers by EU country, 2012 (MWth)**



Source: European Commission (2016c), p.24

The age of the installed units of natural gas, oil and coal boilers differs. The largest share of natural gas boilers was installed after 2002, but there were still close to 30 million units that were installed before 2002, sometimes even earlier than 1992 as seen in Figure 28. For oil and coal boilers, the units were essentially older than natural gas units, reflecting the decreasing role of these boilers

<sup>114</sup> A traditional boiler burns gas, oil, or solid fuels to heat water. The hot gases produced go through a heat exchanger which transfers the heat to water, thus raising the water's temperature. Then the hot water is distributed to the whole heating system (pipes and radiators). Boilers can also be electric, in which case the boiler heats hot water used for the heating system using only electricity.

Condensing boilers are similar to traditional boilers but they are more efficient. One of the hot gases produced in a traditional boiler during the combustion process is water vapour (steam), which arises from burning the hydrogen content of the fuel. Condensing boilers also process the heat of condensation of the water vapour contained in the exhaust gas, therefore extracting additional heat from the waste gases by condensing this water vapour to liquid water. They can run on the same energy carriers as traditional boilers. Condensing boilers are easy to combine with solar thermal systems. Gas-fired condensing devices can also cope very easily with highly fluctuating requirements for heating and hot water. Most non-condensing boilers could be forced to condense through simple control changes but it would quickly destroy any mild steel or cast-iron components of a conventional high-temperature boiler due to the corrosive nature of the condensate. For this reason, most condensing boiler heat-exchangers are made from stainless steel or aluminium/silicon alloy.

<sup>115</sup> European Commission (2016c), p.16

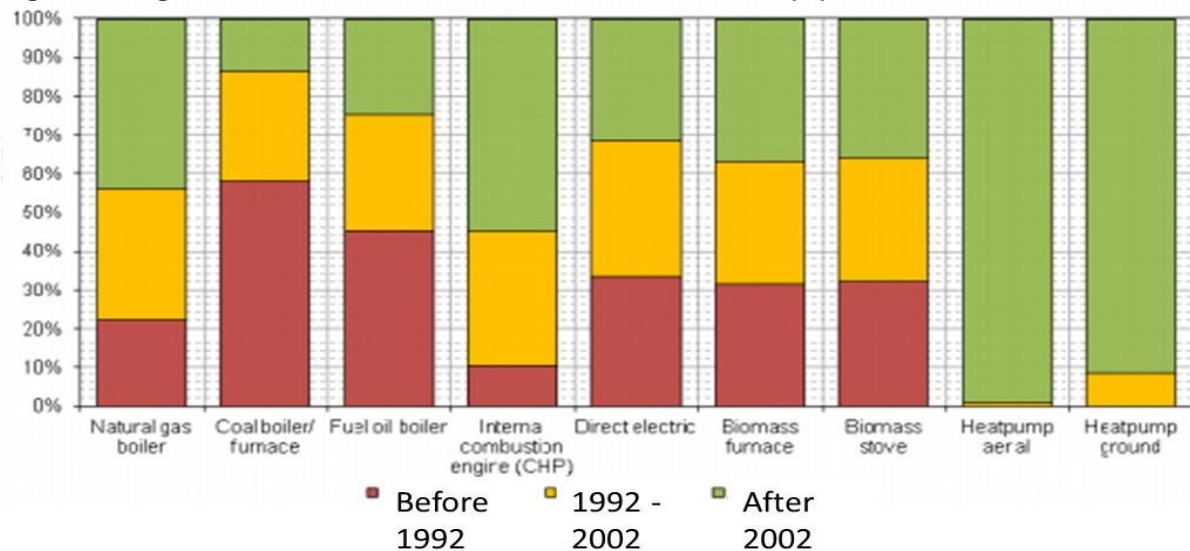
<sup>116</sup> European Commission (2016c), p.177





which are not being replaced by the same technology. The stock of coal fired boilers is particularly old in comparison, with 58 per cent of all units being installed before 1992 (and 45 per cent of all oil boilers).

**Figure 28: Age distribution of installed boilers in the EU, 2012 (%)**



Source: European Commission (2016g), p.11

CHP units produce both heat and electricity simultaneously from a single primary energy source (which can be oil, coal, natural gas, or solar for instance). This co-generation process provides synergy that improves efficiency by up to 40 per cent, reaching total efficiencies of 80-90 per cent. CHP plants are traditionally large-scale units and often used for industrial processes and district heating. However, they are also available in smaller units (5-10 KWe).<sup>117</sup> Decentralised CHP plants are not very widespread, but internal combustion engines are the commonest form of CHP technology for decentralised applications in buildings and they are mainly based on conventional gas engines. Usually, cogeneration internal combustion units (CHP-ICs) are fuelled by natural gas, but there are also engines which are fuelled by heating oil, LPG, or biogas. There is poor data availability on the use of decentralised CHP units: from the countries with available data, units installed in Germany account for 89 per cent of all units installed.<sup>118</sup> Decentralised CHP units in buildings are relatively new compared to the other fossil fuel fired heating technologies and 88 per cent of the units were installed after 2002 and less than 1 per cent before 1992.

Regarding electric heating systems, the countries with the largest installed capacity are France (about 88 MWth), Spain (57 MWth), Portugal (21 MWth), and the UK (14 MWth). Most electric heating systems were installed between 1992 and 2002 (35 per cent of installed units) and before 1992 (34 per cent of installed units).<sup>119</sup> Improved efficiencies are expected with the development of heat pumps.

<sup>117</sup> A variety of micro-CHP systems exist, including the traditional combustion ones, Stirling engines and fuel cells.

<sup>118</sup> European Commission (2016c), p.41

<sup>119</sup> European Commission (2016c), p.30

Electric radiators are inexpensive to install but can be quite expensive to run. It is also possible to have electric ('storage') radiators which heat up heat-retaining stones using overnight (cheap-rate) electricity and then the stones release the heat in the daytime when electricity would be otherwise more expensive to use. Electric heating creates peaks of electricity demand during winter times when the temperature drops, potentially posing problems for the whole grid. Production and distribution of electricity also results in high losses (up to 60 per cent). Source: Ademe website, <http://www.ademe.fr/particuliers-eco-citoyens/habitation/construire/chauffage-climatisation/chauffage-electrique>





Heat pump technologies are a relatively new technology compared to fossil fuel. They are a closed circuit of pipes that are capable of transferring calories from an outside environment to inside in order to produce heat. Heat pumps use the heat present in the air or in the ground, but need electricity to operate. A gas heat pump works on the same principle but uses gas rather than electricity as the main energy input.<sup>120</sup> The type of heat pump used is determined by the location of the house/building and what sort of plot there is.<sup>121</sup> In 2012, they represented 7 per cent of installed capacity. Heat pumps can also be operated in a reverse mode for cooling purposes, and these play a major role in southern European countries such as Italy where heat pumps represented 22 per cent of the total installed capacity.<sup>122</sup>

Biomass burning heating technologies represented about 20 per cent of the installed capacity used for heating. Countries with a very high share of biomass burning technologies in installed capacity were Estonia with 73 per cent, Latvia with 65 per cent, Slovenia with 63 per cent, and Romania with 57 per cent.<sup>123</sup>

Solar panels are systems that capture the energy from sunlight and are usually placed on rooftops. There are two types of panels: thermal solar panels and photovoltaic panels.<sup>124</sup> Small panels (less than 15 m<sup>2</sup>) in individual installations are the most common application, except in Spain where multi-family facilities have also developed solar technologies.<sup>125</sup>

There is also the option to be connected to a district heating system, whereby heat is produced centrally by one or more larger units in the form of hot water and then transported through a network of pipes to individual houses. The hot water is then used to heat the house. District heating accounts for only about 12 per cent of the total building heat market.<sup>126</sup> The largest installed capacity can be found in Poland (58GW) and in Germany (49GW) as seen in Figure 29, and the largest proportion of citizens served by district heating system can be found in Northern and Eastern European countries such as Latvia (about 65 per cent), Denmark (about 63 per cent), and Estonia (about 62 per cent). The energy source used to generate heat for district heating networks are not well known as not even the district heating associations collect it on a regular basis. Some available data for 2012 show that the main fuel was natural gas (40 per cent), followed by coal (29 per cent) and biomass (16 per cent).<sup>127</sup> District heating can also be sourced from renewable electricity (through heat pumps), geothermal and solar thermal energy, waste heat from industrial processes, and municipal waste.

---

<sup>120</sup> Gas-fired heat pumps combine high efficiency gas-fired condensing technology with environmental heat extracted from low temperature sources (air, water, ground) and upgrades it to a higher temperature and releases it where it is required for space and water heating. More technical details see the Association of the European Heating Industry (EHI) website, <http://www.ehi.eu/>

<sup>121</sup> When a heat pump uses the ground as an energy source to generate heat in a building, it is said to be 'geothermal'. They are amongst the most efficient devices for heating, cooling, and hot water use (typically well over 100 per cent), but the pipes need space. For heat pumps that capture heat in the ground, pipes are laid out underground (60-120 cm deep) horizontally or vertically (up to 50 metres deep) and captors need to cover 1.5 to 2 times the area to be heated. For more technical details, see Ademe website, <http://www.ademe.fr/particuliers-eco-citoyens/habitation/construire/chauffage-climatisation/pompes-a-chaaleur>

<sup>122</sup> Cooling devices are aerothermal reversible heat pumps mainly used for air-conditioning/cooling, especially in countries with a warm climate and high cooling demand. Note that in some national statistics, heat pumps used for cooling are counted as heat pumps and sometimes they are not. In Italy for instance, if heat pumps used to generate cooling are counted, there were 15 million heat pumps in 2012 but, but if only the heat pumps used for heating are counted, the number was down to only 1 million. Source: European Commission (2016c), p.177

<sup>123</sup> European Commission (2016c), p.177

<sup>124</sup> Thermal solar panels convert solar energy into thermal energy (heat), and use it to heat up water for use in the home. Their efficiency is around 80 per cent. Solar panels use the light of the sun, therefore even on cloudy days, they are still able to capture some form of energy but any shade on the panels at any time of day will reduce their performance. Photovoltaic solar panels (PV) convert solar energy into electrical energy (continued current goes through a convertor to become alternative current). This electricity can be used in any household electrical appliances, including for space heating, water heating, or for cooling purposes in air conditioning units. In case of surplus, the electricity can be re-injected in the distribution grid. PVs efficiency is around 15%. For more information, see Federal Public Service, Health, Food chain safety and environment website, <https://www.health.belgium.be/en/which-are-alternative-heating-techniques>

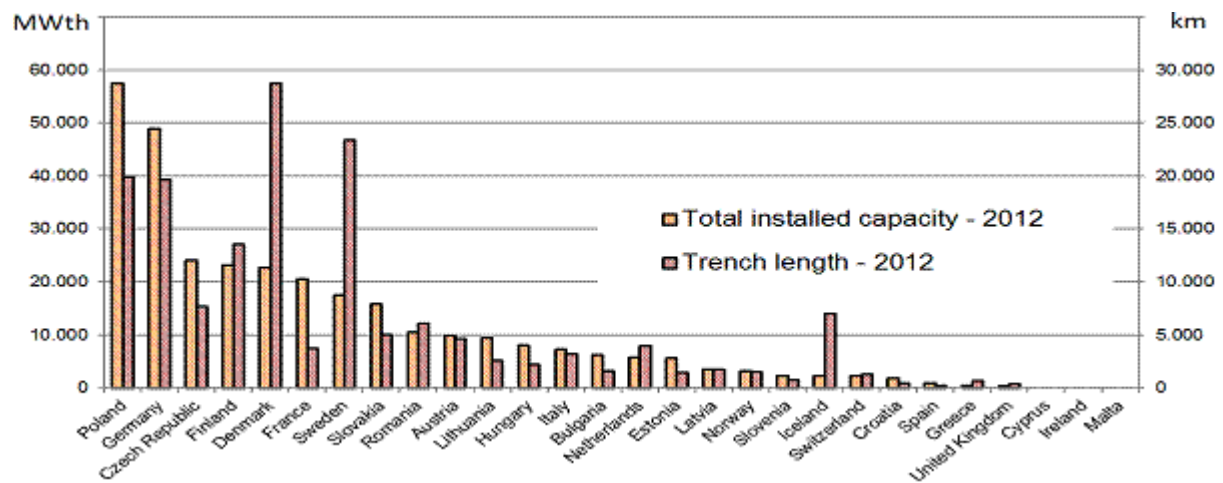
<sup>125</sup> In the 2000s, Spanish law made solar thermal energy mandatory in all new multi-family constructions. Source : European Commission (2016c), p.59

<sup>126</sup> Stratego, Enhanced heating and cooling plans (2015), p.4

<sup>127</sup> European Commission (2016e), p.8



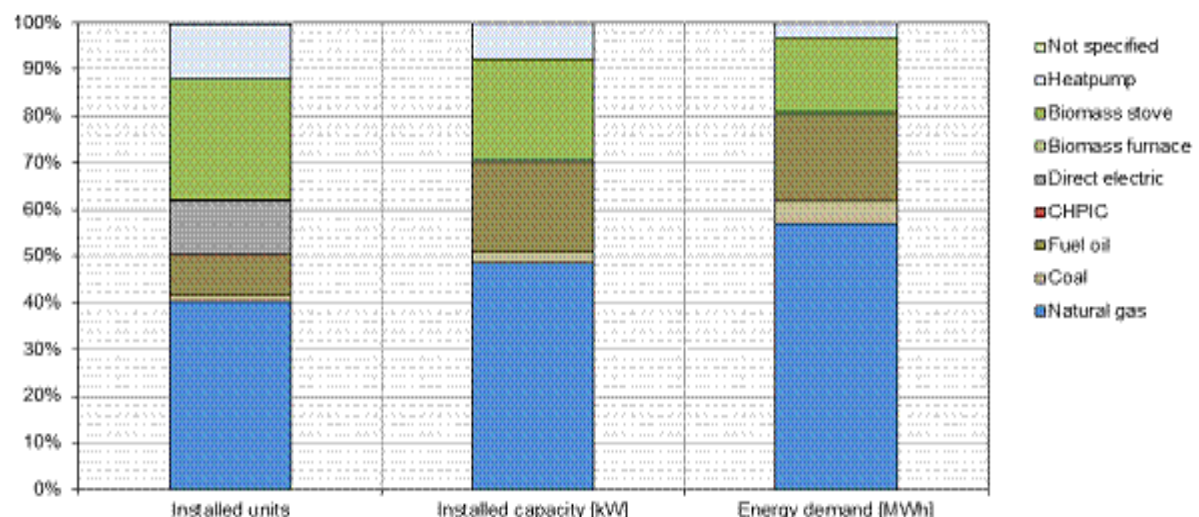
**Figure 29: District heating: installed thermal capacity and trench length in the EU, 2012 (MWth and km)**



Source: European Commission (2016c), p.161

One remark regarding the available technologies in 2012 and their corresponding share in the energy demand: fossil technologies tend to have a higher capacity per unit than the average of all technologies, and they also tend to have more operating hours per year than the average as seen in Figure 30. In a similar way to the electricity generation sector, the replacement of fossil fuel technology, especially natural gas in the case of heating, will be conditional on technological improvements.

**Figure 30: Share of heating technologies (units and capacity) and demand related to final energy carriers in the EU, 2012 (%)**



Source: European Commission (2016c)

The energy sources and the technologies used to generate heat show wide differences across Europe. Natural gas technologies are predominant and comparatively newer, and therefore on average more efficient, than other fossil fuel technologies. Other options already exist, such as CHPs, electric heating, heat pumps, renewable heat and district heating. In order to decarbonise the heating (and cooling) sector, dramatic changes will need to happen, but the implementation of low-carbon options faces critical energy challenges with few simple answers as heating demand is diverse, varying by building type, location, connections, and fuel availability.



## VI. Options to decarbonise the heating and cooling sector

Thanks to the introduction of fuels such as natural gas into the heating system, many changes have already happened in a generation on how consumers acquire heat, on the level of comfort, and the quality of air expected, but evolution is slow and the heating sector depends on long innovation cycles. The following paragraphs tentatively group the options under four headings, following the EU main policies and regulation: efficiency improvements, raising the renewable share, electrification of the sector, and the development of heat networks.

### 6.1. Improving efficiency and energy savings

Better insulation in existing houses will improve energy demand in buildings, and cutting down on the need for heating and cooling will help meet emissions targets. For instance, in Denmark, energy demand for a typical 100 m<sup>2</sup> existing building is approximately 175 kilowatt hour per square metre (kWh/m<sup>2</sup>) per year. For new builds, because of planned insulation regulations, demand is expected to fall to 22 kWh/m<sup>2</sup> per year by 2020, a drop of almost 90 per cent.<sup>128</sup> In new houses built to the passive house standard, energy demand for heat could in theory be reduced to close to zero.

#### 6.1.1. Upgrade boilers

Demand reduction via higher efficiency for appliances or energy savings measures is another obvious starting point. There are about 132 million boilers in residential buildings in the EU according to the EU's 2016 heating and cooling strategy, of which 22 per cent of gas boilers, 34 per cent of electric heaters, 47 per cent of oil boilers and 58 per cent of coal boilers were older than their technical life in 2012. Energy can be saved by upgrading these equipments to more efficient ones. Upgrading existing boilers to newer version has a limited disruption to consumers and is likely to see more public and political acceptability than drastic changes to alternative technologies, and would still reduce energy demand in space heating.

One example can be seen in the Netherlands, where condensing gas boilers are already the prevailing technology thanks to large-scale replacement since the early 1980s. Where conventional boilers had a typical efficiency of about 70-80 per cent, typical condensing boilers offer efficiencies of 90 per cent (or even higher depending on the temperature of the water returning to the boiler).<sup>129</sup> Since the replacement of old boilers by new condensing gas boilers, Dutch gas demand for space heating in buildings has become at least 50 per cent more efficient, half of which was attributed to the upgrades (the rest coming from better insulation).<sup>130</sup>

#### 6.1.2. Develop micro CHP (mCHP) and fuel cells technology

In fuel cells, electricity and heat are produced through an electrochemical reaction between the fuel and oxygen used. Both hydrogen and oxygen are needed for the reaction but each can come from a different source, for example hydrogen reformation from natural gas and oxygen from the ambient air. Fuel cell CHPs can be supplied with different fuels and the environmental impact mainly depends on the fuel used for the production of hydrogen. If natural gas is used, they can be easily connected to existing gas grids. There are many types of fuel cells and even if the primary energy is a fossil fuel, the technology is still considered to be a 'low carbon technology' because it can be more efficient than just burning a fossil fuel for heat and getting electricity from the national grid. Fuel cells have a thermal efficiency of 50–60 per cent and an electrical efficiency of 35–40 per cent. In the coming

---

<sup>128</sup> Eurogas (2014)

<sup>129</sup> IEA (2017c), p.1.19

<sup>130</sup> Lankhorst G. (2014)





years overall efficiencies of 95–102 per cent are expected.<sup>131</sup> Fuel cells are not widespread in Europe and only demonstration plants have been installed.

### 6.1.3. Switch to other forms of heating and cooling systems

Another option is to shift to a new energy carrier, but this would mostly be an option for new builds or for buildings undergoing extensive refurbishment. The Stratego reports<sup>132</sup> offer average conversion efficiency as seen in Table 3. The actual numbers will depend on specific pieces of equipment, and although there are major differences between fuels the efficiency ratings for renewable energies are among the highest ones.

**Table 3: Average conversion efficiencies in local boilers and electrical appliances**

Fuel supply sources and energy carriers	Average conversion efficiency
Coal and coal products	65%
Peat	60%
Crude, NGL and feedstocks	80%
Oil products	80%
Natural gas	85%
Geothermal	100%
Solar/wind/other	100%
Biofuels and waste	65%
Heat (district heat)	100%
Electricity for heat pumps (residential)	300%
Electricity for resistance heaters (residential)	100%

Source: Stratego, Enhanced heating and cooling plans (2015), p.5

Some countries are still considering natural gas heating systems as part of their decarbonisation strategies. For instance, a study carried out on behalf of the Spanish national association for gas, Sedigas, showed that GHG emissions could be reduced dramatically by switching the 50.2 TWh of oil used for heating in Spain to condensing gas boilers (-25 per cent of carbon dioxide and nitrogen oxides, -64 per cent carbon monoxide, -90 per cent sulphur oxides and -95 per cent particulate matter). This would cover about two million customers.<sup>133</sup> Similar research was done in France on actual conversions from fuel oil to natural gas in various sectors including chemical-petrochemical, food, and urban space heating. The results show an effective reduction in GHG emissions as seen in Figure 31 while natural gas demand increased by 4.2 TWh (about 4 bcm) in 2016 as a result of these conversions.

Natural gas heating systems have already improved and innovation could continue to make natural gas an option for the heating sector. For instance, in the 1980s, standard boilers produced 0.75 kWh of heat from 1 kWh of natural gas. The same amount of natural gas produced 1 kWh of heat via condensing boilers from the 1990s, and modern heat pumps would produce about 1.3 kWh of heat for the same natural gas input, an improvement of about 70 per cent of heat produced from natural gas in roughly a generation.<sup>134</sup>

<sup>131</sup> European Commission (2016c), p.40

<sup>132</sup> Stratego, Enhanced heating and cooling plans (2015), p.5

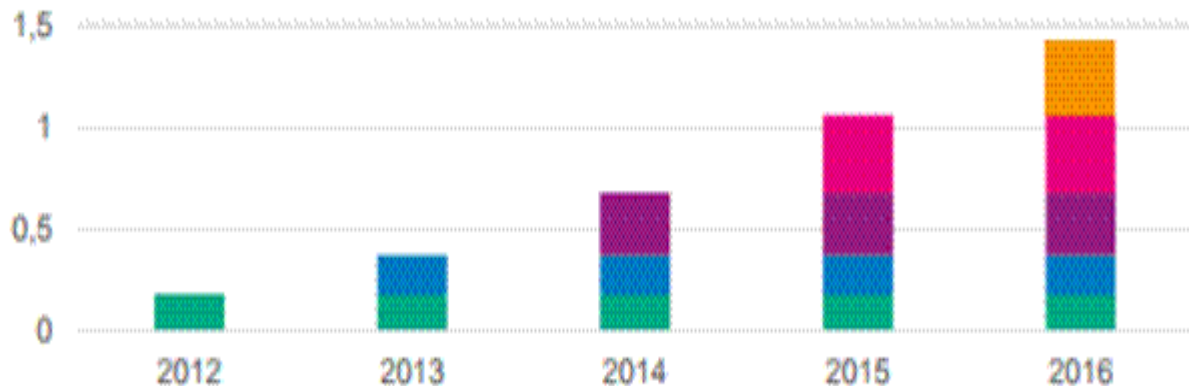
<sup>133</sup> Gella A. (2017)

<sup>134</sup> Blakey S. (2013)





**Figure 31: CO<sub>2</sub> emissions avoided due to fuel-oil to natural gas conversions in France (mt)**



Source: GRTGaz (2017)

## 6.2. Increasing the share of renewables

According to the EEA, the additional use of renewable energy helped the EU to cut its demand for fossil fuels by 116 Mtoe between 2005 and 2013. The biggest improvement was seen in electricity generation (71 per cent) but changes were also evident in the heating and cooling sector (19 per cent). The fossil fuels that were replaced were essentially coal (47 per cent) and natural gas (30 per cent).<sup>135</sup>

Renewable energies for heating (and cooling) are developing. They can be used instead of traditional systems or in conjunction with them. In its 2017 report on renewables, the IEA expected the EU's consumption for renewable heat to increase by 18 per cent over the 2016 to 2022 period with buildings accounting for the majority of this growth.<sup>136</sup>

### 6.2.1. Replacing fossil fuels with renewables

Renewable heat provides solutions for decarbonising the heat demand that remains after energy efficiency improvements. There are many renewable technologies available for space heating (industrial demand for process heat is limited to low temperatures uses). Renewable heat technologies include bio-energy (such as biomass boilers for residential and service buildings, district heating, CHPs, and industry process heat), solar thermal (used for water heating, some space heating in buildings, in district heating systems, and for low-temperature process heat in the industry), geothermal (for direct use of heat in district heating systems, residential and public buildings, or in industry) and heat pumps (residential, commercial, industrial, and district heating uses). Note that heat pumps are not renewable energy per se, but they are often classified as such because the energy input is essentially solar heat stored in the air and ground in addition to electricity (or natural gas) and it is highly efficient.

### 6.2.2. Hybrid systems

A way to increase the share of renewables is to install a hybrid heating system. This is the combination of different but complementary heating solutions. For instance, a gas-condensing boiler and an electric heat pump work well together: when the outdoor temperature gets cooler and less heat is available from the air, ground, or ground water, the gas-condensing boiler provides the heat. This system allows different energy carriers to work together in order to provide heating and cooling in

<sup>135</sup> European Environment Agency (2015)

<sup>136</sup> IEA (2017b)



buildings. Eurogas notes that gas appliances such as condensing boilers, heat pumps, mCHPs, and hybrid options can partner with many renewable systems to produce heat as seen in Figure 32.

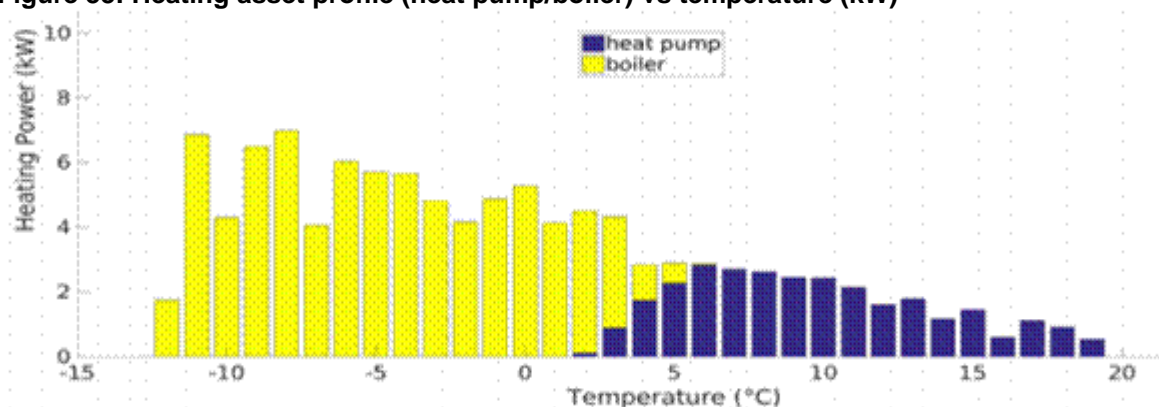
**Figure 32: Heating technologies and available options for partnerships**

Energy	Means of heat creation	Potential partners					
		Bio-methane	Solar	Biomass	Heat from air	Heat from water	Electric
Gas	Condensing boiler	x	x	x			
	Heat pump	x	x		x	x	
	Micro CHP	x	x				x
	Hybrid	x	x		x	x	x
Oil	Condensing boiler		x	x			
	Hybrid		x		x	x	x
Solar	Solar panel						
Solid fuel (coal, pellets, woodchips)	Boiler		x	x			
Electric	Heat pump		x		x	x	
	Radiators		x				
	Electric boiler		x				

Source: Eurogas (2014)

Combining a gas heating system and a heat pump will maintain some gas demand but at a fairly low level as the gas boiler may only function around 25 per cent of the time, while the heat pump delivers in effect the majority of the energy requirements during spring, summer, and autumn (as seen in the example shows in Figure 33). This would translate into a drop in gas demand of 75 per cent compared to a single condensing boiler system. Gas demand will also be more volatile as the gas boiler will only be called on when outdoor temperatures fall below a certain point. Interestingly, the gas boiler does not need to run on natural gas: an alternative solution has even been developed in the Netherlands combining a hybrid heat pump with green gas in more than 100 homes in the municipality of Winsum.<sup>137</sup>

**Figure 33: Heating asset profile (heat pump/boiler) vs temperature (kW)**



Source: Lancaster O. (2017)

<sup>137</sup> For more information, see Gasterra website, Gas only supplied 'by design', <https://www.gasterra.nl/en/news/gas-only-supplied-by-design>



### 6.2.3. Repurpose the gas network for green gas

Green gas is another way to increase the share of renewables in the heating and cooling sector. Most natural gas networks could be used to carry low carbon gases such as biomethane, synthetic natural gas, or hydrogen (although the latter requires the upgrade of heating appliances with hydrogen compatible models). Transporting green gas via the natural gas networks would make good use of existing infrastructure (over 2.2 million kilometres of pipelines in Europe that connect large geographical areas and a significant share of the population, up to 98 per cent in the Netherlands or 97 per cent in the UK) and avoid stranded assets.

The production of biomethane is still limited in Europe at about 2 bcm (which would be enough to supply gas to heat the equivalent of approximately 600 000 households), but its production and use continue to expand, with in excess of 450 plants in operation in 2015.<sup>138</sup> In France for instance, 215 GWh of biomethane was injected into the grid in 2016, which was 2.5 times more than in 2015.<sup>139</sup>

Hydrogen may be another option to decarbonise the heat sector. How much, how quickly and at what cost hydrogen could be blended into the natural gas network(s) is still unknown and answers to these questions will most likely depend on the special characteristics of each market (for example, the nature of the pipes). Steam methane reforming is already widely used in the industrial sector but combined capture and storage (CCS) technology is needed to remove emissions, while electrolysis (power to gas) produces far less CO<sub>2</sub> emissions with the added bonus of offering a possible solution to renewables intermittency by allowing renewable energy to be stored and later used for heating homes in a potentially very efficient way (an installation in Germany showed a system efficiency of 86 per cent with heat recovery).<sup>140</sup> Regulations place a limit on the share of hydrogen allowed in the network, for instance, in the UK, Italy, Belgium and Sweden, it corresponds to 1.5 per cent of the volume, in Czech Republic, 2 per cent, Switzerland and Austria 4 per cent, Spain 5 per cent, France 6 per cent, Germany 10 per cent and in the Netherlands 12 per cent,<sup>141</sup> but potentially up to 20 per cent may be possible, before a full conversion of networks to hydrogen.<sup>142</sup> The UK is an interesting case study because the infrastructure configuration needed to support the conversion of gas to hydrogen may be favourable and may be among the least cost options for decarbonising heat (see the accompanying paper by M. Keay).

## 6.3. Electrification of the heating sector

The European Commission recognised in its Energy Roadmap 2050 that there was a need for an integrated approach between the decarbonisation of heating and the availability of a decarbonised electricity supply. The logic is that electricity, given its high efficiency and emissions free nature (at use), could make major contributions to decarbonisation scenarios, reaching a 36-39 per cent share in 2050 (almost doubling from the 2012 level and becoming the most important final energy source), although this would require an almost carbon free electricity sector in the EU, and around 60 per cent CO<sub>2</sub> reductions by 2030.<sup>143</sup>

The trend towards electrification essentially means the further development of highly efficient heat pumps. However, even with this technology, some seasonality of power demand for heating is to be expected. Supplying heat solely with electricity would be challenging and would place a significant strain on electricity networks due to the amount of energy that would be required but also due to the seasonal variation in demand if the heat load was transferred to the electrical network. For instance,

---

<sup>138</sup> IEA (2017b)

<sup>139</sup> GRTGaz (2017)

<sup>140</sup> For more information, see Regan N. (2015)

<sup>141</sup> Presentation by Cadent at the Oxford Institute for Energy Studies, 5 March 2018

<sup>142</sup> Stern J. (2017)

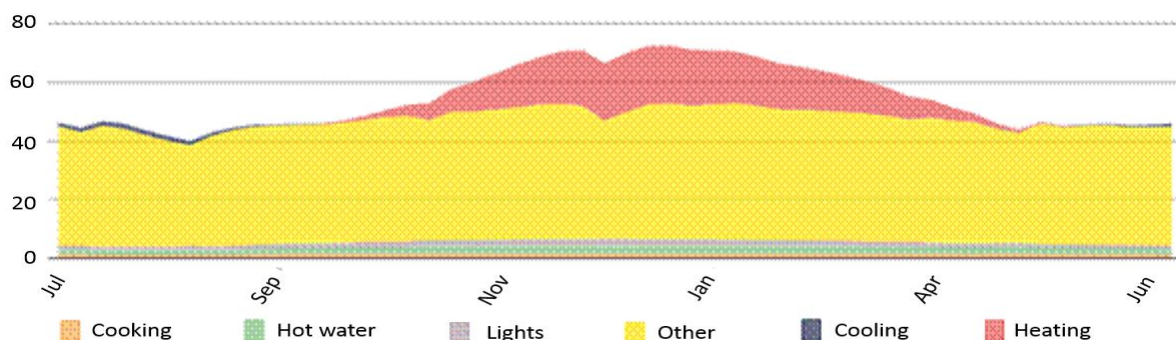
<sup>143</sup> European Commission (2011a), p.3





total German heat consumption is estimated to be three times that of electricity demand,<sup>144</sup> and in the UK, it is more than double electricity demand.<sup>145</sup> A report by the Energy and Climate Change Committee showed that “*electrifying heat completely would add 300 GW to peak electricity demand, a roughly five-fold increase from current levels*”.<sup>146</sup> The report also mentions the impossibility to deliver the same ramp up rate that consumers are used to through gas central heating from electricity. In France, the second largest electricity market after Germany, the heavy reliance on (direct) electric heating creates challenges during winter times when heating demand rises as seen in Figure 34.<sup>147</sup>

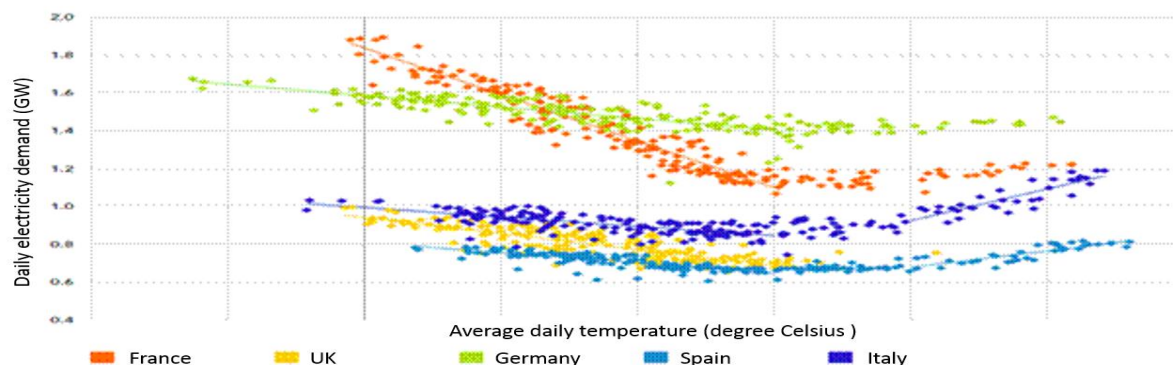
**Figure 34: Thermo-sensitivity of electricity generation in France by end-use, July 2015-June 2016 (GW)**



Source: RTE (2016a)

RTE, the French Transmission System Operator, notes that for each degree Celsius below average temperatures, electricity demand rises by almost 2000 MW. This figure is three times the amount observed in the UK (800 MW/°C) and nearly four times that seen in Spain (550 MW/°C). As a result, electricity generation in France is highly thermo-sensitive as seen in Figure 35.<sup>148</sup>

**Figure 35: Thermo-sensitivity of electricity generation in selected EU countries, July 2015-June 2016 (GW)**



Source: RTE (2016b)

<sup>144</sup> Argus News & Analysis, 22 September 2017, German housing energy transition 'no rocket science', <https://direct.argusmedia.com/newsandanalysis/article/1539722?keywords=germany%20heat>

<sup>145</sup> For more information, see Oxford Energy (2016)

<sup>146</sup> Energy and Climate Change Committee (2016), p.17

<sup>147</sup> A split by sector shows that the residential demand (and to a lesser extent service sector demand) is the one driving the winter rise, while industry demand remains flat throughout the year. Source: RTE (2016a)

<sup>148</sup> Natural gas demand is also thermo-sensitive, and for each degree Celsius below average temperatures in winter, additional demand in France rises by 5400 MW. Residential heating is responsible for about two thirds of gas thermo-sensitivity and about half of electricity thermo-sensitivity (industry, tertiary and mobile electric heaters represent the other half). French electricity demand also shows a thermo-sensitivity in the summer (+400MW for each degree Celsius above average temperatures), and other countries in Southern Europe, such as Italy and Spain, present even larger variations. Source: Carbone 4 website, Tensions Sur Les Énergies De Réseau Lors De La Pointe De Consommation Hivernale, <http://www.carbone4.com/tensions-sur-les-energies-de-reseau-lors-de-la-pointe-de-consommation-hivernale/>





## 6.4. Expand heat networks

A district heating network is a network of insulated pipes used to deliver heat, in the form of hot water or steam, from the point of generation to the end user. They were essentially developed across Europe during the post war period and remained popular on the continent in places such as Germany, Scandinavia, and much of Eastern Europe. The number of district heating systems in the EU is close to 3500 but they only account for about 12 per cent of the heating sector.<sup>149</sup>

District heating networks are an efficient way to produce heat: instead of having natural gas distributed to each individual boiler in households, a larger boiler produces hot water that is then distributed via heating pipes. District heating does not favour one fuel over another, but it is considered to be an option which could decarbonise the heating (or cooling) sector due to its higher efficiency (compared to individual boilers) and it is also a facilitator for the consumption of biomass and waste fuels.

As for the electrification option, extensive infrastructure of pipes under town and cities would be needed. It would need to be combined with heat generated from solar thermal energy plants, wind turbines, and conventional gas and coal power stations. In addition, it would also be necessary to capture and redistribute heat that would otherwise be wasted (such as waste heat from factories, incinerators, and transport systems). The main drawbacks include the comparatively high running costs, investment costs, and losses in the distribution system. For instance, heat losses of up to 30 per cent may occur in distribution networks with low consumer energy density, while in energy dense areas with pre-insulated pipes, the losses may be less than 3 per cent. Denmark is one of the countries where transportation losses are relatively high (in the range of 15-20 per cent) because the district heating network there is spread across areas with low housing density.<sup>150</sup>

All these options, and others to be developed in the future, will help to decarbonise the heating (or cooling) sector, but as shown in this section, there is no one-size-fits-all approach and there is no one solution better than another. It is likely that a combination of various options to decarbonise heat will be less risky and potentially lower cost. In addition, while measures improving efficiency can be implemented pretty much everywhere, other options may be constrained by local specificities, for instance, district heating are better suited for dense urban areas while heat pumps would be easier to develop in rural zones. While the EU and governments will provide the main framework (objectives, policies, and targets), it will be down to regions or localities to design the path to decarbonise heat depending on local specificities, on the type of decarbonised energy they prefer, and on their ability and willingness to pay. But the task ahead is massive, politically sensitive, and not without challenges.

## VII. Main challenges to decarbonising buildings and process heat

Delivering the EU's clean energy targets will need to cover the heating and cooling sector, otherwise, objectives will be missed but it will be a major challenge. The objective of this section is not enter into technical / economical / political / regulatory details about the challenges ahead, as this will need to be looked at and analyzed in separate papers, but rather to highlight some of the main hurdles to decarbonise heat, essentially in the building sector and for process heat, which are the largest gas consumers.

---

<sup>149</sup> Seppänen S. and Magnusson R. (2015)

<sup>150</sup> European Commission (2016c), p.152



## 7.1. Diversity and number of stakeholders involved

The heating and cooling sector constitutes a large number and diversity of actors and technological options. This is explained by the fact that thermal energy cannot be transported economically over long distances (roughly over 40 km<sup>151</sup>), so it needs to be produced and consumed locally. As a result, the sector is a decentralised and fragmented market that covers half of the EU's final energy demand.

Policies will need to focus on the specificities of every agent and be tailor-made for the end-use of heating and cooling. For instance in the space heating sector, which is the largest user, different forms of building ownership will involve different measures to drive energy-efficient renovation. In privately owned residential buildings, which represent about 70 per cent of the European population, the main barriers are likely to be incentives (for instance to incentivise owners to pay for renovation if the tenants are the ones paying for energy consumption), tenancy rules (some countries allow for higher rents if efficiency improvements are carried on), and other financial aspects.<sup>152</sup> As for public buildings (social housing, schools, universities, and hospitals for instance), shortage of funds is traditionally the main obstacle in otherwise often energy intensive buildings. The service sector (banks, offices, and shops) represents about 25 per cent of the building stock, and the European Commission reckons that energy demand is typically 40 per cent more than in the residential buildings, especially for electricity.<sup>153</sup>

The lack of proper statistical data is one example that proves how difficult it is to deal with this sector. Adequate planning and policy will be needed but implementing decarbonisation measures will be challenging and complex.

## 7.2. Consumers' investment cycle and disruption

Heating systems last generally for 20 or even 30 years, and household equipment is typically kept past its expected useful lifetime or until it breaks down.<sup>154</sup> Then, the decision on the replacement may not solely be based on costs as other factors such as geographical area, building ownership, type of building (new or old), the climate, access to various types of energy, and familiarity with the associated technologies will also play a role.<sup>155</sup>

All the measures concerning renovation, replacement, or the new-build market require knowledge of the future benefits, advice on the technical possibilities, and financial commitments, but one should also not underestimate also the physical disruption involved in upgrading a heating and cooling system. This ranges from just replacing a gas boiler to installing heat pumps in the garden at the household level, and from building underground heat networks to upgrading low voltage electricity networks at the regional and national level.<sup>156</sup> These disruptions will play an important role and are likely to trigger some resistance, even if financial measures may make switching to new technologies more attractive.<sup>157</sup>

## 7.3. Decarbonising heat will come at a cost

It is not just the organisation of and options to decarbonise the heating and cooling sector that will be a challenge. The cost of decarbonisation will also be a major hurdle. Figure 36 below provides an

---

<sup>151</sup> European Commission (2016b), p.3

<sup>152</sup> European Commission (2016e), p.4

<sup>153</sup> This sector also consumes most of the energy used for space cooling (supermarkets, data centres), although this is still a very small share of total demand. Source: European Commission (2016e), p.5

<sup>154</sup> European Commission (2016e), p.6

<sup>155</sup> IEA (2016), p.221

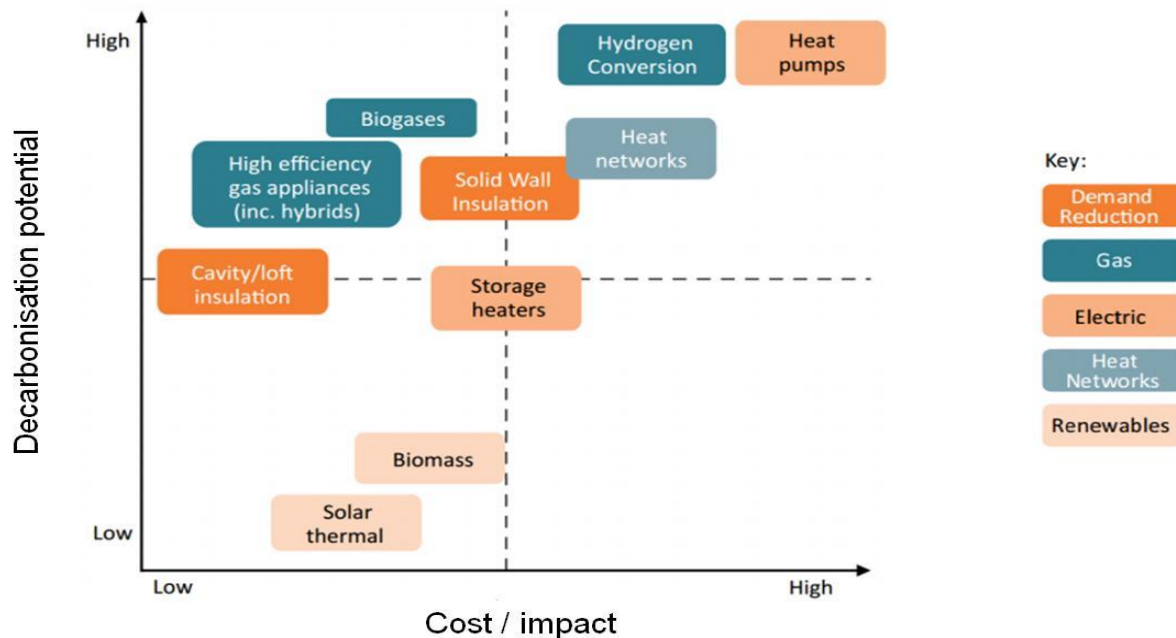
<sup>156</sup> Oxford Energy (2016)

<sup>157</sup> Eurogas, (2014)



overview of the potential and costs for low carbon heating options. It is interesting to note that high efficiency gas appliances, including hybrids, and biogases are among the least cost options but with a high decarbonisation potential. However, aside from the gas industry, they don't seem to have been the focus of low-carbon scenarios, which tend to favour electrification and non-green gas renewables.

**Figure 36: Low carbon heating options: decarbonisation potential vs costs**



Source: Imperial (2016)

More renewables in the heating and cooling sector will also require more storage and innovation measures.<sup>158</sup> Several Member States have put in place various instruments to support renewable growth in their economy, especially in the heating and cooling sector as capital costs are often higher than for fossil fuel alternatives<sup>159</sup> (but operational costs are generally lower). These measures include carbon taxation, fiscal incentives, renewable district heating, and requirements for renewable heat in building standards. The IEA reckons that several renewable heat technologies are cost-competitive with fossil fuel alternatives, and gives the examples of solar thermal systems in hot climates and wood pellet boilers in Austria and Scandinavia. But at times of cheaper fossil fuels as seen since 2015, longer payback periods are needed and the financial attractiveness of renewable systems is diminished.<sup>160</sup>

Whichever the technological option(s) chosen, large scale upfront investment in new infrastructure will be needed, at the national, regional, local, and even household level. It is unlikely that existing market structures alone will provide the necessary trigger to deliver the necessary investments and innovation needed. If one chooses to update the gas grid to include more green gas for instance, where does one start? And if it happens by region, how will residents be protected from comparatively higher costs?<sup>161</sup> Additionally, other factors will influence the decarbonisation pathway. For instance, a study showed that the low carbon hydrogen option was the lowest cost option for the UK,<sup>162</sup> but it

<sup>158</sup> For more information, see Agentur für Erneuerbare Energien website, Dossier Warmespeicher, <https://www.unendlich-viel-energie.de/mediathek/grafiken/grafik-dossier-warmespeicher>

<sup>159</sup> Higher initial investment costs can be due to the larger size and engineering complexity of biomass heating systems and cost of ground loops and low-temperature heat distribution systems for GSHP technologies.

<sup>160</sup> IEA (2016), p.221

<sup>161</sup> Oxford Energy (2016)

<sup>162</sup> Cumulative additional cost vs status quo to 2050 at maximum deployment: £130 billion for the hydrogen option vs £270 bln for electrification with heat pumps, £190 bln for electrification with 'direct electric' and £180 bln for the hybrid gas-electric option. Source: Element Energy & E4tech (2018), p.8



also noted that it was also a more uncertain option compared with electrification and hybrid options as “the safe delivery of hydrogen to millions of buildings remains, as yet, unproven”.<sup>163</sup> The need for carbon capture and storage (CCS) for this option also add time and cost uncertainty. Finally the study notes that this option would require, as well, the highest level of state intervention and planning to be deployed.

## 7.4. How to choose a heating (cooling) system?

### 7.4.1. No “one size fits all” option

The choice of a specific fuel or technology and the efficiency of a heating system varies widely across Europe, and even at the national and local level. It is dependent on a series of factors, among which climate is an important one. Colder climates and longer winter seasons influence the heat demand itself as well as the number of days per year during which heating is needed. For instance, a typical northern European household will require over eight times more heat in January than in August, although the levels of building insulation will also impact building heat demands.<sup>164</sup> As a result, heat pumps are generally more popular in countries with a mild climate while district heating systems are widespread in countries with colder temperatures such as in Denmark where district heating covers over 60 per cent of homes with that number rising to 95 per cent in Copenhagen.<sup>165</sup> The type and use of buildings also influence the choice of a heating system (single or multiple family houses, apartment buildings, space for offices), in addition to its positioning (facade orientation – and roof area - in the case of solar panels), its surface and location in the choice of geothermal systems and of course, also its connection: oil (or stand alone renewables) may be the only alternative if the property has no connection to the gas grid or alternative services.

### 7.4.2. Renovation of the existing building stock

The characteristics of existing buildings influence the range of efficient technological options. According to the European Commission, two thirds of the building stock was built when energy efficiency requirements were limited or non-existent and most of these buildings will still be in use by 2050.<sup>166</sup> Simple actions such as insulating the attic, walls and foundations, and installing double or triple glazing would trigger energy savings. As for appliances, about 80 per cent of the boiler market goes on replacing existing boilers while only 20 per cent involves the installation of appliances in new buildings.<sup>167</sup>

The age of the building stock also influences its heating demand. More than a third of buildings still in use in Europe were built more than 50 years ago (although some are much older), well before any energy efficiency performance standards were adopted, and only a small proportion of these have undergone major energy renovation. Ninety per cent of today’s homes are expected to still be in use in 2050. There are 132 million boilers installed in buildings across the EU and almost half of these are inefficient boilers, which were installed before 1992 with efficiency of 60 per cent or less; and of the fifty five million gas boilers installed in the EU, the European Commission estimates that 22 per cent are inefficient.<sup>168</sup>

More efficient buildings and heating systems will have an impact on gas demand. For instance, the International Energy Agency (IEA) notes that between 2000 and 2015, the amount of gas needed for space heating per unit of floor area fell by 44 per cent in Germany, saving 11.5 bcm, and by 28 per

---

<sup>163</sup> Element Energy & E4tech (2018), p.9

<sup>164</sup> Regan N. (2015)

<sup>165</sup> For more information, see Renewable energy focus.com website, District heating: A real alternative?, <http://www.renewableenergyfocus.com/view/42569/district-heating-a-real-alternative/>

<sup>166</sup> European Commission (2016e), p.4

<sup>167</sup> Eurogas (2014)

<sup>168</sup> European Commission (2016e), p.6





cent in the UK saving 7.5 bcm.<sup>169</sup> The report also shows that energy efficiency improvements in space heating helped mitigate seasonal peaks in gas demand. In Germany, for example, the energy intensity of residential space heating improved by 35 per cent between 2000 and 2012, while industry improved by 10 per cent and residential cooking by 6 per cent, which resulted in a reduction in daily peak demand in 2012 of almost 30 per cent.<sup>170</sup>

Energy use per square metre has decreased steadily in most countries since 2000 (-12 per cent), but this energy efficiency improvement was partially offset by an increase in population and dwelling size.<sup>171</sup> The Stratego reports note these factors will increase the need for electrical appliances. These will be more efficient than in the past but the efficiency gains on energy demand will be dampened by the effects of population growth and dwelling size. By how much is difficult to predict.<sup>172</sup> For instance, in the UK, the National Grid considers that 'by 2030 there will be an additional five million people living in an extra two million homes in the UK and by 2050 an additional nine million people in an extra four million homes.'<sup>173</sup>

All these differences in the building sector will have an impact on the decarbonisation options that will be available and chosen, and as a consequence, on future natural gas demand but trying to quantify the impacts will be a major challenge.

#### 7.4.3. Process heat in industry: limited options for renewables?

Thermal energy can be used in many qualities and temperatures, depending on the purpose and the technology. Processes are specific to sectors and even sub-sectors and require different temperatures. Heat demand above 500°C is typically provided by industrial furnaces, while heat demands below 500°C are mostly provided by steam boilers and CHP units.

Industrial process heat with temperatures above 200°C accounts for about 50 per cent of industrial heating and cooling, but these temperatures pose a challenge as they cannot be met with all energy fuels, especially renewables.<sup>174</sup> Taking the German example, where process heat accounts for about 65 per cent of total industry energy consumption,<sup>175</sup> the majority of the industrial process heat was generated from natural gas (45 per cent), followed by coal (30 per cent), district heating (9 per cent), electricity (8 per cent), renewables (5 per cent), and oil (2 per cent) in 2015.<sup>176</sup> Renewable energies have lots of potential for the development of industrial process heat but there are also structural and technical conditions that will limit the scope of development. Industrial processes require heat at different temperature levels as seen in Figure 37. Metal production and processing and the glass and ceramics sectors have by far the largest process heat requirement while the food and paper sectors have a temperature requirement only of up to 500°C.

For heat requirements below 300°C, several renewable options can be envisaged such as some forms of solar thermal, deep geothermal energy, or heat pumps as seen on Figure 38. For higher temperatures, the combustion of solid biomass and biogas can easily reach over 500°C while biomethane, hydrogen, and syngas can achieve much higher temperatures.

More broadly, it also depends on the size of the companies, as small and medium size enterprises will have fewer resources and less access to finance to make improvements, similar to the residential sector.

---

<sup>169</sup> IEA (2017d)

<sup>170</sup> IEA (2017d)

<sup>171</sup> Odyssee-Mure (2015)

<sup>172</sup> Stratego, Enhanced heating and cooling plans (2015), p.4

<sup>173</sup> National Grid (2017)

<sup>174</sup> Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017)

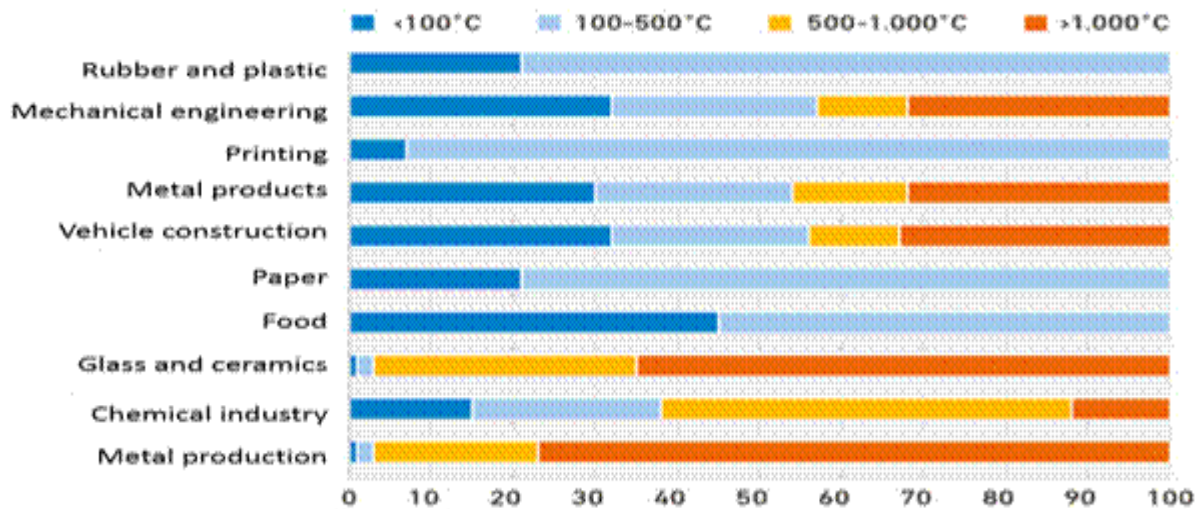
<sup>175</sup> Data for 2015. Source: Agentur für Erneuerbare Energien website, <https://www.unendlich-viel-energie.de/mediathek/grafiken/endenergieverbrauch-nach-anwendungsbereichen-der-industrie-in-deutschland-im-jahr-2015>

<sup>176</sup> Data for 2015. Source: Agentur für Erneuerbare Energien website, <https://www.unendlich-viel-energie.de/mediathek/grafiken/endenergieverbrauch-nach-anwendungsbereichen-der-industrie-in-deutschland-im-jahr-2015>



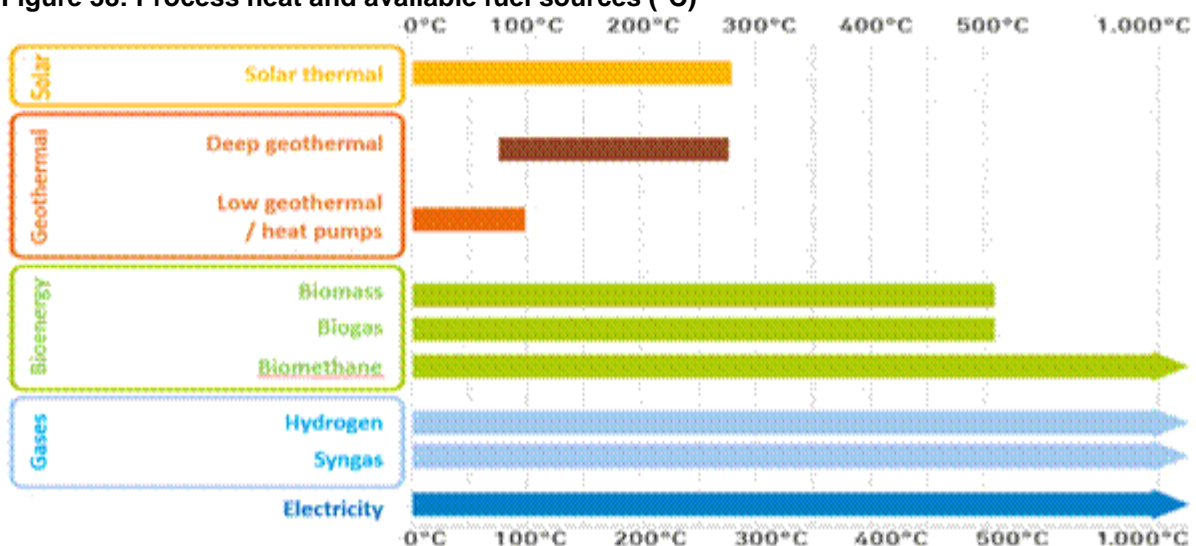
In 2015, about 40 per cent of the gas in this sector was used for process heat at temperatures above 500 degrees. In other words, this volume (34 bcm) of natural gas is not likely to be impacted by decarbonisation measures on the short term, although at some point in the future, it may be replaced by green gas (biomethane and hydrogen), but this will most likely happen post 2030 and beyond. In addition, some coal and oil uses could maybe be converted to natural gas, provided that network connections exist and insentives are in place, and if this were to happen, this would represent about 24 bcm of natural gas.

**Figure 37: Heat temperature requirements for several industrial sectors (not including space heating and water heating) (%)**



Source: Agentur für Erneuerbare Energien<sup>177</sup> (author's translation)

**Figure 38: Process heat and available fuel sources (°C)**



Source: Agentur für Erneuerbare Energien<sup>178</sup> (author's translation)

<sup>177</sup> <https://www.unendlich-viel-energie.de/mediathek/grafiken/erzielte-temperaturen-aus-erneuerbaren-waermequellen>

<sup>178</sup> <https://www.unendlich-viel-energie.de/mediathek/grafiken/erzielte-temperaturen-aus-erneuerbaren-waermequellen>



## VIII. Consequences for future natural gas demand

This section draws together some initial conclusions on the impacts of the decarbonisation of the heating sector for natural gas demand in Europe. Policies and measures will be varied and adapted to the specificities of the various markets, but it seems that the first focus will be on the building sector. Space heating is the main consumer of natural gas used for heating purposes and any changes are likely to have (negative) consequences on demand. However, the variety of measures, consumers, technological options, and timeframes lead to a wide range of possible scenarios. The following paragraphs look at existing scenarios and how they have approached the problem. These examples are intended to indicate issues that will be important and to help provide a context for future research of the *OIES Natural Gas Programme*.

### 8.1. Up to 2030: limited changes for natural gas demand

There is a wide range of possibilities for the future of natural gas demand for heating due to the variety of options and the long lead-times. However, it seems that at least up to 2030, current policy scenarios consider a relatively modest decline in gas demand, which will be essentially concentrated in space heating use in buildings.

For instance, natural gas remains the largest single fuel source for total final energy demand for heating and cooling in Europe in the reports 'Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)'. This report was prepared for the EC and used for its Strategy in Heating and Cooling in 2016.<sup>179</sup> In its current policy scenario, which assumes that all implemented and foreseen policy measures will be in place by the year 2030,<sup>180</sup> the share of natural gas in the mix remains unchanged at about 46-47 per cent. However, with a 7 per cent lower total demand for heating and cooling,<sup>181</sup> the amount of natural gas consumption also declines from 239 bcm in 2012 to 231 bcm in 2020 and about 221 bcm in 2030 (in an average year) due to better thermal efficiency measures in buildings and rising average outdoor temperatures. The mix also changes, with higher use of renewables (up by 38 per cent) by 2030 while at the same time, the use of fossil fuels declines by 15 per cent. The share of coal also stays relatively constant, despite a decrease in coal fired heating systems in the residential and tertiary sector. This is explained by the fact that coal is used for high temperature process heating in the industry sector and does not have many competitors, aside from natural gas. The sharpest drop happens in oil fired heating systems (under the oil price assumptions in 2016). Biomass remains the single most important renewable fuel despite impressive growth from other renewable energies (but from a very low base). Interestingly, the share of electricity in final energy demand for heating and cooling does not significantly change, despite an increase in electric appliances: the development of heat pumps in the mix helps to curb electricity demand growth thanks to much higher efficiencies of heat pumps compared to direct electric heating.

In the analysis by sector, the residential sector registers the sharpest decline as seen in Figure 39. This is explained by efficiency gains through thermal refurbishments and minimum energy efficiency requirements for new buildings and, consequently, lower demand for space heating, the largest consumer in the residential sector. On the contrary, energy use in the industry sector increases slightly due to favourable economic assumptions and fewer options to improve energy efficiency than in the residential sector, especially in energy intensive industries. The low-hanging fruits have already been harvested and any further improvement in efficiencies will be more complicated in this sector. As

---

<sup>179</sup> These reports also are the main source of data used in this paper and therefore provide some consistency and continuity for the analysis.

<sup>180</sup> Framework conditions are aligned to the EU 2016 reference scenario including assumptions on GDP, building stock development, and fuel prices.

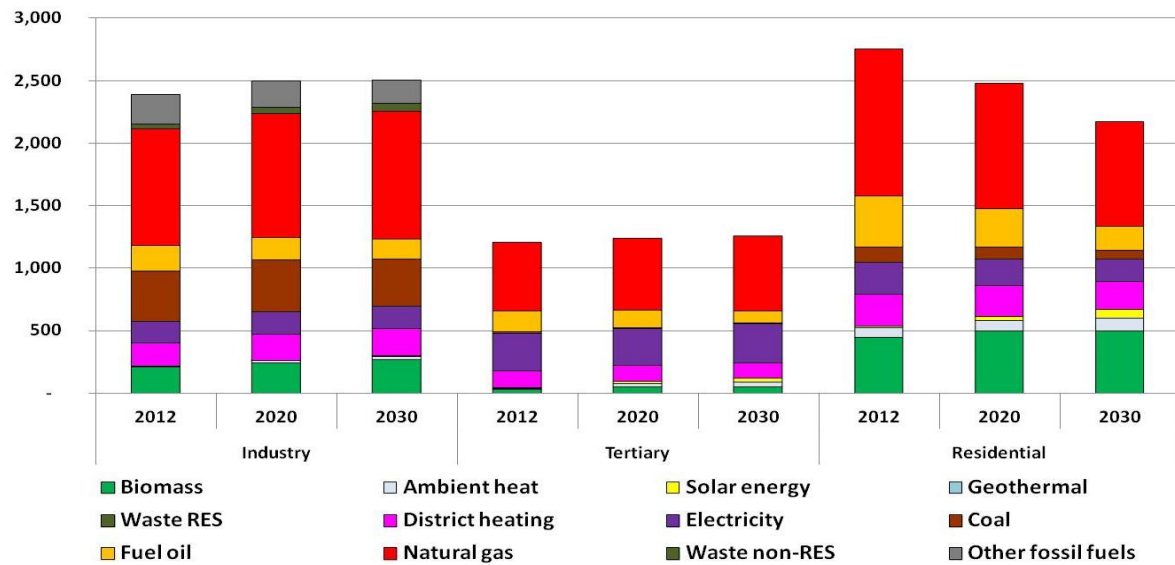
<sup>181</sup> From 6,350 TWh in 2012 to 5,930 TWh in 2030. Note: the data for base year 2012 have been temperature corrected, and therefore they differ ever so slightly from the rest of the report from the data given in Section 2.





a result, the industrial sector becomes the largest market for heating and cooling by 2030 (overtaking the residential sector). The tertiary sector decreases only slightly by 1 per cent.

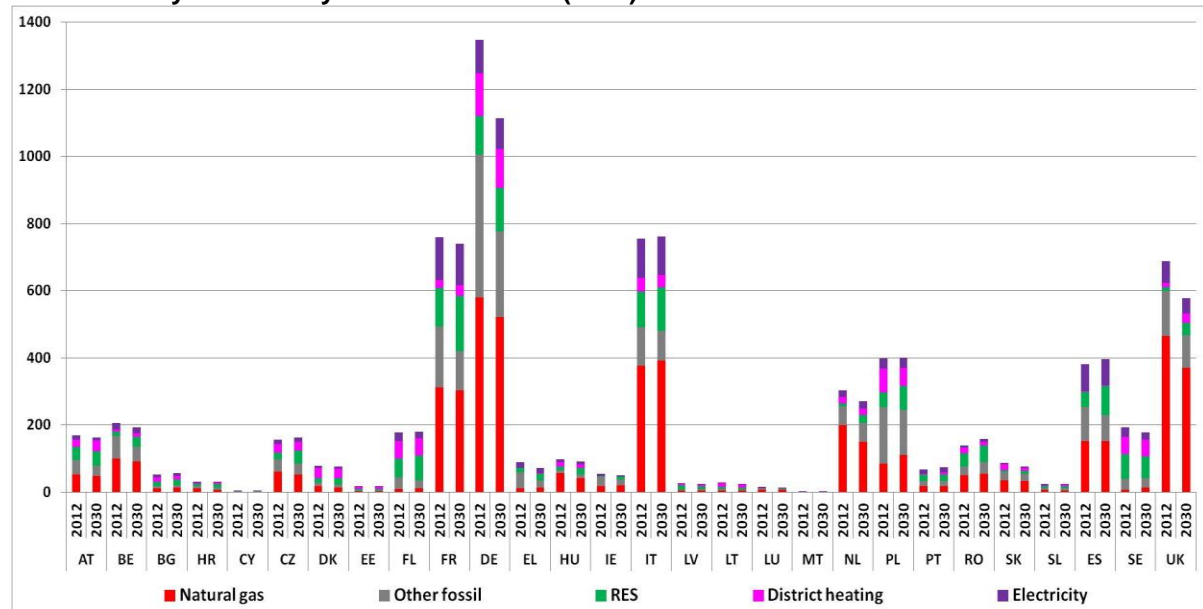
**Figure 39: Current policy scenario for final energy demand for heating and cooling by sector and energy carrier in 2012, 2020 and 2030 in the EU (TWh)**



Source: European Commission (2016d), p.33

As for the energy mix, natural gas remains the most important individual supply source for heating in final energy demand up to 2030. Natural gas demand even increases in ten countries including Italy, which registers by far the largest increase followed by Poland and Romania as in Figure 40. The other large markets (Germany, France, the UK, and the Netherlands) register a decline.

**Figure 40: Current policy scenario for final energy demand for heating and cooling by energy carrier mix by EU country in 2012 and 2030 (TWh)**



Note: RES = renewables

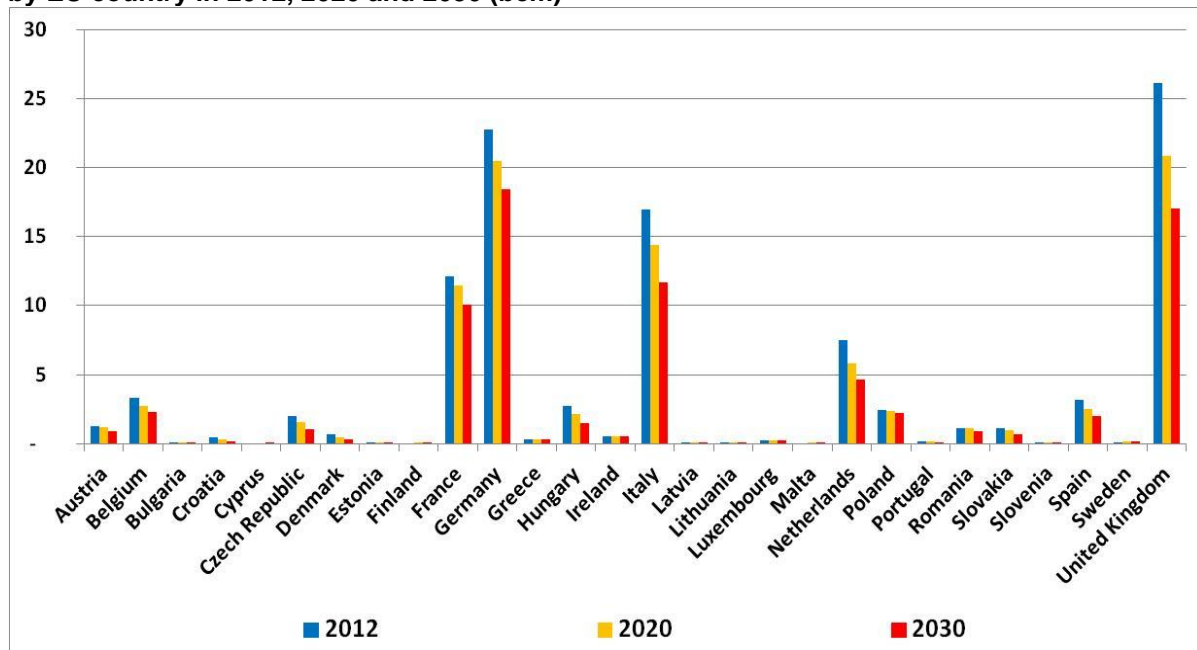
Source: European Commission (2016d), p.34





Focusing on the changes in natural gas demand in the residential sector only, this scenario shows a decline of 21 per cent between 2012 and 2030, from 105 bcm to 75 bcm. The sharpest decline happens in the UK (-9 bcm), followed by Italy (-5 bcm), Germany (-4 bcm) and the Netherlands (-3 bcm) [Figure 41].

**Figure 41: Current policy scenario for natural gas demand for heating in the residential sector by EU country in 2012, 2020 and 2030 (bcm)**



Source: Author's calculations from European Commission (2016d), p.75

## 8.2. After 2030: a wide range of possibilities

The longer horizon to 2050 is more complicated to apprehend due to longer time frames and possible technological development by then. The possible paths and options to decarbonise the systems will multiply. Interestingly, most of the scenarios focus on the building sector, highlighting once again its (continued) importance in the future of the decarbonisation of heating sector beyond 2030.

Another example of its importance is given by the IEA data. The time series on (past) energy and natural gas balances show the traditional split in final energy demand between transport, industry, and the residential and commercial sectors; but in the scenarios published in its World Energy Outlook series, future final energy demand is given for transport, industry, and for buildings (replacing the residential and commercial sector).

In all the IEA scenarios (current policy, new policy, and sustainable development<sup>182</sup>), natural gas faces an increasingly competitive environment with higher penetration of renewables and electricity, and in two of the scenarios, lower demand as seen in Figure 42.

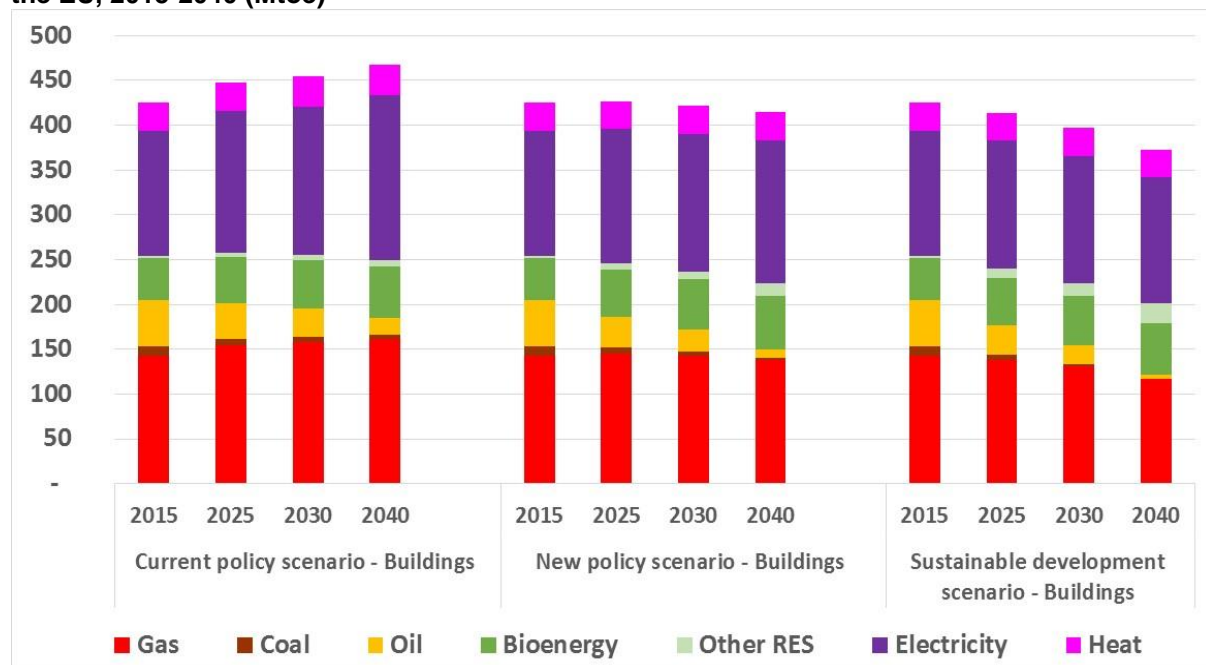
- In the new policy scenario, which includes all implemented and foreseen policy measures, energy efficiency lowers the total demand for heating and cooling in buildings by 0.2 per cent by the year 2040 (compared to 2016). The decline of oil's share is replaced by renewables and electricity. Natural gas loses about 6 bcm (-0.2 per cent) but its share in the mix remains flat at about 33 per cent.

<sup>182</sup> For more information, see the International Energy Agency website, World Energy Outlook, [www.iea.org/weo2017/](http://www.iea.org/weo2017/)



- In the current policy scenario, natural gas used in buildings increases by 23 bcm, while most of the additional demand (+0.3 per cent) is met by electricity.
- On the contrary, in the sustainable development scenario, natural gas demand declines even faster than total demand and loses about -32 bcm. Surprisingly, electricity also declines slightly (-0.1 per cent) while renewables replace oil demand.

**Figure 42: WEO scenarios for final energy demand in the building sector by energy carrier for the EU, 2015-2040 (Mtoe)**



Source: IEA (2017e), pp.672-673

Decarbonisation policies for the heating and cooling sector will affect the level of demand and the mix to meet this demand, but from existing scenarios, it seems that without any major political intervention, energy for space heating (and cooling) in buildings will keep on rising and could even potentially drive additional gas demand. On the other hand, the sustainable development scenario with most likely stronger political intervention show lower energy demand, which will be met by rising renewables use with less fossil fuels, including natural gas, in the mix. However, the changes in gas demand are fairly minimal, which in itself is both surprising and very interesting. An increase of 23 bcm or a decline of 32 bcm is not negligible but it is also not a dramatic change. A warm winter following a cold one could also trigger this sort of change in Europe from one year to another.

The most interesting story to look at to understand future gas demand in the context of decarbonising heat may not be at a European level, as too many different circumstances are at play, but rather at a national level, where very different potential stories are anticipated.

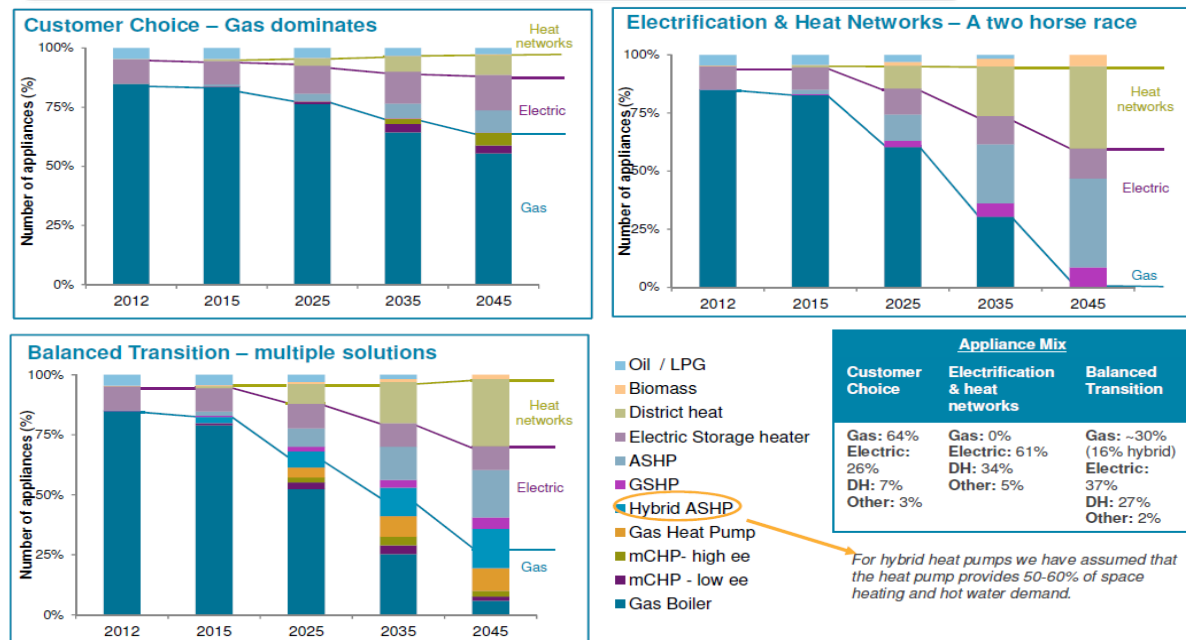
The UK is the largest consumer of natural gas for space heating in the residential sector in Europe.<sup>183</sup> The Climate Change Act of 2008 set binding targets of 80 per cent emissions reduction by 2050 (compared to 1990). To meet these targets, the country will need to significantly decarbonise its residential heat sector, which will need to have reduced its emissions to near zero in 2050. If the European scenarios considered above do not foresee many changes in the fuel mix - even in the case of 'sustainable scenario' - how can the UK achieve these drastic objectives? Two sets of different scenarios are studied below.

<sup>183</sup> See section 3



- The Delta Energy and Environment report, which was commissioned by the Energy Networks Association, analyses how the UK residential heating sector can be decarbonised by 2045.<sup>184</sup> The report considers three main scenarios: in the first one, customers make the choice for their heating systems, in a second one, the whole system is transformed with electrification and heat networks replacing the existing systems, and a third one, which is a hybrid of the first two. The results are shown below in Figure 43.

**Figure 43: Delta Energy and Environment scenarios for energy demand for heating in the UK residential sector, by energy carrier, 2012-2045, (%)**



Source: Delta Energy and Environment (2012)

#### o Scenario 1: Customer Choice

Without major policy intervention, Delta Energy and Environment assumes that customers will chose gas appliances for replacement and refurbishment, with less than 1 per cent of gas customers switching to an alternative fuel. Customers chose low capital cost, low running cost appliances that are relatively straightforward to retrofit and in 2045, there are still about 22 million gas boilers in the UK. In existing homes, mCHP mature and their numbers will grow, helped by electricity prices rising substantially faster than gas prices. Gas heat pumps mature but gain minimal market share and there is some switching away from oil. But all in all, gas heating appliances offer low to moderate upfront costs and low running costs and retain the favour of customers. Biomethane increases to 75TWh or 23 per cent of total gas consumption for residential heat. In the new build sector, heat networks and electric heating dominate, driven by regulations. There is some growth in peak demand on the electricity system from additional heat pumps (in new build and off-gas grid properties), but this only amounts to 8 GW. The scenarios show that the carbon targets are missed but there are low impacts on customers and the wider energy system. Natural gas demand declines, from about 26 bcm in 2015 to about 13 bcm in 2045.<sup>185</sup>

#### o Scenario 2: Electrification & Heat Networks

This scenario requires significant interventions to shift customers away from gas appliances and onto either electric heating or heat networks in order to almost completely decarbonise heat: 61 per cent of the households are on electric heating / heat pumps and 34 per cent of homes adopt district heat and 5 per cent adopt 'other solutions' (biomass). All homes switch away from oil and gas. This delivers on

<sup>184</sup> Delta Energy and Environment (2012)

<sup>185</sup> Author's estimates





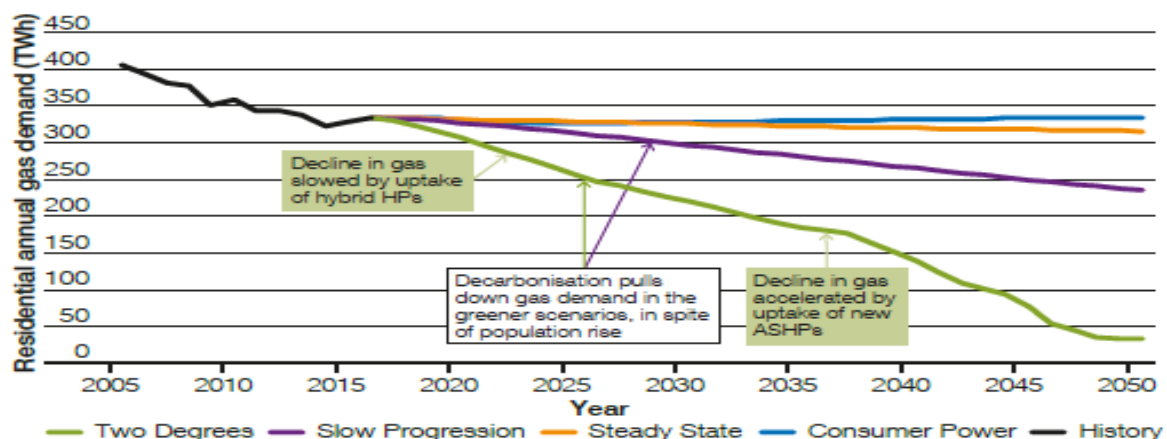
carbon targets but has a high cost on customers, involves extending heat networks, and results in major impacts on peak electricity where an additional 48GW of capacity will be required in addition to major upgrading of the distribution network and the shut-down of all gas networks. Not surprisingly, in this scenario, natural gas demand in the UK residential sector disappears.

- o Scenario 3: Balanced transition

This scenario is somewhere between the first two extreme scenarios. There is still a strong growth in heat networks and electrification of heating but gas continues to play a significant role in suburban homes (the hardest to switch homes). In 2045, there are still about 12 million gas boilers in the UK, but 67 per cent of homes move to electric heating / electric heat pumps, 27 per cent of homes adopt district heat and fuel switching away from oil happens. A range of low carbon gas appliances (including electric heat pumps – gas boiler hybrids) are adopted and about 30 per cent of customers stay on gas (16 per cent hybrid). This achieves significant carbon reductions while minimising impacts on the customer and the energy system, however, in this scenario, 75TWh of biomethane become available (as in scenario 1). There is growth in peak demand on the electricity system and an additional 24GW of capacity will be required in addition to upgrading parts of the distribution network and the shut-down of parts of the gas network. In this scenario, natural gas demand for the residential sector declines, from about 26 bcm in 2015 to about 2.5 bcm in 2045.<sup>186</sup>

- The second group of scenarios are taken from National Grid in its 'Future energy scenarios' report, which looks at several options for decarbonising the residential heat sector. Their four scenarios follow the same lines than the ones developed in the Delta Energy and Environment models:
  - o Consumer power: gas boilers remain with some uptake of alternative sources up to 2030 and by 2050, there are still about 20 million gas boilers in the UK, 1 million air source heat pumps (ASHPs) and 4 million mCHPs and fuel cells. By 2050, gas demand in the residential sector is similar to 2016 (31 bcm) as seen in Figure 44.
  - o Steady state: no significant change to 2030 and 25 million gas boilers still exist in 2050. Gas demand reaches 29 bcm at the end of the period.
  - o Slow progression: some uptake of heat pumps to 2030 and by 2050, 6 million heat pumps have been installed and 20 million gas boilers remain. Gas demand declines to 21.6 bcm.
  - o Two degrees (which meets the 2050 carbon reduction target): combination of ASHPs and hybrid heat pumps are developed up to 2030 thanks to policies and regulation, and by 2050, there are 25 million heat pumps, greater efficiency and new ASHPs. Gas demand declines the most under this scenario, down to 3.6 bcm in 2050.

**Figure 44: National Grid scenarios for natural gas demand in the UK residential sector, 2005-2050 (TWh)**



Source: National Grid (2017)

<sup>186</sup> Author's estimates





These scenarios highlight the fact that any dramatic decrease in gas demand in the heating sector will happen only if drastic measures are decided upon and implemented. If the country decides to go down the road of electrification and the development of heat networks, natural gas demand for the residential sector may disappear altogether. But this path requires strong policies: it is costly and creates the most disturbances for consumers and the networks. It also requires the maturation of various technologies such as hydrogen, biomethane, and batteries.<sup>187</sup> On the contrary, if consumers are given the choice or limited policies are implemented to impose the transition to alternative fuels, the future level of natural gas demand in the residential sector could remain at about 2015 levels up to 2030 and even possibly 2050 minus efficiency impacts. The future path is likely to be somewhere in between the two extreme scenarios, but heat has long investment cycles and decisions will need to be taken soon. If the existing building stock does not improve, decarbonisation will not happen in time and emissions targets will be missed. A renovation rate of about 3 per cent would be needed between 2018 and 2050 to encompass all the existing building stock. If no change happens for another decade, the annual renovation rate will need to be increased to 4 per cent up to 2050. All these begs some questions on how fast can the decarbonisation scenarios happen without major policy intervention and drastic measures to implement the transition to a low carbon heating sector. In a context of rising cost of energy for the consumers and even problems of fuel poverty, such a task will not only be complex and costly, but also most likely, very sensitive.

As for the gas industry, even if the transformation of the heat sector is likely to happen more slowly than in the power sector, decisions still need to be made soon if gas is to have a long-term future beyond 2030 or 2040 in Europe. Stronger political commitment to low carbon heat could have dramatic impact on natural gas demand, as seen in the case of the UK but also potentially in other markets as well, and it should not be discarded. For instance, in the Netherlands, were 98 per cent of the households are connected to the gas grid; the Dutch government has urged municipalities to disconnect the residential houses from the gas network as quickly as possible. The Netherlands is a special case because this happens in the context of sharp decline of the Groningen production,<sup>188</sup> the main supplier for the residential market, but it is nonetheless an example on how quickly political decisions can turn. New houses will also not be connected to the gas grid.<sup>189</sup> The natural gas industry needs to start thinking about these crucial issues and develop a decarbonisation strategy that allows natural gas to have a future in a decarbonised heating and cooling sector but also to be part of the transition, sooner rather than later.

## Summary and conclusions

In February 2016, the heating and cooling sector became the focus of increased attention in its own right with the publication of the first EU 'Heating and Cooling Strategy'. The strategy acknowledges that the decarbonisation of the economy and deliverance of its GHG reduction targets and commitment under the climate agreement reached at the COP21 climate conference in Paris will not happen without action on the heating and cooling sector to reduce (sharply) its energy consumption and to cut its use of fossil fuels. So if Europe is to meet its goal of reducing emissions by at least 80 per cent by 2050, it will need to expand its decarbonisation process to the heating and cooling sector otherwise the objectives will be missed. This will be a major task as this sector is made up of local markets that respond to local specificities, but collectively, these local heating and cooling markets cover about half of the EU's final energy demand.

---

<sup>187</sup> Additional information on the decarbonisation of heat in the UK market and a special focus on the development of hydrogen can be found in the accompanying paper Keay M. (2018)

<sup>188</sup> For more information, see Honoré A. (2017)

<sup>189</sup> The government intends to remove 30,000 to 50,000 households per year from the gas network by 2021 and a further 200,000 homes every year until 2030. Source: Argus, 4 April 2018, Dutch government implements 'gas-free' household plan



The analysis of the heating and cooling sector is limited by the availability of data and the lack of a specific definition, and therefore there is still some confusion on how much –and what kind- of energy the sector consumes. However, the analysis of various in-depth studies shows that although it is moving towards low carbon energy, about 66 per cent of final energy demand still came from the direct combustion of fossil fuels (oil, coal, or natural gas) in 2015, and about 42 per cent came from natural gas alone, making it the most relevant individual energy source.

The heating sector also has a major role in natural gas demand and was responsible for 64 per cent of the gas used in Europe or about 275 bcm in 2015. Six markets accounted for 74 per cent of this demand: Germany (22 per cent), the UK (15 per cent), Italy (14 per cent), France (11 per cent), Netherlands (7 per cent) and Spain (5 per cent). At a national level, natural gas used for heating represented more than 70 per cent of total gas demand in several countries such as Sweden and Estonia, Slovenia, Czech Republic, Luxembourg, France and Germany. Natural gas demand in these countries will be especially sensitive to decarbonisation measures in the heating sector.

The residential sector was the largest user of natural gas in the heating sector, accounting for 116 bcm in Europe in 2015, essentially for space heating. In the industrial sector, about 84 bcm was used to generate heat in 2015. The main source of demand was for temperatures above 500 degrees and space heating. In the commercial sector, 80 per cent of the 50 bcm of gas demand used for heating was directed to space heating. Finally, the production of derived heat represented about 25 bcm of natural gas, most of which was directed to district heating. Any policies to decarbonise heating in buildings and process heating in industry will have important consequences for natural gas demand in the future, but neither the impacts nor the timeframes are likely to be uniform across Europe.

The main focus of EU decarbonisation policies for heating and cooling production so far has been on two main categories of measures: energy efficiency and the promotion of renewables, essentially for final energy demand although some work is also being done on district heating systems. This created a framework of policies and measures that will impact the decarbonisation of the heating and cooling sector, without focusing on it specifically.

The measures on efficiency are technology-neutral. Consumers are encouraged to use high-efficient technology but there is no obligation to use any specific technologies in new or renovated buildings. This is to accommodate the decentralised and much diversified nature of the heating and cooling market as no 'one size fits all' option exists, but any higher-efficiency technologies will effectively lower energy demand for heating and cooling in Europe and as a result, emissions as well. However, policies promoting energy efficiency in buildings are fairly recent, and essentially started in the early 2010s. The effects of these policies will take time to materialise in the European market where buildings are old and waste energy: about 75 per cent of the building stock was still considered energy inefficient in 2015.

Together with demand reduction, the fuel used to generate heating and cooling is also important and renewable heat provides some alternatives to fossil fuels in order to decarbonise the sector. Thanks to the Renewable Energy Directive, the EU is already the largest regional consumer of renewable heat in the world, which was boosted by the replacement of fossil fuel boilers with efficient renewable heating and by increasing the deployment of renewable energy in district heating and CHP.

While discussions about policies focus on the macro level, what happens at the micro level is as important. Heat can be produced by a wide range of technologies, and for the end-user, there are many options to choose from for their heating systems, both in terms of fuel type (energy input) and the operating principle (appliances), although not all these options have the same efficiencies and not all will be available or desirable for all buildings. In the residential and commercial sector, the energy sources and the technologies used to generate heat show wide differences across Europe. Natural gas technologies are predominant (42 per cent of installed capacity) and comparatively newer, and therefore on average more efficient, than other fossil fuel technologies. Other options already exist, such as CHPs, electric heating, heat pumps, renewable heat and district heating. The main options to decarbonise can be grouped under the headings following the EU policies/measures: efficiency improvements (upgrade boilers, develop CHP and fuel cells, and switch to more efficient heating



systems), raising the renewable share (replace fossil fuels by renewables, install hybrid systems and repurpose the gas network for green gas), electrify the heating and cooling sector, and expand heat networks.

Delivering the EU's clean energy targets will need to cover the heating and cooling sector, but it will be a major challenge. The implementation of low-carbon options faces critical energy challenges with few simple answers as heating demand is diverse, varying by building type, location, connections, and fuel availability. A non-exhaustive list of the main hurdles facing the decarbonisation of heat includes the diversity and number of stakeholders involved, the consumers' long investment cycle and disruption caused by switching to other fuels, the cost and development of decarbonised options, the no 'one size fits all option', the renovation of the existing building stock and limited options for the generation of high temperatures in the industry.

So how will the decarbonisation of the heating and cooling sector impact natural gas consumption in Europe? There is a wide range of possibilities for the future of natural gas demand for heating due to the variety of options and the long lead-times. However, it seems that at least up to 2030, current policy scenarios consider a relatively modest decline in gas demand, which will be essentially concentrated in space heating use in buildings as illustrated in the reports for the European Commission 'Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)' (-18 bcm between 2012 and 2030). The residential sector registers the sharpest decline, which is explained by efficiency gains through thermal refurbishments and minimum energy efficiency requirements for new buildings and, consequently, lower demand for space heating. On the contrary, energy use in the industry sector increases slightly due to favourable economic assumptions and fewer options to improve energy efficiency than in the residential sector, especially in energy intensive industries. The tertiary sector decreases only slightly by 1 per cent. As for the energy mix, natural gas remains the most important individual supply source for heating in final energy demand up to 2030.

The longer horizon to 2050 is more complicated to assess due possible technological development by then. The possible paths and options for decarbonising the systems will multiply. Interestingly, most of the scenarios focus on the buildings sector, highlighting its importance in the transition to a low-carbon heating sector. Natural gas faces an increasingly competitive environment with higher penetration of renewables and electricity. In the IEA World Energy Outlook scenarios published in 2017, results show that without major political intervention (current policy scenario), energy for space heating (and cooling) in buildings will keep on rising and will drive additional gas demand. On the other hand, the sustainable development scenario which expects stronger political intervention to lower energy demand includes rising renewables use and less fossil fuels, including natural gas, in the mix. However, the total changes in gas demand by 2050 are fairly minimal, which in itself is both surprising and very interesting. An increase of 23 bcm (current policy) or a decline of 32 bcm (sustainable development) is not negligible but it is also not a dramatic change, suggesting a slow evolution of the heating sector.

The most interesting scenarios about the future gas demand in the context of decarbonising heat can be found at a national level, where very different stories may unfold. The UK is the largest consumer of natural gas for space heating in the residential sector in Europe, and also the subject of the paper by M. Keay, which goes together with this present paper.<sup>190</sup> Scenarios for the UK show that without major policy intervention, customers will essentially chose gas appliances for replacement and refurbishment and there will be only some limited switching to an alternative fuel by 2045/2050. In this scenario, natural gas demand in the residential sector will not decline by much, aside from efficiency improvements. At the other end of the spectrum, with significant interventions to shift customers away from gas appliances and onto either electric heating or heat networks in order to almost completely decarbonise heat, all homes switch away from oil and gas by 2045/2050 and natural gas demand basically disappears in the UK residential sector. These scenarios highlight the fact that any dramatic

---

<sup>190</sup> Keay M. (2018)





decrease in gas demand in the heating sector can happen if drastic policy measures are decided upon and implemented.

Decarbonising the heating sector in Europe will take time and probably longer than many anticipate, and it will necessitate additional measures, especially to increase the rate of renovation of buildings as otherwise less than 40 per cent of the existing stock will have undergone renovation by 2050, which is not as much as needed to make a substantial contribution to meeting the environmental targets. However, the gas industry should not count on political inaction and it would be a mistake to discard scenarios showing fast rising renewables, widespread electrification or the development of hydrogen to replace natural gas by 2030 / 2050 as pure fantasy. The natural gas industry needs to start thinking about these crucial issues and develop a decarbonisation strategy to continue to exist in a context where renewables, hybrid systems, interaction with the electricity sector, expansion of heat networks and development of hydrogen and biogas happen, maybe even sooner rather than later.

These conclusions point to additional questions and provide a foundation for future research by the OIES Natural Gas Programme on issues which relate to the future of gas in a decarbonising world. This author will take a deeper look at the future gas demand first in the industrial sector and secondly in the buildings sector, the two main consumers of gas for heating in Europe. Additional research will also focus on other areas such as the future of gas networks by J. Stern. This is an important topic because if the decarbonisation of heat follows the path of electrification or district heating using renewables, then gas networks could become stranded. Alternatively, the development of green gas could provide a future for these networks thanks to power to gas, and this will be explored in a continuing series of papers by M. Lambert. The development of hydrogen is already actively being looked at in some markets and is the topic of M. Keay's paper on decarbonising heat and the role of green gas in the UK, which with this paper, forms part of the joint research focusing on the impacts of decarbonisation carried on by the *OIES Natural Gas Programme* and the *OIES Electricity Programme*.





## Bibliography

- Blakey S. (2013), Air quality and home heating: A gas industry perspective, Green Week 6 June 2013, Presentation,  
[http://ec.europa.eu/environment/archives/greenweek2013/sites/default/files/content/presentations/8-2\\_blakey.pdf](http://ec.europa.eu/environment/archives/greenweek2013/sites/default/files/content/presentations/8-2_blakey.pdf)
- Delta Energy and Environment (2012), 2050 Pathways for Domestic Heat, Final report,  
[http://www.energynetworks.org/assets/files/gas/futures/Delta-ee\\_ENA%20Final%20Report%20OCT.pdf.pdf](http://www.energynetworks.org/assets/files/gas/futures/Delta-ee_ENA%20Final%20Report%20OCT.pdf.pdf)
- Element Energy & E4tech (2018), Cost analysis of future heat infrastructure options,  
<https://www.nic.org.uk/wp-content/uploads/Element-Energy-and-E4techCost-analysis-of-future-heat-infrastructure-Final.pdf>
- Energy and Climate Change Committee (2016), Low carbon network infrastructure, First report of Session 2016-2017, 17 June 2016, HC267,  
<https://publications.parliament.uk/pa/cm201617/cmselect/cmenergy/267/267.pdf>
- Eurogas (2014), Gas: the right choice for heating in Europe,  
[http://www.eurogas.org/uploads/media/Gas\\_the\\_right\\_choice\\_for\\_heating\\_in\\_Europe\\_PART\\_II\\_Brochure\\_140814.pdf](http://www.eurogas.org/uploads/media/Gas_the_right_choice_for_heating_in_Europe_PART_II_Brochure_140814.pdf)
- European Commission (2008), European energy and transport, trends to 2030, update 2007,  
[https://ec.europa.eu/energy/sites/ener/files/documents/trends\\_to\\_2030\\_update\\_2007.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/trends_to_2030_update_2007.pdf)
- European Commission (2009b), Directive 2009/28/EC Of The European Parliament And Of The Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN>
- European Commission (2011a), Commission Staff Working Paper Impact Assessment Accompanying The Document Communication From The Commission To The Council, The European Parliament, The European Economic And Social Committee And The Committee Of The Regions, Energy Roadmap 2050, Part 1:  
[https://ec.europa.eu/energy/sites/ener/files/documents/sec\\_2011\\_1565\\_part1.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1565_part1.pdf)
- European Commission (2011b), Commission Staff Working Paper Impact Assessment Accompanying The Document Communication From The Commission To The Council, The European Parliament, The European Economic And Social Committee And The Committee Of The Regions, Energy Roadmap 2050, Part 2:  
[https://ec.europa.eu/energy/sites/ener/files/documents/sec\\_2011\\_1565\\_part2.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/sec_2011_1565_part2.pdf)
- European Commission (2013a), Commission Staff Working Document, Accompanying the document, Report from the Commission to the European Parliament and the Council, Financial support for energy efficiency in buildings,  
[https://ec.europa.eu/energy/sites/ener/files/documents/swd\\_2013\\_143\\_accomp\\_report\\_financing\\_ee\\_buildings.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/swd_2013_143_accomp_report_financing_ee_buildings.pdf)
- European Commission (2013b), Commission Staff Working Document, Guidance note on Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EC, and repealing Directives 2004/8/EC and 2006/32/EC Article 14: Promotion of efficiency in heating and cooling, <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=SWD:2013:0449:FIN:EN:PDF>
- European Commission (2016a), Commission Staff Working Document, Review of available information, Accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on an EU Strategy for Heating and Cooling,  
[https://ec.europa.eu/energy/sites/ener/files/documents/1\\_EN\\_autre\\_document\\_travail\\_service\\_part1\\_v6\\_0.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_autre_document_travail_service_part1_v6_0.pdf)



- European Commission (2016b), Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 1: Final energy consumption for the year 2012, [https://ec.europa.eu/energy/sites/ener/files/documents/mapping-hc-final\\_report\\_wp1.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/mapping-hc-final_report_wp1.pdf)
- European Commission (2016c), Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 2: Assessment of the technologies for the year 2012, [https://ec.europa.eu/energy/sites/ener/files/documents/mapping-hc-final\\_report-wp2.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/mapping-hc-final_report-wp2.pdf)
- European Commission (2016d), Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Work package 3: Scenarios for heating & cooling demand and supply until 2020 and 2030, [https://ec.europa.eu/energy/sites/ener/files/documents/mapping-hc-final\\_report-wp3-wp4.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/mapping-hc-final_report-wp3-wp4.pdf)
- European Commission (2016e), Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions, An EU Strategy on Heating and Cooling, [https://ec.europa.eu/energy/sites/ener/files/documents/1\\_EN\\_ACT\\_part1\\_v14.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf)
- European Commission (2016f), Proposal for a Directive Of The European Parliament And Of The Council amending Directive 2010/31/EU on the energy performance of buildings, [https://ec.europa.eu/energy/sites/ener/files/documents/1\\_en\\_act\\_part1\\_v10.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v10.pdf)
- European Commission (2016g), Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables), Executive summary, <https://ec.europa.eu/energy/sites/ener/files/documents/mapping-hc-excecitivesummary.pdf>
- European Commission (2017a), Report from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions, Renewable Energy Progress Report, <https://ec.europa.eu/transparency/regdoc/rep/1/2017/EN/COM-2017-57-F1-EN-MAIN-PART-1.PDF>
- European Commission (2017b), Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast), [https://ec.europa.eu/energy/sites/ener/files/documents/1\\_en\\_act\\_part1\\_v7\\_1.pdf](https://ec.europa.eu/energy/sites/ener/files/documents/1_en_act_part1_v7_1.pdf)
- European Commission - Fact Sheet (2016), Factsheet on the Commission's proposal on binding greenhouse gas emission reductions for Member States (2021-2030), [http://europa.eu/rapid/press-release\\_MEMO-16-2499\\_en.htm](http://europa.eu/rapid/press-release_MEMO-16-2499_en.htm)
- European Commission – JRC Science for Policy Report (2016), Synthesis Report on the assessment of Member States' building renovation strategies, Castellazzi, L., Zangheri, P. & Paci, D., [http://publications.jrc.ec.europa.eu/repository/bitstream/JRC97754/syntesis%20report%20building%20renovation%20strategies\\_online%20fin.pdf](http://publications.jrc.ec.europa.eu/repository/bitstream/JRC97754/syntesis%20report%20building%20renovation%20strategies_online%20fin.pdf)
- European Environment Agency (2015), Renewable energy in Europe – approximated recent growth and knock-on effects, <https://www.eea.europa.eu/publications/renewable-energy-in-europe-approximated>
- European Environment Agency (2017a), Renewable Energy in Europe 2017, Recent growth and knock-on effects, No3/2017, <https://www.eea.europa.eu/publications/renewable-energy-in-europe-2017>
- European Environment Agency (2017b), Trends and projections in Europe 2017, Tracking progress towards Europe's climate and energy targets, <https://www.eea.europa.eu/themes/climate/trends-and-projections-in-europe/trends-and-projections-in-europe-2017/index>
- European Union (2009a), Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of Ecodesign requirements for energy-related products (Eco-Design Directive), <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0125&from=EN>



- European Union (2010), Directive 2010/31/EU of The European Parliament and of The Council of 19 May 2010 on the energy performance of buildings, <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32010L0031&from=en>
- European Union (2012), Directive 2012/27/EU Of The European Parliament And Of The Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0027&from=EN>
- European Union (2017), Regulation (EU) 2017/1369 Of The European Parliament And Of The Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU (Energy Labelling Regulation), <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R1369&from=EN>
- Oxford Energy (2016), Expert meeting November 2016, Decarbonising heat, <https://www.energy.ox.ac.uk/wordpress/wp-content/uploads/2015/01/Decarbonising-Heat-briefing-note.pdf>
- Gella A. (2017), Calidad del aire en las ciudades españolas: Transporte urbano, sector residencial y terciario, Energía Limpia 31 May 2017, Presentation, [https://www.sedigas.es/reunionanual/wp-content/uploads/AGella\\_RA17SDG.pdf](https://www.sedigas.es/reunionanual/wp-content/uploads/AGella_RA17SDG.pdf)
- GRTGaz (2017), Bilan Gaz 2016, <http://www.grtgaz.com/fileadmin/medias/communiques/2017/FR/GRTgaz-Bilan-Gaz-2016-17012017.pdf>
- Heat Roadmap Europe, a low carbon heating and cooling strategy 2050 (2017), Profile of heating and cooling demand in 2015, <http://heatroadmap.eu/resources/3.1%20Profile%20of%20the%20heating%20and%20cooling%20demand%20in%20the%20base%20year%20in%20the%2014%20MSs%20in%20the%20EU28.pdf>
- Honoré A. (2017), The Dutch Gas Market: trials, tribulations and trends, <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/05/The-Dutch-Gas-Market-trials-tribulations-and-trends-NG-118.pdf>
- IEA -International Energy Agency- (2016), Renewables 2016, Analysis and forecasts to 2021, OECD Paris, <http://www.iea.org/publications/freepublications/publication/MTRMR2016.pdf>
- IEA -International Energy Agency- (2017a), Natural gas information, OECD Paris
- IEA -International Energy Agency- (2017b), Renewables 2017, Analysis and forecasts to 2022, OECD Paris
- IEA -International Energy Agency- (2017c), CO<sub>2</sub> emissions from fuel combustion, OECD Paris, <https://www.iea.org/publications/freepublications/publication/CO2EmissionsfromFuelCombustionHighlights2017.pdf>
- IEA -International Energy Agency- (2017d), Energy efficiency 2017, [http://www.iea.org/publications/freepublications/publication/Energy\\_Efficiency\\_2017.pdf](http://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf)
- IEA -International Energy Agency- (2017e), World Energy Outlook 2017, OECD Paris
- Keay M. (2018), Decarbonisation of heat and the role of 'green gas' in the United Kingdom, <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2018/05/Decarbonisation-of-heat-and-the-role-of-green-gas%E2%80%99-in-the-United-Kingdom-NG-128.pdf>
- Lancaster O. (2017), On the road to a green energy UK: Freedom – hybrid heating, <http://www.wvutilities.co.uk/media/2451/final-on-the-road-to-a-green-energy-uk-freedom-work-v2.pdf>
- Lankhorst G. (2014), 'Renewables and gas – the perfect partners in heating', 2 September 2014, Brussels, Speech by the President of Eurogas,



<http://www.europeanenergyforum.eu/events/renewables-and-gas-%E2%80%93-perfect-partners-heating>

National Grid (2017), Future Energy Scenarios, <http://fes.nationalgrid.com/media/1253/final-fes-2017-updated-interactive-pdf-44-amended.pdf>

Odyssee-Mure (2015), Energy Efficiency Trends and Policies in the Household and Tertiary sectors, <http://www.odyssee-mure.eu/publications/br/energy-efficiency-trends-policies-buildings.pdf>

Regan N. (2015), Heating Our Homes: Gas Innovation Now and In The Future, <http://www.europeanenergyinnovation.eu/Articles/Autumn-2015/Heating-Our-Homes-Gas-Innovation-Now-And-In-The-Future>

RTE (2016a), Bilan électrique, <http://bilan-electrique-2016.rte-france.com/consommation/14-2/>

RTE (2016b), Vision Européenne de l'électricité, <http://bilan-electrique-2016.rte-france.com/europe/75-vision-europeenne-de-lelectricite/>

Seppänen S. and Magnusson R. (2015), Inclusion of the heating sector in the EU ETS, Finnish Energy Industries 30 June 2015, Presentation, [https://energia.fi/files/995/gs\\_ets\\_heating\\_presentation\\_2015\\_0.pdf](https://energia.fi/files/995/gs_ets_heating_presentation_2015_0.pdf)

Stern J. (2017), The Future of Gas in Decarbonising European Energy Markets: the need for a new approach, <https://www.oxfordenergy.org/wpcms/wp-content/uploads/2017/01/The-Future-of-Gas-in-Decarbonising-European-Energy-Markets-the-need-for-a-new-approach-NG-116.pdf>

Stratego, Enhanced heating and cooling plans (2015), Quantifying the Heating and Cooling Demand in Europe Work Package 2 Background Report 4, <http://stratego-project.eu/wp-content/uploads/2014/09/STRATEGO-WP2-Background-Report-4-Heat-Cold-Demands.pdf>

Warwick HRI (2007), Final report to Defra, AC0401: Direct energy use in agriculture: opportunities for reducing fossil fuel inputs, [http://ukerc.rl.ac.uk/pdf/AC0401\\_Final.pdf](http://ukerc.rl.ac.uk/pdf/AC0401_Final.pdf)

NOTE: Websites and articles from newspapers, newsletters and magazines listed in the footnotes have not been included in this bibliography.