2050

Heat Roadmap Europe

A low-carbon heating and cooling strategy

Profile of heating and cooling demand in 2015

D 3.1

2017

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Table of Contents

1. Introduction

In Europe, there is a clear long-term objective to decarbonise the energy system, but it is currently unclear how this will be achieved in the heating and cooling sector. The Heat Roadmap Europe (HRE) project will enable new policies and prepare the ground for new investments by creating more certainty regarding the changes that are required. Heat Roadmap Europe is co-funded by the European Union, brings together 24 academic, industrial, governmental and civil society partners, and runs from 2016-2019.

The overall objective of the HRE project is to provide new capacity and skills for lead users in the heating and cooling sector including policymakers, industry, and researchers at local, national, and EU levels by developing the data, tools, and methodologies necessary to quantify the impact of implementing more energy efficiency measures on both the demand and supply sides of the sector.

This WP3 report presents a breakdown of both the demand and supply of heating and cooling energy for the year 2015 and thus provides the starting point for the scenario analyses up until 2050.

Conventional energy balances (both national and Eurostat) generally provide the final energy demand split by sector (residential, industry, tertiary and transport), energy carrier and also by sub-sector for industry. They do not usually provide information on end-uses such as heating, cooling, mechanical energy or useful energy (i.e. the heat that is used by the consumer, e.g. for heating a room). A recent review found that several EU countries provide end-use balances for the residential sector and some for the tertiary sector, but only three countries do so for the industry sector (United Kingdom, Germany and Austria) (Fraunhofer ISI et al. 2016). However, the method and definitions used in the various countries deviate from one another and it is not possible to derive a consistent EU-wide end-use energy balance simply by combining national data (Fraunhofer ISI et al. 2016).

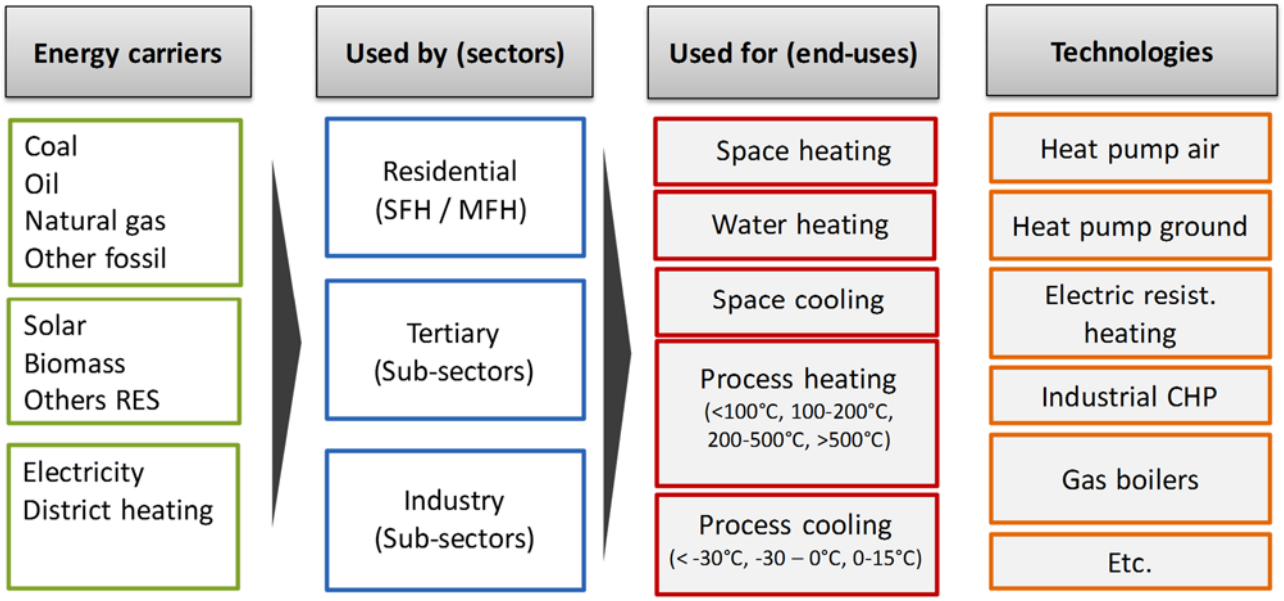
As a consequence, the energy demand for heating and cooling (H/C) cannot be derived from the currently existing official energy balances in a consistent way for all EU countries. Neither is it possible to calculate the share of renewable energies in H/C without simplification as done, for example, in the SHARES project[1], which excludes all electricity consumption from H/C energy use. This approach does not provide accurate results in many countries.

Therefore, this deliverable aims to profile the energy demand for H/C by calculating energy balances for all 28 EU countries that include H/C. However, the focus of the analysis and input-data quality checks is on the 14 EU countries with the highest H/C demand as in the other HRE deliverables. The remaining 14 countries were added so

[1] http://ec.europa.eu/eurostat/de/web/energy/data/shares

that figures could be presented for the entire EU28. The balances are based on the same method applied across countries, which should make them comparable and consistent. The approach used combines empirical data, e.g. market shares, industrial production or technology stock with bottom-up model simulation to derive energy demands for 2015. The bottom-up model FORECAST[2] is used for this purpose.

2015 was chosen as the start year for scenario development in the HRE4 project so the H/C profile is also developed for 2015. This poses a few challenges related to data availability. At the time of calculating the 2015 profiles, there was no final energy demand balance available from Eurostat, which is ideally used for calibration. Other input data are also only available for earlier years (e.g. industrial production statistics). As a consequence, we calculate the 2015 heating and cooling profiles based on model runs that begin in 2012.



SFH = Single-family house; MFH = Multi-family house, CHP = combined heat and power, RES= Renewable energy sources

Figure 1: Overview of disaggregation of H/C profiles by country (based on Fraunhofer ISI et al. 2016)

The H/C profiles comprise all the elements also included in the Eurostat final energy balances (e.g. energy carriers and sectors). They are then broken down by sub-sector, end-use technology and even by temperature level for the industry sector to provide a complete picture of energy demand for H/C in the various market segments.

Figure 1 provides an overview of the different dimensions considered. Two examples are given here of how the resulting H/C profiles can be used: to obtain the final energy demand for space heating in multi-family houses in Belgium that is provided by air-

[2] http://www.forecast-model.eu/

source heat pumps; and to show the coal used to provide process heat in the iron and steel sector in Italy in the temperature range above 500°C.

The profiles include final energy demand as well as useful energy demand. We define useful energy demand as the heat provided by the combined system of a boiler plus storage.

In the following, the definitions and data sources are described, before an overview of the main results is provided. The annex gives a more detailed analysis of the H/C profiles in each sector (industry, residential and tertiary).

2. Method, definitions and data sources

2.1. Method

The approach used combines empirical data with bottom-up modelling of energy demand. The empirical data are taken from official national statistics, surveys as well as various statistics provided e.g. by industrial organisations. An overview of the main data sources is provided in section 0. For the bottom-up modelling, we use the energy demand model FORECAST. A separate bottom-up model based on sales data is used only for space cooling as described below.

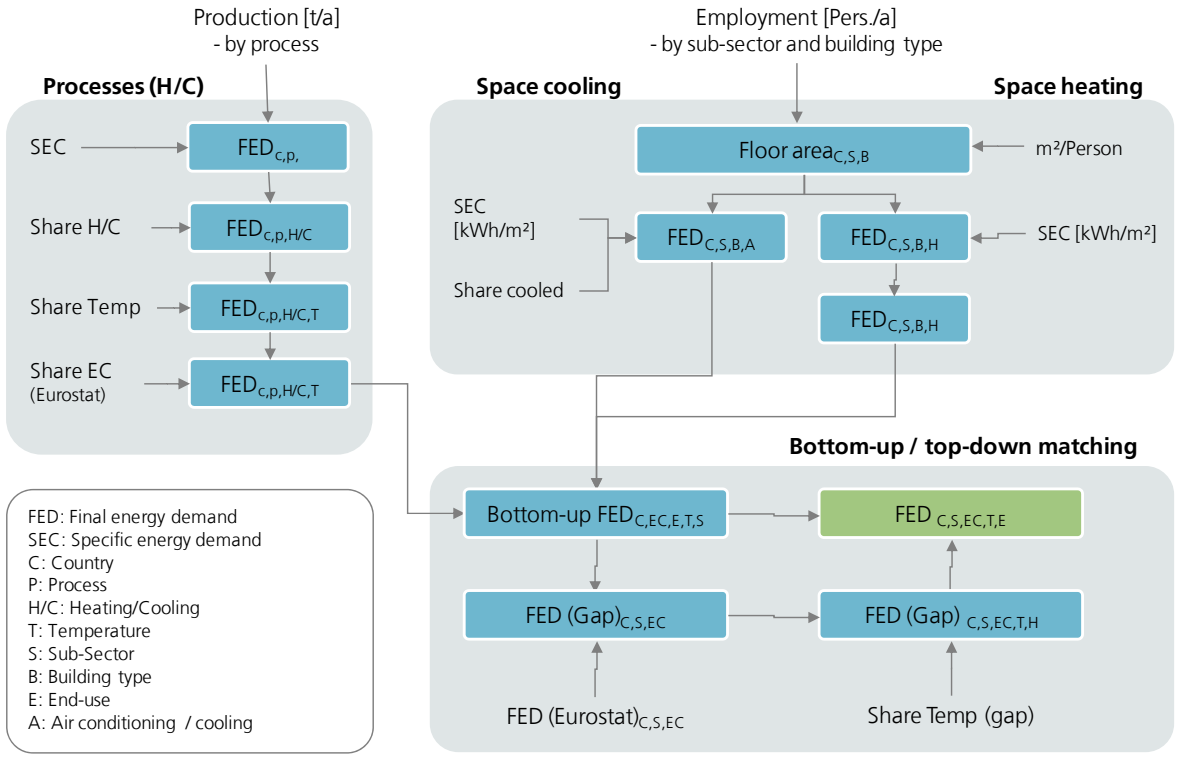
2.1.1. Deriving end-use energy balances using the bottom-up model FORECAST

The FORECAST model comprises three individual modules; each represents one sector in line with the Eurostat (or national) energy balances: industry, services/tertiary and residential. While all the sector modules follow a similar bottom-up methodology, they also consider the particularities of each sector like technology structure, actor heterogeneity and data availability. Energy demand is calculated based on technology structure and technology characteristics as well as economic drivers and prices.

In the short term, the most important determinants of energy demand are ambient temperature (affecting mainly space heating) and economic activity (affecting mainly industrial process H/C demand). While the FORECAST model includes a detailed simulation of technological change based on vintage stock models, these effects are more important in the longer term (e.g. towards 2030 and beyond) and less so in the short term.

FORECAST takes ambient temperature into account using the annual average heating/cooling degree days (HDDs/CDDs) as shown in Table 4. Industrial activity is reflected using the annual value added by sub-sector and the physical production per year for major energy-intensive bulk products (e.g. tonnes of oxygen steel produced). 2015 production data were not available for most of the around 60 products considered and forecasts were made based on past time series. Activities in the services sector are driven by the number of employees and the sub-sector-specific energy demand per employee and floor area.

As an example, Figure 2 shows how end-use energy balances are derived in FORECAST-Industry based on bottom-up data by process and end-use. This approach combines activity data such as production and employment with specific energy demand by process/end-use.



Source: Fraunhofer ISI et al. (2016)

Figure 2: Schematic representation of an end-use balance model calculation for the industry sector (FORECAST-Industry)

Note that the calculation of H/C profiles is largely based on earlier work summarized in Fraunhofer ISI et al. (2016). We also refer to this publication for a more detailed description of the methodology by sector. However, we extend the H/C profile here by including individual technologies such as heat pumps or industrial CHP units and information on the technology stock such as the number of units installed in certain market segments.

2.1.2. Space cooling

Space cooling demand and supply are calculated using a bottom-up model developed by Armines. The demand is then split into sub-sectors according to the cooling shares calculated by the FORECAST model (Aebischer et al. 2007). This approach is used to update the cooling demand figures and is described in the following (for a more detailed description of the approach and the input data, we refer to the separate HRE deliverable on space cooling[3]).

Total space cooling demand and electricity consumption under standard conditions are estimated using equipment sales. These include all vapour compression technologies

[3] D3.2: Cooling technology datasheets and accompanying report "Dittmann, Perret-Gentil, Riviere, Paardekooper, Connolly (2017): "Space Cooling in Europe: Technology Data and Demand Modelling, Mines ParisTech – ARMINES, Paris"

2.2. Definitions

The following summarises the main definitions used for the H/C profiles.

Final energy, delivered heat and useful energy

We define final energy in line with Eurostat as the energy input to the heating unit at the final consumer. Like Eurostat, we also exclude ambient heat used in heat pumps. Only the electricity or gas consumption of heat pumps is included in the final energy.

The definition of useful energy is less standardized. Different studies use different definitions. We define useful energy as the energy distributed to the end-user, e.g. the heat to a room provided by a radiator. Thus, useful energy takes into account potential losses from local distribution, e.g. in the pipes in a building. Fraunhofer ISI et al. (2016) use a similar definition for useful energy. However, our results are not based on useful energy but on delivered energy instead. This is defined at the conversion step from final energy to useful energy (see Figure 4). We define delivered energy as the heat or cold produced by the combined system of an onsite boiler and storage before it enters the distribution system. Possible losses in the distribution system (e.g. within a building) are not taken into account for delivered energy.

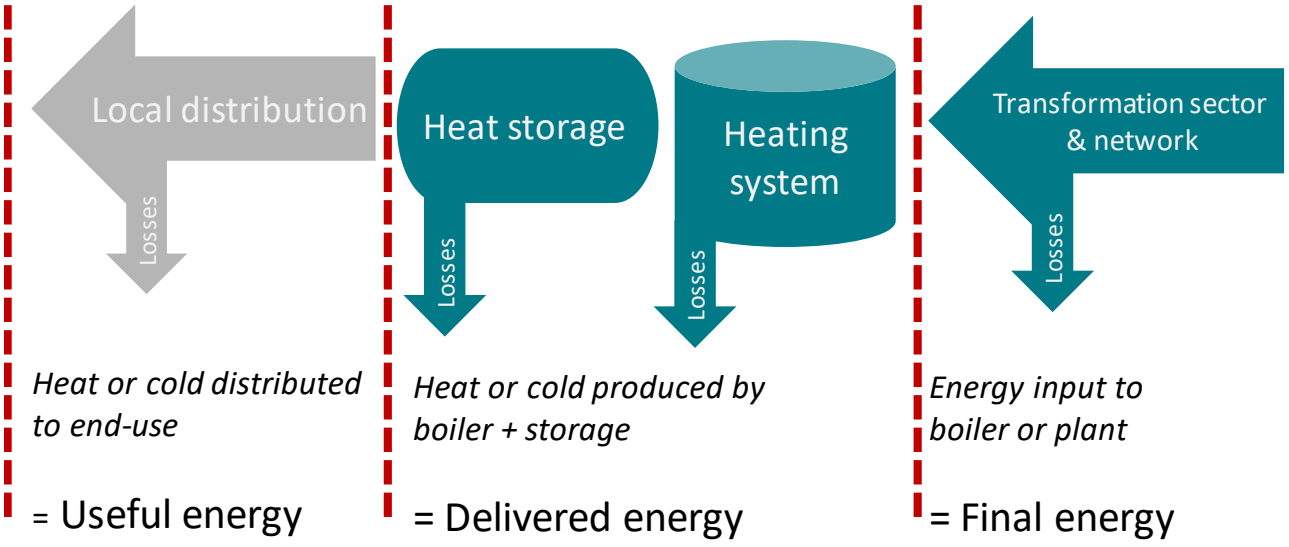


Figure 4: Definition of final, delivered and useful energy

Technologies and energy carriers

A major extension of this report compared to Fraunhofer ISI et al. (2016) is the inclusion of technology information. In order to keep the amount of data to a manageable level, we use one combined dimension to represent energy carriers and technologies. While

some energy carriers are well defined by particular technologies (e.g. gas is mainly used in gas boilers), others are not (e.g. electricity). In the latter case, we split electricity use into individual technologies including air-source and ground-source heat pumps, direct electric resistance heating and compression cooling. Table 1 provides a complete overview.

Table 1: Definition of technologies/ energy carriers

Technology/ Energy carrier (final energy)	Definition / comment
Total	Sum of all energy technologies/energy carriers
Gas	includes all gas technologies not listed separately below, still mainly individual boilers
Oil	see gas
Coal	see gas
Electric heating	Direct electric heating (resistance heating also for night storage)
District heating	DH substations
Biomass	Includes all biomass/biofuels/biogas technologies not listed separately below
Solar thermal	Only solar thermal.
Heat pumps total (electric)	Include only electricity in final energy demand; ambient heat not included; gas heat pumps not included
Heat pumps air-source (electric)	See heat pumps total; only heat pumps using air as heat source
Heat pumps ground-source (electric)	See heat pumps total; only heat pumps using the ground as heat source
Others (RES)	Mainly RES waste and deep geothermal
Others (fossil)	Mainly fuels used in industry including waste, stack gas, etc.
Compression cooling (electric)	Aggregates all cooling technologies

Sectors and sub-sectors

In terms of sectors, we follow the Eurostat energy balance definition by including industry, tertiary/services and residential. For industry sub-sectors, we aggregate the Eurostat energy balances slightly in order to have fewer very small sub-sectors. This aggregation leads to a total of 8 sub-sectors (see Table 2). For the tertiary sector, we also include 8 sub-sectors (see Table 3). Note that Eurostat does not provide information for sub-sectors in the tertiary sector.

Table 2: Definition of sub-sectors in industry

Sub-sectors	NACE 2.0 Divisions
Iron and steel	24.1, 24.2, 24.3, 24.51, 24.52
Non-ferrous metals	24,4, 24.53, 24.54
Paper, pulp and printing	17, 18
Non-metallic mineral products	23
Chemical industry	20
Food, drink and tobacco	10, 11, 12
Engineering and other metal	25, 26, 27, 28, 29, 30
Other non-classified	13, 14, 15, 16, etc

Table 3: Definition of sub-sectors in services

Economic subsector	NACE (2.0)	Description
Trade	G	Wholesale and retail trade
Hotel and restaurant	I	Hotels and restaurants, camping sites, mountain refuges, bars, canteens, catering
Traffic and data transmission	H, J	Transport (railway, road, water, air), storage and communication, cargo handling, post, telecommunications,
Finance	K	Finance and insurance
Health	Q	Health and social work, hospital activities, social work activities with accommodation
Education	P	Primary and secondary education, higher education
Public administration	O	Public administration and defence, compulsory and social security
Other services	L,M,N,R,S	Other services (waste, sport, social services) + real estate and other services

Heating degree days (HDDs)

Heating degree days are used to correct space heating demand to the respective climate conditions of 2015. HDDs are taken from Eurostat as shown in Table 4. For most countries, 2015 has lower HDD values than the average annual values from 2010 to 2015. This means the demand for space heating was lower because 2015 was a relatively warm year.

Table 4: Heating degree days (HDDs) used (source: Eurostat)

Country	2010	2011	2012	2013	2014	2015	Average 2010-2015
EU-27/28	3,473	3,119	3,420	3,218	2,809	2,904	3,157
Austria	3,704	3,404	3,554	3,640	3,125	3,318	3,457
Belgium	3,174	2,399	2,772	3,024	2,315	2,633	2,719
Bulgaria	2,596	2,796	2,611	2,414	2,371	2,374	2,527
Croatia	n.a.	n.a.	n.a.	2,301	1,895	2,256	n.a.
Cyprus	442	832	826	701	556	750	685
Czech Republic	3,832	3,234	3,399	3,512	2,918	3,090	3,331
Denmark	3,971	3,150	3,423	3,402	2,855	3,114	3,319
Estonia	4,818	4,083	4,579	4,152	4,142	3,791	4,261
Finland	6,058	5,251	5,857	5,278	5,242	5,031	5,453
France	2,707	2,053	2,441	2,636	2,085	2,257	2,363
Germany	3,611	2,868	3,126	3,288	2,661	2,908	3,077
Greece	1,343	1,790	1,655	1,451	1,393	1,578	1,535
Hungary	2,936	2,815	2,771	2,687	2,286	2,597	2,682
Ireland	3,125	2,754	2,858	2,835	2,631	2,913	2,853
Italy	1,992	1,861	1,968	1,933	1,632	1,810	1,866
Latvia	4,622	3,940	4,320	4,037	3,948	3,658	4,088
Lithuania	4,409	3,768	4,082	3,872	3,727	3,524	3,897
Luxembourg	3,358	2,624	2,917	3,229	2,500	2,853	2,913
Malta	385	549	662	460	374	544	496
Netherlands	3,300	2,512	2,814	3,010	2,285	2,625	2,758
Poland	3,881	3,317	3,552	3,505	3,095	3,113	3,410
Portugal	1,290	1,087	1,348	1,340	1,147	1,080	1,215
Romania	2,988	3,173	3,090	2,863	2,729	2,786	2,938
Slovak Republic	3,467	3,248	3,299	3,241	2,718	3,057	3,172
Slovenia	3,041	2,818	2,832	2,867	2,342	2,700	2,767
Spain	1,913	1,562	1,871	1,910	1,570	1,612	1,740
Sweden	5,874	4,927	5,504	5,186	4,887	4,910	5,214
United Kingdom	3,403	2,846	3,183	3,179	2,740	3,017	3,061

2.3. Data sources

The following table provides an overview of the main data sources used.

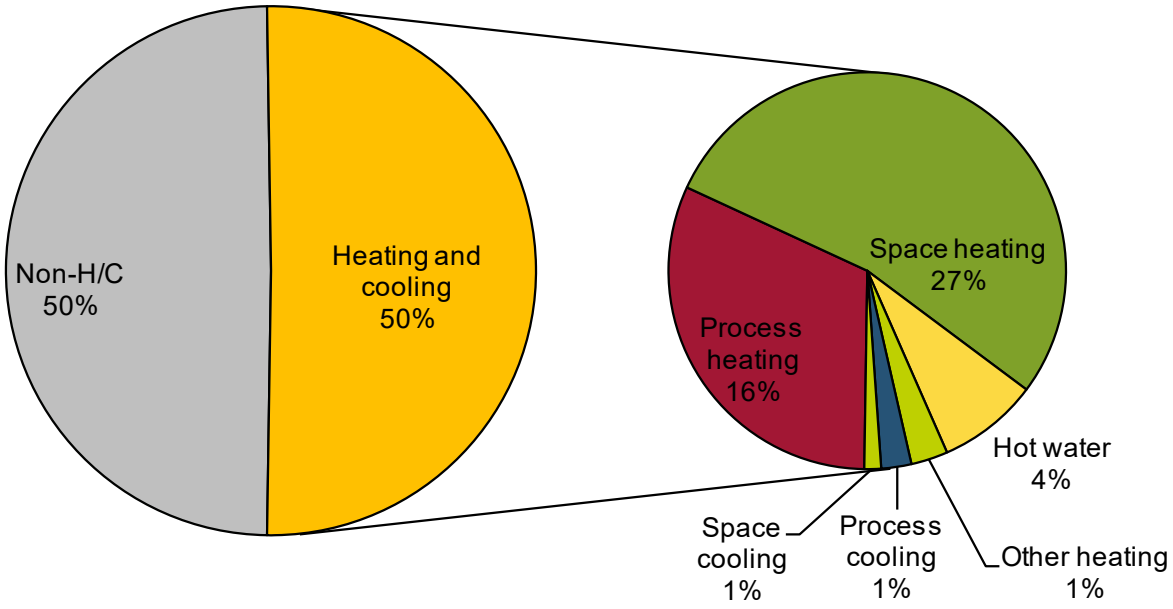
Table 5: Selected data sources used

Sector	Sub-area	Data sources used
Residential sector	Dwelling stock, living area	Enerdata (2016b), Enerdata (2016c), Eurostat (2016)
	Technology and energy-related data	Enerdata (2016b), Enerdata, TU Vienna, Fraunhofer ISI et al. (2016), Fraunhofer ISI, Fraunhofer ISE, IREES et al. (2016)
Tertiary sector	Building and technology data	EUROSTAT (number of employees), EU Building observatory, BPIE, Odyssee database (general), FhG-ISE survey data (district heat), various EuP preparatory studies, IREES and ARMINES (cooling technologies)
Industry sector	Industrial production	Prodcom, UNFCCC, Eurostat, industrial organisations (VDP, Cembureau, World Steel Association, Glassglobal) US geological survey
	Technology data	PLATTs database, Eurostat CHP statistics, numerous individual studies for individual sub-sectors, e.g. Fleiter et al. (2011)
Cross-cutting	Renewable energy technologies	Eurostat energy balances, EHPA market reports, Observ´ER market reports
	Final and useful energy demand	Eurostat and national end-use energy balances such as DUKES for the UK.
	Space cooling	Space cooling sales: BSRIA WMI Market studies, Eurovent Market intelligence Specific demand (Service sector): District cooling deliveries (Werner, 2015) Specific demand (residential sector): Dynamic building demand modelling (Rivière et al., 2008) Standard SEER values of sales: EU studies (Adnot et al., 1999), (Adnot et al., 2003), (Rivière et al., 2009), (Rivière et al., 2012), current Eurovent Certification product directory, public information and regulatory information from air conditioner labels and MEPS (EC, 2002), (EU, 2011), (EU, 2012) and (EU, 2016);

3. Summary of main results

The resulting heating and cooling profiles allow a very detailed insight into the pattern of H/C demand and supply by country, end-use, sector, sub-sector, energy carrier and temperature level.

A few selected main results are presented here. A more detailed analysis of the results is given in the annex to this report and allows deeper insights into the individual sectors.



Other heating = cooking in residential buildings

Figure 5: Heating and cooling demand in 2015 in the EU28 by end-use compared to total final energy (FED) demand

Further key results are:

- With a final energy demand (FED) of 6350 TWh in 2015, H&C is very important and accounts for **~50% of EU28 FED**
- **Space heating** (53% of FED for H/C) is the most important individual end-use followed by **process heating** (32% of FED for H/C)
- **Cooling** accounts for ~2% of total FED for H&C and has low shares in most countries, but the potential to grow strongly in the future
- **Space heating** is important in almost every country, while **space cooling** is only relevant in southern countries.

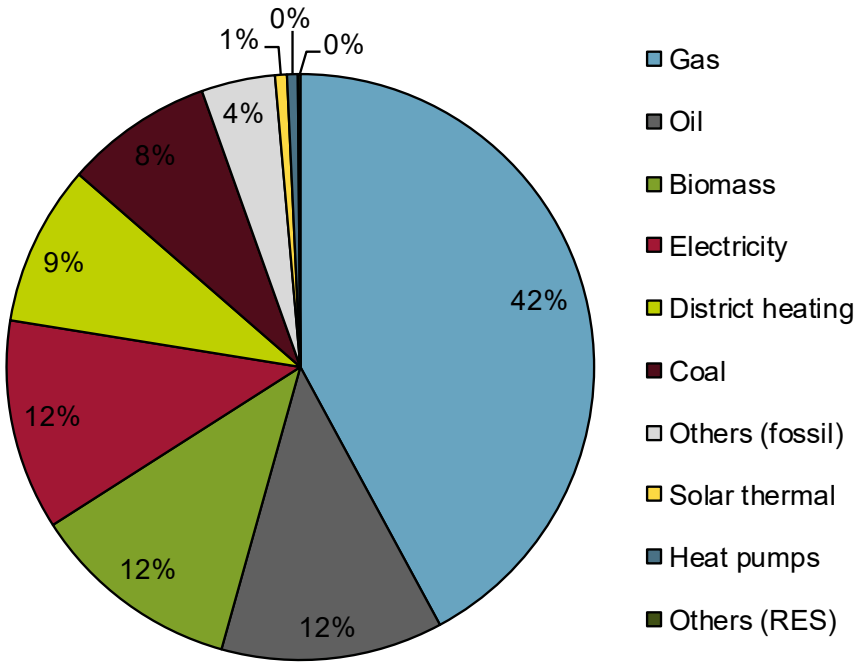
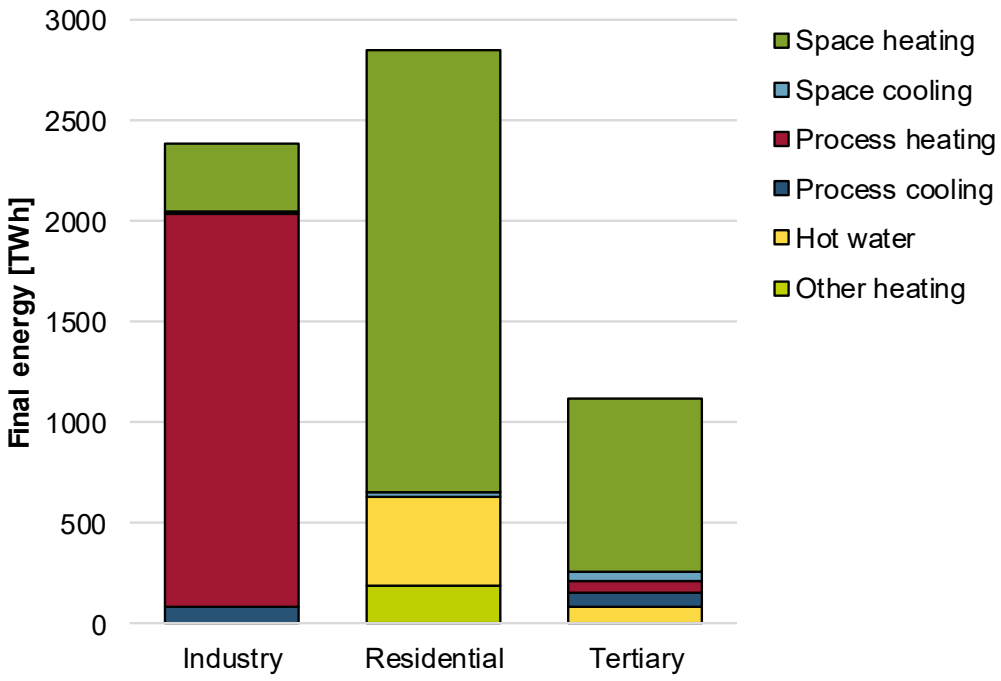


Figure 6: H&C final energy by energy carrier in 2015 (EU28)

The energy carrier mix for H/C shows the following pattern:

- **Fossil fuels** account for >65% in EU28 FED
- Electricity and district heating account for 21% (mainly based on fossil fuels)
- **Renewable energy sources** (RES) account for about 13%
- **Gas** is the most dominant fuel in EU28 (422%) and in most countries
- Of the available **RES**, only **biomass** is used substantially (12%); solar thermal, geothermal and heat pumps are still marginal in almost every country
- However, the composition of **energy carriers** for H&C supply is very diverse across countries.



Other heating = cooking in residential buildings

Figure 7: H&C FED by sector and end-use (EU28, 2015)

Key results by sector:

- With about 2850 TWh, the residential sector has the highest FED for H/C followed by industry (2390 TWh) and the tertiary sector (1120 TWh)
- Process heat accounts for about 80% of H/C FED in the industry sector
- Industrial process heat >200°C accounts for ~50% of industrial H&C FED, and poses a challenge when switching to RES
- The end-use and energy carrier structure in industry vary strongly by sub-sector
- In residential space heating, SFHs are twice as important as MFHs as an EU28 average
- In the tertiary sector, all sub-sectors are dominated by space heating
- Space cooling is much more important in the tertiary sector than in the residential sector.

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