Preparatory Studies for Ecodesign Requirements of EuPs (III)

ENER Lot 21 – Central heating products that use hot air to distribute heat
Task 3: Consumer behaviour and local infrastructure

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Task 3: Consumer behaviour and local infrastructure

This chapter presents an analysis of the influence that consumer behaviour and local infrastructure have on the use of central heating systems that use hot air to distribute heat during particular phases of their life-cycle (notably the use and end-of-life phase). To some extent, product design can be used to influence a consumer's behaviour so as to influence the environmental impacts and the energy efficiency associated with product use. This section also identifies barriers and restrictions to possible Ecodesign measures due to social, cultural or infra-structural factors. A second aim is to quantify relevant user-parameters that influence the environmental impact during product life that are different from the standard test conditions as described in Task 1. Further, analysing real life use conditions of products in comparison with standard test conditions will provide a more accurate picture of the real energy use.

3.1 Consumer behaviour

This section looks at how consumer behaviour affects the real life efficiency and environmental impacts of air-based central heating systems in the use and end-of-life phase. Assessment of the impact of consumer behaviour needs to take into account their influence on following parameters:

- Factors that influence purchasing decisions
- Installation requirements
- Frequency and characteristic of use
- Real life efficiency, such as load efficiency (real load vs. nominal capacity), temperature- and/or timer settings; quality and consumption of auxiliary inputs; power management enabling-rate and other user settings, repair and maintenance practice (frequency, spare parts, transportation and other impact parameters)
- End-of-life behaviour

3.1.1 Factors influencing purchase decisions

The purchase of a heating system is the first step by which consumer behaviour can have an effect on the products covered by the ENER Lot 21 preparatory study. Appliance functionality, investment and operation costs are usually the primary deciding factors influencing the purchase of an air-based central heating system. Purchasing price and running costs are discussed in further detail in Task 2.

According to information provided by stakeholders through questionnaires, the most important criteria for the customers are:

- Product price
- Functionality (performance, time of response, etc.)
- Type of fuel used

Safety and running costs have also been pointed out as important drivers for the purchase decision. Aesthetics and design are not important in the purchasing decision of an air-based central heating system. Another aspect quoted by stakeholders as possible driver for the customer is the noise level of the system.

Regarding environmental characteristics, the most important criteria for customers are:

- Energy consumption
- Type of fuel
- Product technical life

Pollutant emissions are not a driver for purchase according to stakeholders. It is important to note that the aspects pointed out as important for the end user relate to consumer expenditure, which can be the underlying driver for the purchasing decision.

Oughton and Hodkinson[1] present a list of factors influencing choice of residential heating systems:

- Personal preferences: aesthetics, perception of thermal comfort and convenience of use
- Routine of daily occupation (use patterns)
- Potential energy and cost savings
- Installation costs
- Advice from heating product manufacturers and energy suppliers (e.g. gas, electricity, etc.)
- Local or national building regulations
- Possible choices in existing or new buildings
- Availability of infrastructure or fuel supply

Other factors such as the influence of installers, contractors, architects and building developers are also important. These are discussed in further detail below.

- Functionality

Most air-based central heating systems are used as the primary source for heating homes and buildings. As discussed in Task 1, hot air central-heating appliances can be used in very diverse

[1] Oughton & Hodkinson (2008) Faber & Kell's Heating and Air-Conditioning of Buildings. Tenth edition. Elsevier Ltd.

sectors. According to the approach[2] proposed by DG ENTR Lot 6 study, taking regional, national and EU level patterns into consideration, the application of central space heating market in EU can be classified into following dwelling types:

- Multi-family residential dwellings
    - Low-rise multi-family dwellings
    - High-rise multi-family dwellings
- Public sector dwellings
    - Health care dwellings
    - Educational dwellings
    - Dwellings for Justice
    - Dwellings for Defence
    - Home office and municipalities dwellings
    - Other public buildings
- Service sector dwellings
    - Retail stores/malls
    - Wholesale dwellings (excluding warehouses)
    - Dwellings for motor vehicle trade
    - Hotels and restaurants
    - Dwellings for business services
    - Transportation and communication
    - Financial institutions
- Heating demand in primary and secondary sectors
    - Industrial buildings
    - Warehouses
    - Agriculture sector

The heating modes will largely depend on the functions of the sector in which the hot air appliances are used: for instance for central heating in houses, low output and constant comfortable temperatures will be required, whereas for a gymnasium or a supermarket heating demands are far less stringent. Well-designed central heating systems that use hot air can warm the indoor faster than hydronic central heating. This is because hydronic heating systems use intermediate fluids (such as water).

[2] ARMINES (2011) Preparatory study ENTR Lot 6 (Air conditioning and ventilation systems), Task 3 report. Study commissioned by the European Commission. Available at: www.ecohvac.eu/documents.htm

A UK study conducted household interviews with six recent buyers of new heating systems in the Oxfordshire area. One of the questions asked included reasons for purchasing and installing a new central heating system. Although the responses referred particularly to central heating boilers, general observations can be made about the installation of new central heating systems in general. The survey findings indicate that the three main motivations for changing the central heating system were:

- System breakdown or development of faults
- Home improvements (particularly kitchen refits)
- Changing household needs which require a heating system with a higher output or different qualities

The survey results also found that a system change prompted by concerns over the efficiency of the existing installation appeared rare. Figure 3.1 provides a breakdown of reasons and percentages from the study.

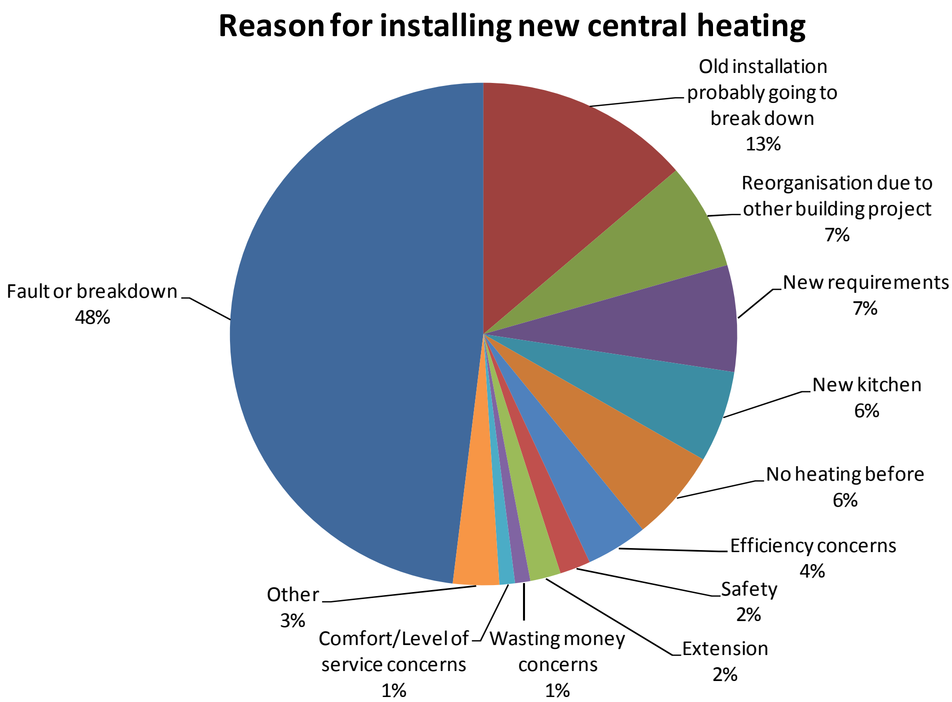

Figure 3.1: Main reasons for installing a new central heating system (GfK2 data)[3]

- Influence of installers and housing developers

Air-based central heating systems require professional installers to ensure proper and safe installation. Therefore, to a certain extent installers have an influence on the type of air-based central heating system that the consumer purchases. Installers may be used to working with a select range of models which they have experience with and some installers have relations with manufacturers, creating loyalty towards certain types and brands of central heating systems[3].

[3] Environmental Change Institute, ECOFYS & ISR (2000) The UK domestic heating industry – Actors, Networks and Theories. In: Lower Carbon Futures for European Households. Available at: www.eci.ox.ac.uk/research/energy/downloads/lcfreport/appendix-c.pdf

Furthermore, housing developers, architects, consultants or investors/landlords can also influence the decision of the air-based central heating system. Manufacturers also offer trainings to installers on the newly developed technologies, repair and maintenance techniques, etc. Changes of use in buildings (i.e. residential buildings converted to offices or vice-versa) may also influence the suitability of the heating system installed when the building was planned.

Depending on the sales channel of central air-based heating products (via distributors, contractors or installers), different heating professionals will try and influence consumers on their choice of heating system. See Figure 3-2 for an example of actors that are implicated in the process of choosing a heating system.

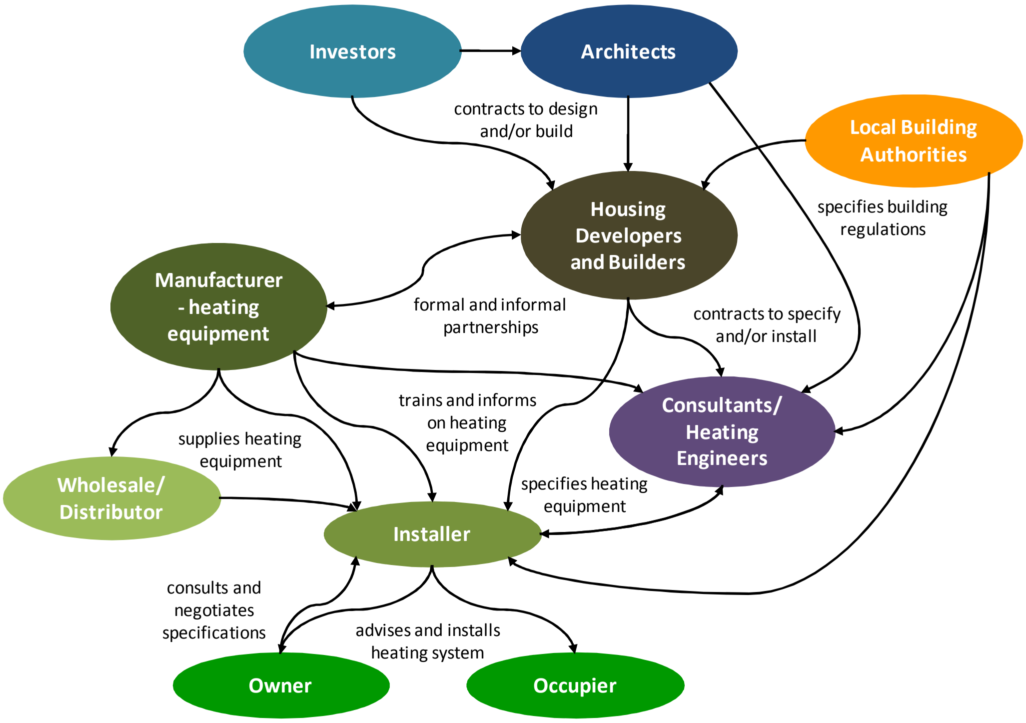

Figure 3-2: An example (not generic) of what actors are involved in the specification of installed heating equipment[4]

A number of actors in the professional network come to play when a new heating system is about to be installed. For new buildings the contractors will often hire professional heating (or HVAC) consultants to advise and specify the system. This is done based on information on the building, its heating requirements, the owner's or occupier's preferences and product information from heating equipment manufacturers. In existing buildings the owner or occupier may simply ask an installer to plan and specify the heating system, or also contract a heating (HVAC) specialist for larger and complex systems. Regardless of the process, it is important that the right information on the products and building are used to ensure the heating system is suitable for the purposes and dimensioned correctly.

[4] Environmental Change Institute, ECOFYS & ISR (2000) The UK Domestic Heating Industry – Actors, Networks and Theories. In: Lower Carbon Futures for European Households, 2000. Available at: www.eci.ox.ac.uk/research/energy/downloads/lcfreport/appendix-c.pdf

- Economic factors

Findings of Task 2 indicate that in the industry and service sectors, the demand for hot air central heating appliances may be tied to economic growth. This is particularly the case for Eastern European markets, which are likely to continue their current growth in industry and services. This is expected to positively impact the hot-air heating appliances market. Within the residential sector, the growing demand for air-conditioning appliances (see DG TREN Lot 10 study[5]) may help shift the central heating market towards air circulation systems, which should open an opportunity for hot air heating systems to penetrate the residential market. However, since the scope of ENER Lot 21 is limited to those appliances above 12kW of cooling capacity, this kind of machines for the residential market are installed in apartment buildings rather than in single homes. Furthermore, air-based central heating systems are generally less expensive than boiler/hydronic systems, which use heated liquids (such as water) for heat distribution.[6] However, a major limitation of air-circulating systems compared to water-based ones, is the space taken up by air ducts compared to hot water pipes. There are however some technologies in the market which have less space requirements, such as mini-duct systems. As a result, the market for hot air systems is more likely to develop in locations where the price for floor space is lower, such as in rural areas. Finally, costs related to energy consumption, performance, and repair and maintenance services are also important aspects that influence consumer purchasing decision.

- Safety and health risks

There are some safety risks associated with owning an air-based central heating system. The risk of fire can exist in the case of improper installation or inappropriate behaviour (electrical or gas heaters). The risk of carbon monoxide poisoning can exist in the case of direct heating fire systems. Nevertheless, local regulations consider those points.

Other health risks include breathing in warmer dry air. The warm air produced by the central heating system holds more moisture than cold air, and thus will pull moisture from other sources, including occupants from the room. Warmer air will dry out the mucous membranes of the nose, which can in turn cause colds and aggravate asthma and allergies. Skin may also become drier, chap or itchy[7]. The effects of warm air can be offset by adding more moisture to the air (e.g. drying clothes indoors, or drying clothes or towels indoors, or putting indoor plants, which will release moisture throughout the day, use of an air humidifier, etc.). Some warm air distribution systems include air humidifiers and dehumidifiers as options to improve customer's comfort.

Finally, dust mites and allergies to dust-mite is another health affect to consider with the purchase of an air-based central heating system. Dust mites thrive in the winter in warm sealed environments which is created with central heating systems and sealed windows. Other problem that air-based heating systems using water or moisture might present is contamination by *legionella* bacteria. *Legionella* is commonly found in water and can multiply in cooling towers if

[5] ARMINES. Preparatory study EuP Lot 10. Study commissioned by the European Commission. Available at: www.ecoaircon.eu

[6] The Sideroad. Hydronic Heating versus Forced-Air-Heating. www.sideroad.com/Home_Improvement/hydronic-heating-forced-air-heating.html

[7] RISKCOLLECTIVE. Central Heating and your health. www.riskcollective.com/central-heating-and-your-health-top-tips-for-keeping-warm-and-safe-this-winter-2537.htm

water temperature is suitable. Humidification systems can also be a potential hazard. However, water treatment and control is a common practice in the industry and risks associated to *legionella* have been minimised.

- Other factors

Ease of use in terms of design and functionality are also important factors that influence consumer purchasing decision on a central heating system that uses hot air for heat distribution. These central heating systems are usually straightforward to use and gives the user great control over the amount of heat delivered and the duration. Most of these heating systems have built-in thermostat controls, which can be set at optimum temperatures for the building or for certain more advanced systems for individual rooms. Finally, as consumers are growing increasingly aware of environmental issues, air-based central heating systems that incorporate environmentally friendly or renewable energy (heat pumps, solar heating) components may be more attractive to certain consumers.

3.1.2 Installation requirements

Different installation requirements apply depending on the type of air-based central heating system and building codes. Three main types of installation practices exist based on the type of air-based central heating system:

- **Room sealed units**: combustion air taken from outside the building to be heated and flue gasses evacuated by means of an extractor fan
- **Power vented units**: combustion air taken from inside the building to be heated and flue gasses evacuated by means of an extractor fan
- **Gravity vented units**: combustion air comes from inside the building, evacuation of flue gasses due to natural draft (no extraction fan)

In the majority of cases, air-based central heating systems need to be installed by professionals as proper ventilation and duct systems have to be put in place. Ventilators are almost always fitted as part of the original installation. It is important that these ventilators remained unblocked.

Many central heating systems using hot air to distribute heat are 'open flued'. This means they have a 'chimney' type flue to remove the burned gas, or products of combustion. For the open flue to work correctly and safely it is of critical importance to have a ventilation grill to outside air that lets fresh air in to replace the flue gas going out (up the chimney flue), and to provide oxygen for combustion[8].

Task 1 provides more detailed information on standards and regulations that govern the installation requirements for central heating systems using hot air for heat distribution.

[8] Mike BRYANT. Specialist of boiler repair. www.mikethehoilerman.com/warmair.htm

3.1.3 Frequency and characteristic of use

In the domestic sector, most air-based central heating systems are likely to be used continuously over the heating period season, but the heat demand is influenced by the weather conditions, varying user needs, etc. In commercial and industrial sectors, the frequency and characteristics are likely to vary according to the precise activities carried out in the building. For instance, the effect of local conditions is less important for the retail sector and even less in the industrial sector, although not negligible. Regardless, energy consumption and end-user patterns of hot air central-heating products will depend on the nature of the building envelope (e.g. materials, air-tightness), and on levels of insulation and ventilation. Variables which influence the heating demand in EU 27 include:

- Product related:
  - Type of fuel used
  - Capacity output
  - Efficiency range
- Purchasing process related:
  - Consumer
  - Building developers
  - Landlords
- Environment related:
  - Length of heating season
  - Consumer environmental awareness
  - Energy supply infrastructure

User-defined parameters include the following aspects which will be discussed further in this section:

- Frequency and characteristic of use: e.g. months per year and hours per day the equipment is used, and at which capacity
- Consumer and product design interaction, e.g. if a certain hot air appliance is designed in a way to ensure easy access to components requiring maintenance services which facilitate best-practices in product maintenance.

▶ Impact of climate conditions on the usage of air-based central heating systems

As for all central heating appliances, the colder the local climate is, the higher is the demand for space heating. The heating supply should compensate for heat transmission losses through walls and roofs and for heating supply air in mechanical or natural ventilation systems. Therefore, outdoor temperature is the most important variable in order to explain both the daily magnitude and variations from one year to another in the overall heat demand. However, while this is true for the residential and services sector, the correlation between outdoor temperature and heat demand is generally not so visible in the industrial sector, where much of the hot air appliances are used.

The calculation of heating degree days (HDD) and the length of the heating season are important indicators that can be used to help estimate heating demand based on climatic conditions. HDD is an indication of heat demand based on outdoor temperatures. The greater the number of heating degree days, the more the heating system must work in order to keep the inside environment comfortable. HDD is calculated relative to the base temperature, which is the outside temperature above which a building needs no heating. Figure 3.2 shows the average heating degree days for EU-27 over the period 1980-2004, weighted by dwelling stock. Due to the large climatic differences between Member States (MS), the frequency and characteristics of use are likely to vary considerably across Europe. Table 3—1 regroups the HDD averages across MS by average heating season and number of heating days per group.

According to the recently published "The European Environment State and Outlook 2010", heating degree days have declined in almost all European countries since 2004. Climate change has lead to an increase in mean land surface temperature and winter temperatures in Europe are increasing more rapidly than the temperature during summer[9]. Therefore, despite a short term increase in 2008 and 2009, heat demand still remained below the 1980–2004 mean. This indicates that warmer winter days (and thus decreasing heating degree-days) will be an important aspect to consider for later tasks.

For a typical European space heating demand corresponding to a degree-day number of 2600, an increase of the indoor temperature by 1 °C will increase the heat demand for space heating by 8%.[10] This relative change will be lower for colder climates and higher for warmer climates. Available long-term measurements of indoor residential temperatures give the level of 18 °C in United Kingdom, 20 °C in Ireland, 21-22 °C in Sweden. [11] In South-East Europe, substantially reduced indoor temperatures have been a reality during the recent years for the poorest part of the population with respect to affordability. The optimum indoor temperature for health is between 18-24 °C[12]. Climatic conditions and user preferences for indoor air temperature are primordial factors in determining the frequency and the characteristics of use (temperature and timer settings) of central heating.

[9] EEA (2010) The European Environment State and Outlook 2010: Thematic Assessment, Mitigating Climate Change. Available at: www.eea.europa.eu/soer/europe/mitigating-climate-change/at_download/file

[10] EcoHeatCool (2006) Final Report.

[11] EuroHeatCool (2006) The European Heat Market.

[12] WHO (2004) Heat waves: risks and responses. Health and Global Environment Change Series no. 2.

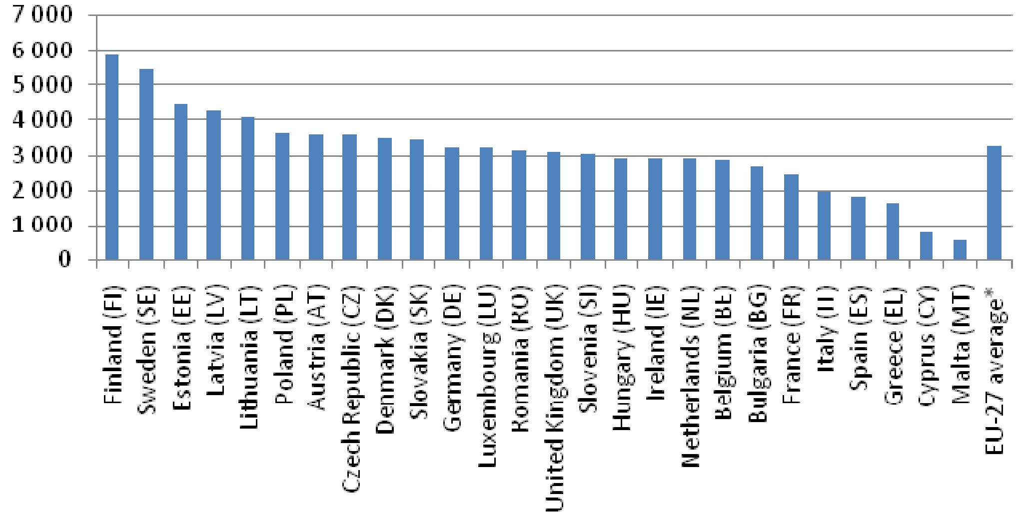

Figure 3.2: The mean heating degree-days over the period 1980-2004 for EU-27, ranked from the highest to the lowest[13]

It is also important to consider different climate zones of Europe because this can affect the efficiency of the heating system.

The yearly average of the daily temperature outside an EU dwelling is 11.7 °C, with the coldest month being in January (3.5°C) and the warmest August (20.7°C). At the level of country capitals, the coldest month is in Helsinki (Finland) in February (-4.5°C) and the warmest is Larnace (Cyprus) in August (27.3 °C)[14].

As examples of particular climate zone three regions have been highlighted:

- The coldest member states include Sweden, Estonia, Latvia, Finland (5,423 degree days long term) with a heating season of 10 month (Group 1).
- The warmest member states are Cyprus(787 degree days long term), Spain, Portugal, Greece, Malta and Italy(Rome) with a heating season of 4 month and with over 4,000 Wh/m^2/day on a horizontal surface (Group 3).
- The rest countries from the EU-27 are from the middle climate category with a heating season of 6-8 month (Group 2).

Table 3—1 regroups the HDD averages across MS by average heating season and number of heating days per group[15].

[13] Eurostat. Energy statistics. http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/themes

[14] ENER Lot 1 preparatory study on Boilers, task 3 report.

[15] The three climatic zones are defined as proposed in the JRC Study to develop Ecolabel and Green Public Procurement for Buildings :

- Cold zone : HDD > 4200°C.day
- Moderate zone : 2200°C.day < HDD < 4200°C.day
- Warm zone : HDD < 2200°C.days

Table 3—1 : Average heating season for EU-27 based on average HDD from 1980-2004

Member State	Mean heating degree-days over period 1980 - 2004	Heating season in months	Number of days in heating season	Grouped by heating season average	Average number of days per group	Average duration in months of heating season per group
Finland (FI)	5,849	10.8	323	Group 1	288	9.6
Sweden (SE)	5,444	10.2	306			
Estonia (EE)	4,445	8.8	265			
Latvia (LV)	4,265	8.6	257			
Lithuania (LT)	4,094	8.3	250	Group 2	214	7.1
Poland (PL)	3,616	7.7	231			
Austria (AT)	3,574	7.6	229			
Czech Republic (CZ)	3,571	7.6	229			
Denmark (DK)	3,503	7.5	226			
Slovakia (SK)	3,453	7.5	224			
EU-27 average*	3,254	7.2	216			
Germany (DE)	3,239	7.2	215			
Luxembourg (LU)	3,210	7.1	214			
Romania (RO)	3,129	7.0	211			
United Kingdom (UK)	3,115	7.0	210			
Slovenia (SI)	3,053	6.9	208			
Hungary (HU)	2,922	6.7	202			
Ireland (IE)	2,906	6.7	202			
Netherlands (NL)	2,902	6.7	201			
Belgium (BE)	2,872	6.7	200			
Bulgaria (BG)	2,687	6.4	193			
France (FR)	2,483	6.1	184			
Italy (IT)	1,970	5.4	163	Group 3	138	4.6
Spain (ES)	1,842	5.3	158			
Greece (EL)	1,663	5.0	151			
Portugal (PT)	1,282	4.5	135			
Cyprus (CY)	782	3.8	114			
Malta (MT)	560	3.5	105			

* weighted by dwelling stock

3.1.3.1 Calculation of frequency and characteristic of use

3.1.3.1.1 Heat demand

The ENER Lot 1 preparatory study on boilers analysed EU-27 heating demand and use based on a variety of factors including climatic conditions, EU housing characteristics, demographics, etc. Although ENER Lot 1 and ENER Lot 21 products are not in the same product scope, the main function of the two product groups are similar in that they both are central heating systems. Therefore, findings of ENER Lot 1 study may be interesting and relevant for ENER Lot 21 products.

The main findings on heat load of the Lot 1 study indicate that:

- The average EU-25 space heating/cooling energy demand is 7,400 kWh/dwelling/year, which means 85 kWh/m² in an average dwelling area of 82 m².
- In northern European countries, the heat load is twice this value, whereas in southern European countries the heat load is half of the average value.
- Climatic conditions do not explain completely heating demands, e.g. the highest calculated heat loads per dwelling can be found in the middle of the EU, i.e. in Luxemburg (15,400 kWh/dwelling/year) and Belgium (12,200 kWh/dwelling/year).
- The heat demand in the tertiary sector is around 100-110 kWh/m², or 23 kWh/m³.
- The heat demand in the industrial sector is around 100-110 kWh/m², or 17 kWh/m³.
- The average industrial building in Germany is around 9,744 m³ of volume and 2,500 m² of area.

As shown in Task 2, the Ecoheatcool database estimated a heat demand in the service sector of 229.4 kWh/m², which is twice the figure provided in ENER Lot 1.

In the MEErP methodology report[16] the average space heat demand per dwelling in EU25[17] is described as 12,622 kWh per year, which is 70% higher than the figure in ENER Lot 1.

3.1.3.1.2 Use pattern

Regarding the use pattern of central heating appliances, different assumptions are found in the literature, though mostly focused on residential applications. Johnson (2011)[18] estimates the use pattern of residential air conditioners in 1,995 working hours per year, or 23% of the time, for 18

[16] COWI and VHK (2102) MEErP Methodology Part 2 Final

[17] MEErP Methodology Part 2 Final, p. 151-152

[18] Johnson, E.P. (2011) Air-source heat pump carbon footprints: HFC impacts and comparison to other heat sources. Energy Policy, doi: 10.1016/j.enpol.2010.12.009

different UK residential property types. Nonetheless, it has to be noted that this study was carried out based on the UK climate conditions and different residential buildings in the UK.

The use pattern suggested in the draft standard prEN 14825 and in the ENER Lot 10 preparatory study is 1,400 hours of heating per year, for heating-only appliances operating in the average European climate. This figure is not far from the estimate given by Johnson (2011).

The German standard DIN V 18599-10 defines 33 different types of non-residential buildings such as personal offices, hotels, restaurants, schools etc. and various use-patterns for them. Relevant usage parameters for heating appliances are as follows:

- Average of 273 operating days per year with a minimum of 150 days and maximum of 365 days.
- Average operating usage of 14 hours per day, with minimum of 6h/day and maximum of 24h/day.
- Minimum operating hours per year – 1,500 h for foyer, spectator and audience areas (theatres and event locations).
- Maximum operating hours per year – 8,760 h for hospital ward or dormitory, hotel bedroom, server room, computer centre, exhibition rooms and museums with conservation requirements.

One stakeholder suggested an average duration of the heating season of 216 days of 24 hours with a degree of part load around 20%. This will give a total working time of 5,184 hours per year, independently of the operating mode. The equivalent time per year at full load would be 1,037 hours.

This preparatory study analyses two different product groups of central heating products used in residential and non-residential applications: warm air heaters (residential and non-residential) and heat pumps over 12 kW of cooling capacity (non-residential).

Even though the work pattern of warm air heaters and heat pumps might be different, the primary function is the same and so are the heating days required per year and the heating hours per day for each building and occupation type. On the other hand, the respective hours in full load, part load, or stand-by mode might be different depending on the characteristics of the product and the system.

Therefore, the heating hours per year are estimated in this preparatory based on the existing standards discussed above. Table 3—2 shows the working hours used in this preparatory study.

Table 3—2: Average working hours per year in heating mode of ENER Lot 21 products

Product	Application type	Average heat demand per year	Sources	Equivalent active hours for heating per year	Sources
Warm air heaters	Residential	7,400 kWh/dwelling	ENER Lot 1	1,400	prEN 14825
	Non-residential	63,000 kWh/building	ENER Lot 1, ENER Lot 20	3,024	Eurostat, DIN V 18599-10
Heat pumps	Non-residential				

3.1.3.2 *Best practices in the use phase*

This section discusses best practices in product usage related to how consumer behaviour can minimise the energy losses in the usage of central heating systems that use hot air to distribute heat.

The end-user's behaviour has a significant impact on the energy consumption. Improving simple operational and maintenance practices can reduce energy consumption of 15% or more[19]. Best practices in sustainable product use include:

- Regular maintenance practices
- Choosing a heater with thermostat controls, since it avoids energy waste and over-heating
- Adapted design of the central heating system (power of the appliance, design and size of air ducts, vents and fans)

Maintenance practices can strongly impact the performance of hot air central heating appliances (e.g. changing filters, cleaning the heat-exchanger in the case of indirect-fired appliances). Already, worldwide, a number of governmental agencies and organisations provide recommendations for smart use of central heating products in general and "energy-saving tips" to end-users of such products. Such strategies to reduce the energy use aim at reducing the amount of heating needed, which can be achieved through better equipment settings and through the reduction of heat losses and gains.

One of the most important ways to ensure that air-based central heating systems are being used most efficiently is by providing adequate insulation for the homes and buildings where they are used. Retro-fitting insulation can dramatically improve comfort and save energy. This, however, may be difficult or too expensive in some types of constructions.

In terms of actual use of the central heating system, it is also suggested that thermostats are turned down at night and when away from home. In most homes, 2% of heating bills can be saved for each degree lowered on the thermostat for at least 8 hours each day. Programmable thermostat to automate this process is also an option[20].

[19] Australia Energy Smart Initiative
[20] American Council for an Energy-Efficient Economy. Heating. www.aceee.org/consumer/heating#improve

3.1.4 Real life efficiency direct influence: operational practices

The aim of this subtask is to understand how the real life efficiency of hot air central heating products differs from that tested in standard conditions, and to quantify user defined parameters. Air-based central heating products like warm air heaters, heat pumps and air handling units are mainly used in the industrial and commercial sector. However, the results of this section can be applied to residential usage as well. The differences between the standard test conditions and real life conditions in which hot air central heating products operate will be investigated in detail in order to provide a more accurate picture of the real energy use and environmental impacts of these appliances. Climate conditions, heat generator, heat distribution system, controls, internal room loads and building shell conditions all influence the energy efficiency of heating systems. More specific aspects are analysed in the following section.

- Location of the appliance

Differences between real life conditions and recommended location of the central heat producing unit appear only occasionally. For example, air handling units are designed for indoor or outdoor installation and sometimes, the ambient conditions do not comply with the installation requirement for indoor installation.

According to numerous standard test conditions, heating devices are tested in a well-ventilated, draft free room with a specific ambient temperature (e.g. 20°C ± 5°C). Other ambient temperatures for testing are acceptable provided that the test results are not affected.[21]

Due to the fact that most heaters of central heating products are cased in a bigger housing (e.g. air handling units) influences like wind, etc. cannot affect the heat transfer directly. Other local influences on energy efficiency depend on the ambient temperature where the heat distribution system is installed. In lower ambient temperatures the potential heating loss is higher. To analyse the local effects on central heating products, it is essential to consider the whole heat distribution system.

Furthermore e.g. non-room-sealed burners take the oxygen needed for the combustion from the surrounding room, so the location of the appliance has to be well-ventilated. Lack of air will affect the quality of combustion and consequently the efficiency of the heater.

For the efficiency of heat pumps, the location of the appliance is a fundamental factor. The heat source (air, water, ground, etc.) has to be constant. Therefore, the location has to be chosen well to reach a good coefficient of performance (COP).

- Design and installation of the system

There are often differences related to the proper design and insulation of the air handling unit and ductwork. In order to minimise the purchase costs, unit size is sometimes selected too small and for the same economical reason quality of ductwork is often very poor. On the other hand,

[21] European Committee for Standardization. EN 1020 – Non-domestic gas-fired forced convection air heaters for space heating not exceeding a net heat input of 300 kW, incorporating a fan to assist transportation of combustion air and /or combustion products, chapter 6 – Test methods

bigger projects with less budged limitation tend to oversize the installation in order to assure a good functioning of the system in the worst scenario. This is translated in a central heating system working at part load and performing a poor efficiency. According to manufacturers, a good planning of the real heating needs and a correct design and sizing of the system is key to achieve the optimum performance of each technology. One major impact on energy efficiency of a central heating device is the installation quality of the hot air central heating system and the connected distribution system, as well as the correct adjustment of all components. Ductworks should be established according to the technical standards regarding air tightness and insulation.[22] Missing or insufficient insulation results in energy losses. Therefore it is of great importance to control the quality of installation, in order to minimize heat loss of the distribution system.

Depending on the type of fuel that is used and the supply pressure, a heating device has to be adjusted according to manufacturer's instructions. This means that appropriate equipment (e.g. injectors) has to be installed and adjusted. Standard test methods prescribe that these instructions have to be followed exactly.

Transferred to real life usage this shows that central heating products should only be installed and brought into service by professional technicians. Otherwise it is possible that the heater is not adjusted correctly which can lower its efficiency.

Regarding heat pumps, insufficient insulation, wrongly dimensioned heat pumps and components are the most common issues that lower the efficiency of the product.

- Impact of the gap between user practices and test standard conditions

Table 3—1 provides estimations of the heating time duration for central heating products. These are based on discussions and interviews with stakeholders[23].

Differences between real life use conditions and recommended use are considered by stakeholders to be small. Differences may occur when the consumer purchases a too small unit compared to his needs to minimize the cost[24]. As mentioned in the previous section, other stakeholders commented that the usual operation of air handling units is at part load, which means that the product is oversized.

- Dosage, quality, and consumption of inputs (e.g. fuel)

Test standards include exact requirements for the type and composition of the fuel used for combustion. For example, gas-fired burners have to be supplied with a specific test gas that has to match given parameters and characteristics. All efficiency tests are conducted with this specific test gas. Corresponding to this procedure there are several requests for every type of fuel that can be used. These characteristics of the fuel have an impact on the efficiency because they influence the quality of the combustion directly. Transferred to real life usage this implies that the used fuel and its quality will take effect on the efficiency of any hot air central heating product that generates heat through combustion.

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[22] Schild, P.G.& Railio, J. (2011) Airtight ductwork – The Scandinavian success story. The REHVA European HVAC Journal. Volume 48, Issue 2.

[23] Stakeholder response to the ENER Lot 21 questionnaire.

[24] Stakeholder response to the ENER Lot 21 questionnaire.

Transferred to heat pump technology, the characteristics of the heat source can have a major impact on the efficiency. For example the temperature profile of the heat source is a very decisive factor that affects the COP (coefficient of performance). Therefore variation in the temperature profile results in a variation of energy efficiency.

- Exhaust gas routing

Most hot air central heating devices that are operated with fossil fuels have to be equipped with an exhaust gas system that carries the flue-gas to the outside of the building (indirect-fired heating). This is achieved by connecting the central heating device to a flue pipe system.

Due to the reason that a blocked flue pipe or an inappropriate dimensioning affects the efficiency of the combustion, there are specific technical rules and instructions regarding the installation of the exhaust gas routing that have to be followed. In real life the installation can differ from the requirements, which can influence the efficiency of the product.

Due to the importance of safety in such devices, in some Member States those flue gas systems have to be inspected by technical organisations periodically.

- Operating thermostat settings and user behaviour

Most central heating products come with room thermostats. A thermostat is a temperature regulating device that compares the actual temperature value with the target value and gives a signal to the heat generator whether additional heating or cooling is needed.

Regarding operative thermostat settings, end-users have numerous options to control room conditions. They can manually switch the device on and off, set the desired temperature and programme the thermostat according to occupancy patterns. Therefore it is of great importance to know how to adjust the thermostat correctly and not to influence the temperature sensor by covering it or placing it near heating sources. Manufacturer's instructions usually contain installation and adjustment guidelines that have to be followed.

There are some additional aspects of user behaviour that have negative impact on energy efficiency of central heating devices. Setting the room temperature too high is one of the main problems. This results in a lower efficiency, especially for heat pumps, because they are dimensioned for low temperature heating (e.g. floor heating). Wrong ventilation in heated rooms, additionally fortifies the heating loss (e.g. tilted windows).

3.1.5 Real life efficiency indirect influence: repair and maintenance practices

Regular maintenance is needed to keep air-based central heating systems clean of debris and dust, and to ensure proper air flow. Annual costs of maintenance over the appliance's lifetime are shown in Task 2.

Many manufacturers also provide 1 – 5 years warranty on their appliances, in which case repair costs in the first five years will be covered by the manufacturer. When an annual service maintenance is contracted, such as is commonly done for oil and gas-fired appliances, repair of failed components is typically already included in the service contract, and repair costs can therefore be neglected, but maintenance costs can be higher from the fifth year onwards[25].

Following the manufacturer's repair and maintenance practices, including recommended inspection are important actions to follow for consumers to ensure the effective functioning and sustained operating life of warm air central heating products. Specific maintenance and installation instructions for an air-based central heating system include the following instructions:

- Clean or replace air filters regularly[26]. Some manufacturers recommend that air filters are cleaned every two weeks during the heating season.
- Clean registers. Warm-air supply and return registers should be kept clean and should not be blocked by furniture, carpets, or drapes.
- Tune up the heating system. Oil- and gas-fired warm air heaters and heat pumps should be tuned up and cleaned regularly. Regular tune-ups not only cut heating costs, but they also increase the lifetime of the system, reduce breakdowns and repair costs, and cut the amount of carbon monoxide, smoke, and other pollutants pumped into the atmosphere by fossil-fuelled systems.
- Seal ducts. In homes heated with warm-air heating, ducts should be inspected and sealed to ensure adequate airflow and eliminate loss of heated air. It is not uncommon for ducts to leak as much as 15-20% of the air passing through them. And leaky ducts can bring additional dust and humidity into living spaces. Thorough duct sealing costs several hundred dollars but can cut heating and cooling costs in many homes by 20%.
- Check for wasted fan energy. If warm air heaters are improperly sized or if the fan thermostat is improperly set, the fan may operate longer than it needs to.[27]

3.1.6 End-of-life behaviour

The aim of this section is to study the issues related to the end-of-life consumer behaviour of hot air central heating products covered by ENER Lot 21.

The end-of-life behaviour of consumers concerning air-based central heating systems is important to consider ensuring that the environmental impacts of ENER Lot 21 products are considered across their entire life cycle. Aspects of actual consumer behaviour regarding end-of-life includes aspects such as:

- Economical product life (=actual time to disposal);
- Percentage of recycling, re-use and disposal; and second hand use
- Best Practice in product end-of-life.

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[25] U.S. Department of Energy (2007) Energy conservation standards for residential furnaces and boilers – final rule technical support document.

[26] Tryjefaczka, M. (2011) Performance of filters has the top priority in the Air-conditioning (AC) inspections. The REHVA European HVAC Journal. Volume 48, Issue 2.

[27] American Council for an Energy-Efficient Economy. Heating. www.aceee.org/consumer/heating#improve

3.1.6.1 Economic product life

The lifetime of the appliances is of interest in this study as a key parameter in assessing the Life Cycle Costs of the appliances in the later stages of the study (Tasks 5 to 7).

Average economical product life is the length of time during which the air-based central heating system may be put to profitable use. This is usually less than its technical life (time until which the air-based central heating system functions sustaining minimum acceptable performance criteria). Some preliminary estimates on average economic product life are presented in Task 2, which are based on discussions, interviews with industry stakeholders and questionnaires. As a response to the questionnaire, stakeholders provided estimations for the different appliance types. It should be taken into account however that product lifetime of air-based central heating systems can vary greatly depending on use patterns, climatic conditions and across Member States.

Table 3—3: Product life time of small combustion appliances[28]

Type of appliance	Heat generation source	Average product life (years)	
		Economic life	Technical life
Warm air heaters	Direct- fired gas	10	15
	Indirect-fired gas	15	20
	Liquid fuel	10	20
Heat pumps	VRF	15	20
	Ducted single split	15	20
	Non-ducted single split	15	20

Central heating appliances have few moving parts and they are made of durable materials due to safety reasons. Hence, their wear is generally low and their lifetimes are long. Parameters that have the greatest influence on the lifetime of appliances are quality of material, frequency of use, and maintenance.

Replacement of central heating appliances is rarely due to technical failure of the appliance, but rather to the wish of the user to install a better performing appliance. Replacement is usually pushed by the (fuel) market and possible environmental/energy policies, more than defects in existing appliances. See Figure 3.1 in the previous section.

3.1.6.2 Recycling, re-use and disposal options

This section provides information on some of the end-of-life options for central heating systems using hot air to distribute heat. According to information provided by stakeholders through questionnaires, national legislation is usually the driver for the end-of-life practices.

[28] Sources: Industry; EN15459 Energy performance of buildings – Economic evaluation procedure for energy systems in buildings

- Recycling

According to industry stakeholders, at their end-of-life, air-based central heating units can be refurbished and re-adjusted. Units are almost 100% recyclable as they are made of metals such as steel or certain plastics that can be recycled. In the current market situation, they have a positive value as a scrap metal at end-of-life. In practice, in most cases the installer of the central heating system takes back the old appliance without any charge. Thus, the revenue at the end-of-life goes to the installer rather than to the consumer, who nevertheless benefits as he does not need to worry about the transport of the heavy and bulky appliance. In some cases it is the manufacturer of central heating machines who offers the take-back system to the customers. For further information on recycling options, see the paragraph below on disposal options and description on the WEEE Directive.

- Reuse/second-hand use

Little information has been identified on the existence of a second hand market for air-based central heating systems. It can be generally assumed that the second hand market of these products is rare because of the nature of the product e.g. relatively long product-life span and specificities related to the type of building or house that limits its use. For example, a homeowner looking to replace his home central heating system would most likely seek to replace it with a heating system similar to the previous system to avoid possible renovating costs.

- Disposal

In terms of disposal options of air-based central heating products the EU introduced in 2005 new legislation to deal with waste from electrical and electronic equipment (WEEE). The purpose of this legislation is to ensure that old electrical and electronic equipment is recycled or reused rather than disposed in landfill sites (dumps). Another aim of the legislation is to encourage better design of electrical and electronic products to ensure that they can be recycled easily and more efficiently. Central heating products that use hot air to distribute heat used in the residential sector fall under the scope of the WEEE Directive (category 1) under large household appliances (electric heating appliances, electric radiators, other large appliances for heating rooms).

The latest data from Eurostat indicates that 1.7 million tonnes of large household appliances were collected in 2008[29]. Of the amount of large household appliances that were collected, 81 % went to reuse and recycling and 17 161 tonnes (approximately 1%) of collected large household appliances are re-used as a whole appliance. Further analysis and data collection is needed to estimate the share that air-based central heating systems account for within large household appliances. However, product recycling varies depending on the country, and in the case of central heating systems (which usually require installation by a professional) take-back systems are more common than in other household EEE products.

[29] Eurostat. WEEE, epp.eurostat.ec.europa.eu/portal/page/portal/waste/data/wastestreams/weee

3.1.6.3 Best practice in end-of-life behaviour

Ensuring that air-based central heating systems are properly collected through the WEEE Directive for further re-use, recovery, or recycling is a best practice in end-of-life behaviour. However, end-user involvement is vital to the success of recycling initiatives as these rely on the willingness of individuals to change current behaviours and participate. This is especially the case for those products and materials that pose a greater challenge when recycling, whether it is due to a lack of awareness, or the product type[30].

A UK study provides some insight into household consumer attitudes and activities concerning the management of WEEE in the UK. Findings of the study indicate that current WEEE recycling and collection schemes are largely reliant on consumers making the effort to dispose of items responsibly, which can be difficult if infrastructure is sparse and information lacking.

In order to encourage best practice in consumers to recycle their air-based central heating (e.g. by taking them to designated treatment sites or calling appropriate services for pick-up), adequate local infrastructure to enable easy and simple actions is primordial to help empower people to participate in more sustainable waste management practices. In addition to adequate local infrastructure, consumers must also be aware of why they need to change their behaviour, therefore raising and maintaining public awareness about the importance of properly disposing of air-based central heating systems is also necessary. However, some installer and manufacturers provide take-back services taking care of the substituted product and components. Therefore, the end of life practices of installers and manufacturers have also importance in the amount of waste generated by central heating products.

The common end-of-life practices in the EU-27 for products covered in this preparatory study are further investigated in Task 4.

3.2 Local infrastructure

The aim of this section is to identify and describe barriers and opportunities relating to local infrastructural factors. This task deals with the differences between theory and practice, which is very important for the success of ecodesign. The benefit of technology only persists if the product is properly used. Therefore, the influence of consumers and the influence that local infrastructure factors have on the product are crucial to consider when analysing the success of new technologies, marketing strategies, etc. This section also looks at the barriers that may hinder users/consumers to purchase or use ENER lot 21 products in a more environmentally sound manner.

[30] Darby, Lauren & Obara (2005) Household recycling behaviour and attitudes towards the disposal of small electrical and electronic equipment. Available at: 2004aix.meng.auth.gr/pruwe/dhmosieuseis/household_recycling_behaviour_EEE.pdf

3.2.1 Local infrastructure factors

Other than outside temperature, other factors affecting a building's heating energy consumption include the building's infrastructure such as:

- Building/housing construction type
- Age
- Nature of the building shell materials
- Window style, size, location
- Building's floor plan area
- Number of rooms/distribution
- Solar gains/orientation of the building
- Shading
- Level of insulation in ceilings, walls and floors.[31]
- Number and ages of occupants
- Occupant comfort preferences

There are various modelling and calculation methods available to determine the heat loss (difference in temperature inside and out, ventilation, building insulation, etc.) or heat gain (solar heat, people, equipment use, etc.) for buildings.[32] Often manufacturers or contractors will configure and design the heating system to fit the needs of the building and its users. For air-conditioning and ventilation systems the cooling capacity and the air flow rate are the key parameters for sizing a system for a building.

Space heating and cooling of buildings is generally assumed to be one of the most climate sensitive end-uses of energy. Therefore, air-based central heating products interact to a great extent with their surroundings as their main functions are to control and maintain temperature in the room where they are used. In addition to the climatic conditions and building infrastructure, other factors related with local infrastructure that affect the use of air-base central heating systems include:

- **Energy aspects:** includes electricity reliability, electricity tariffs, special local tariffs influencing consumer behaviour (night-tariffs, progressive tariffs, etc.);
- **Availability of installation and maintenance services** (e.g. availability and level of know-how/training of installers): professional care as well as professional installation is crucial for optimal performances. Lack of qualified craftsmen (installers and chimney sweepers) can be detrimental for both market development and environmental performances of appliances;

[31] CSIRO & NatHERS Nationwide House Energy Rating Schemes (2001) Division of Building and Construction Engineering,

[32] VHK (2007) Preparatory study ErP Lot 1 (boilers), Task 3 Report. Study commissioned by the European Commission. Available at: www.ecoboiler.org

- **Building regulations and codes** (e.g. restriction on the use of air-based central heating systems due to preference of housing developers and building owners for other types of central heating system);
- **Use of alternative heating products** (e.g. consumers may use other products for heating such as local room heating products for the same swelling, which may affect how the air-based central system is used);
- **Fuel quality and availability:** Constant and adequate quality of fuel are important, either for gas or liquid fuels. There are wide differences between MS. Shifts towards more environmentally-friendly fuels or technologies may be hindered due to convenience reasons and the negative environmental impacts associated with transporting fuels;
- **Quality of information given to consumers:** lack of knowledge or lack of independent reliable information on products, and on their energy and environmental performance.
- **Local regulations**: Local regulations may also impose limitations for air pollution concerns (e.g. forbidding all gas or liquid fuel installations independent of their performance).

In addition, depending on specific Member States, different energy sources are used for central heating. For example, gas, oil, and electricity are the energy sources for over 90% of heating systems, though there is variation between countries. Other country specific factors such as special local tariffs that influence consumer behaviour (night-tariffs, progressive tariffs, etc.) exist in the UK.

3.2.2 Barriers to ecodesign

In practice, many barriers to ecodesign may come from the supply chain rules. For example, investment-related questions may be directly involved: often the more energy-efficient the product is the more expensive the purchase price. For example, in the case of commercial buildings, buyers and product distributors are not often in charge of the system operation afterwards and thus do not pay the final fuel/electricity bill. It is also common, that the proper matching of the product and the heating requirements is not carried out due to missing information on both the product side and the user's side.

Some barriers to ecodesign that have been identified include:

- **Preference for stabilised technologies**: technology changes often generate a temporary increase in breakdown rates due to a necessary learning period.
- **Market failures**: The rate of market adaptation with each new technology varies. Sometimes promising technologies simply fail to see a break-through in the market (for various reasons).
- **Lack of knowledge**: End-users are often not aware of the difference of energy efficiency among competing products (i.e. no use of energy efficiency labels). Some end-users also lack information on the cost to power their equipment over

the product lifetime (typically small end-users) accordingly the demand from energy efficient appliances is not very strong from their side. Commercial and industrial customers investing in larger products may have sufficient technical knowledge to compare products based on their technical specifications. This lack of resources among end-users for confident and accurate assessment of either the available technology options and related energy saving potentials adds up to the fact that in many cases the new equipment is purchased when the old equipment fails and there is no time to analyse in details the purchase decision (more specifically for small end-users).

- **Cost factors**: many end-users may opt for a cheapest model (if given a choice), though very rarely aware of the energy consumed by air-based central heating products during its lifetime.
- **Compatibility and liability issues**: depends to a great extent by the services required by the end-user.
- **Design and convenience**: e.g. use of power management or shutting off devices seems too time-consuming for users.
- **Rebound effects**: even though the sold devices are more energy efficient, overall more energy is consumed due to higher ownership rates or due to increased use of the product because of its "energy-efficient" status.
- Purchase decisions for commercial or industrial hot air central-heating appliances are generally not made on life cycle cost or payback considerations. Equipment buyers, whether small/medium end-users or large supermarkets normally follow an elaborated procurement process (call for tender), and normally select the product providing best value for money i.e. an equipment that meets specifications at the lowest cost. The green (public) procurement and eco-responsible purchase in public and private sector are important initiatives to be analysed.
- For medium-sized end-users and large supermarkets, large restaurant chains, the persons in charge of selecting the equipment do not focus on energy efficiency as choice criteria because they are generally not the ones in charge of operating it or paying the electricity bill (i.e. split incentives).

3.3 Conclusions

Task 3 has addressed consumer behaviour and local infrastructure issues associated with central heating systems that use hot air to distribute heat. The tentative findings indicate that some of the major factors that influence the purchase and selection of certain types of air-based central heating systems include purchase price and energy prices, aspects related to changing building needs which may require a heating system with a higher output or different qualities, influence of installers and consultants that stipulate the use of a certain type of central heating system, replacement of an older heating system, facility of use and certain safety and health factors.

In terms of data on frequency and characteristics of use, climatic conditions, house/building size, and demographics, these still need to be investigated more to estimate the heating demand of warm air central heating products in the EU-27. Further quantitative information regarding frequency and characteristics of use will be provided following further discussions with industry experts and stakeholders.

Regarding end-of-life behaviour, it is unlikely that central heating products are reused. Rather the products are scrapped and the metals are reused In the EU, disposal and recycling options of central heating products that use hot to distribute heat is regulated by the WEEE to ensure that the maximum amount of end-of-life material from these products are recovered. Due to the professionalization of the sector and the need for expert installation, take-back services are common practice, which increases the recovery and recycling rates.

Local infrastructure factors also influence the use of air-based central heating products. Aspects include building/housing infrastructure conditions (i.e. number of rooms, floor plan area to be heated, quality of insulation, size of windows, type of structure, number and age of occupants, etc.), availability of installation and maintenance services, building regulations and codes (e.g. preference of installers and consultants for a certain type of central heating system), fuel quality and availability, and the quality of information given to consumers.

Finally, a number of barriers to Ecodesign measures and developments have also been identified. These include an absence of life-cycle thinking across the supply chain, fear of complex technologies by consumers, cost factors, rebound effects, and design issues.

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