HARP

Heating Appliances Retrofit Planning

Deliverable 2.3:
Heating solutions and potential
November 2019

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ABBREVIATIONS AND DEFINITIONS

ABBREVIATION	DESCRIPTION
CHP	Combined Heat and Power
CO2	Carbon dioxide
EU	European Union
HARP	Heating Appliances Retrofit Programme
kW	kilowatt
NEZBs	Nearly zero energy buildings
NOx	Nitrogen Oxides
RES	Renewable Energy Source
TCO	Total Cost of Ownership

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1 INTRODUCTION

1.1 The European Heating Market – A brief overview

The heating and cooling sectors combined account for more than half of the EU energy consumption, more specifically, heating and domestic hot water alone account for 79% of total final energy use (192.5 Mtoe[1]) in EU households. However, there is a huge potential of energy savings as 65% of the installed stock of heaters in Europe is old and inefficient. The average replacement rate of the EU boiler is low, currently only 4% per year, which aggravates the problem. Furthermore, in terms of emissions, residential heating accounts for 30% of the EU overall carbon dioxide emissions[2]. Consequently, without an ambitious change of pace, the European heating stock will continue to be old and inefficient for decades to come and the EU will fall behind on its pathway to a decarbonized building sector.

Due to regional and local differences, climatic conditions, heat demands, but also different national energy markets and consumer preferences, the European heating market is fragmented. Hence, the share of boilers, district heating, direct electric heating systems, heat pumps, biomass, solar energy and other low-carbon heating technologies varies depending on the local framework. Nevertheless, the overall European heating market is dominated by natural gas boilers. In 2014 gas boilers represented more than three quarters of the overall sales volume of approx. 7 million heating systems.

In general, the sales figures for heating systems show a decline following the financial crisis. This is increasing the backlog in replacement, meaning that approximately 72 million existing systems stay installed regardless of low efficiency. Accelerating the replacement of existing boilers offers a major opportunity to lower carbon dioxide emissions of the current heating system stock in Europe. It is noteworthy that the heating market is significantly driven by customer demand. The replacement of a heating appliance mostly occurs once the old and inefficient heating appliance breaks down. The nature of this situation often requires a timely replacement that does not allow to consider the full variety of modernisation options as well as possible changes to the whole heating system or to the building (e.g.: additional insulation). Consequently, the swift replacement does bring valuable energy savings but also misses the opportunity of claiming the whole potential of energy savings and CO_2 emission reductions based on available heating systems on the market. In contrast, in case of major renovation and new buildings, a complete shift in the heating system technology is more likely to be considered. The penetration of low-carbon technology in the market of replacements needs to be stimulated in all those cases where it is technically and economically feasible. The European heating industry stands ready to offer these technologies.

1.2 HARP – Project summary

The HARP project, Heating Appliances Retrofit Planning, aims at raising consumers awareness to the opportunities that underlay the planned replacement of their old and inefficient heating appliance. Among the 129 million boilers installed in the EU, a staggering 56% are inefficient (performing as a C or lower energy class) but individuals are rarely aware of the inefficiency of their heating systems and associated costs. The mission is to accelerate the European replacement rate for heating systems, actively contributing to the reduction of energy demand in buildings, in line with the energy efficiency targets set by the EU.

[1] European Commission, 2019: https://ec.europa.eu/energy/en/topics/energy-efficiency/heating-and-cooling

[2] Ecofys, 2016: "EU pathways to a decarbonized building sector"

Consumers often do not think about heating until their system breaks down. When it does, the replacement is always an urgent process, hindering the possibility to look for the best solutions in the market and making smarter choices regarding a heating system that will likely be in operation for the next 20 years. In Europe there are more than 300 million heaters (space, water or combi) that have, on average, been installed more than 20 years ago. Considering the heating energy label framework, market assumptions are more than 50% of these equipment's perform as C or lower.[3] Old and inefficient, this is the status of the installed heating stock. Now is the time to act and raise consumers' awareness about the opportunities of a planned replacement. Taking advantage of the energy label for space and water heating, we can mainstream the labelling concept to the installed heating stock, allowing to use a well-known support decision tool to communicate and motivate the consumer to replace its heating system with modern high-efficiency and renewable solutions.

HARP aims to accompany the consumer decision process by providing an impartial message, based on the energy label and presenting the market solutions that respond to the consumer's heating needs, accounting for economic and non-economic benefits and available national incentives. HARP is promoted by key knowledgeable partners in the fields of consumer behaviour, energy efficiency, heating solutions and business models, working directly with the consumer, or indirectly via professionals who are critical multiplying agents. Promoting dynamic efficient heating communities, where all the agents, from the supply to the demand side are committed to an efficient heating market, supporting the consumer to make smarter choices[4].

1.2.1 Description of task 2.3 in HARP

In this task[5] a deep characterization of available heating solutions on the market is conducted, including conventional as well as renewable products and packages solutions. This is crucial in a market which has meanwhile started to adapt to the new conditions, namely smartness functions, digital solutions, new materials, circular economy, demand side management, power to heat, etc. This information will be carried out from an EU perspective, considering the three climatic areas defined in the heating energy labelling regulations, and refined at the HARP countries level, considering the RES potential aiming to understand potential adoption scenarios in the different countries, to cross with the country specific consumer behaviour models and the RES "interest" identified. The technological characterization will adopt a total cost of ownership (TCO) perspective. Ultimately, the information gathered in task 2.3 will feed into task 2.4 and receive its results to complement the technological analysis with the co-benefits.

This written report – 'Heating solutions and potential' – serves as the Deliverable D2.3 in HARP, which is due to be submitted by the end of November 2019 (month 7 of the project), will thus provide the deep characterization of available heating technologies on the European heating market, covering both conventional as well as renewable solutions and intends to point out potential adoption scenarios.

[3] HARP project website: https://heating-retrofit.eu/
[4] HARP project website: https://heating-retrofit.eu/
[5] For further reading: HARP – Grant Agreement

2 DEEP CHARACTERISATION OF AVAILABLE HEATING TECHNOLOGIES

2.1 Space Heating

2.1.1 Condensing boilers

Highly efficient heat generation

Modern condensing appliances are designed to use virtually the entire energy content of the fuel to transform it into heat. In contrast to previous generations of these appliances, condensing boilers reuse the heat energy of water vapour produced in the combustion process which 'condenses' back into liquid form, and is ultimately reused to pre-heat the cold water entering the boiler. This makes the condensing technology highly convenient, resource- and cost-efficient for heat generation.

Condensing boilers cover almost all output ranges. Wall-mounted units deliver up to 100 kW. With boilers in a cascade system (several appliances connected to each other), the output can be increased to several hundred kiloWatts. Floor-standing units can supply nominal outputs of more than 10,000 kW. Condensing boilers are often the first choice both for new installations and for refurbishment of existing central heating systems across Europe. Currently available condensing boilers can reach an energy efficiency class[6] B to A, while boilers equipped with the most advanced controls can reach an even higher efficiency class A+ (package label).

Heating and domestic hot water

In contrast to a heating-only boiler, a so-called combination boiler (or 'combi' boiler) heats both water for the central heating system and for the domestic hot water taps on demand (instantaneous hot water). A 'System' or 'Open Vent' boiler provides heated water for the central heating system and is connected to a hot water cylinder (storage tank) to provide hot water to the taps. The choice between these two options depends on various factors such as space, water pressure and the number of bathrooms.

Perfected technology that works well with renewables

For more than twenty years, the condensing technology has been constantly advancing: increased comfort and energy efficiency, reduced emissions and noise levels, improved design and reduced size to fit any building setting. Moreover, this highly efficient technology can also be easily teamed with renewable energy sources such as a solar thermal system. Finally, the European heating industry is working on ensuring the compatibility of new appliances with green fuels and gases of different qualities, such as hydrogen and sustainably sourced biogases.

To guarantee high efficiency, it is essential that the condensing gas boiler is installed, serviced and repaired by qualified personnel.

Benefits

- ✓ Increased energy efficiency and reduced emissions;
- ✓ Easily combined with renewable energies;
- ✓ Suitable for modernisation in existing as well as new buildings;
- ✓ Easily installed and maintained;
- ✓ Extremely reliable and future-oriented thanks to connection to existing grids.

[6] In accordance with EU Energy Labelling Framework Regulation 2017/1369

2.1.2 Heat Pumps

2.1.2.1 Electric Heat Pumps

Highly efficient renewable heating

A heat pump uses the renewable energy stored in the soil, groundwater or the environment for heating purposes. The most common are electric heat pumps.

A heat pump operates like a refrigerator in reverse: a refrigerant extracts low-temperature heat from the environment, which causes the refrigerant in the system to evaporate; the refrigerant is then compressed; heat is released in a condenser and is transferred to the water circulating in the heating system.

Heat pumps work most efficiently to guarantee a high level of comfort when:

- the heat source temperature (soil / groundwater / air) is higher, and
- when combined with distribution systems that work at low temperature (e.g. underfloor heating).

Modern heat pumps can be used for space heating, domestic hot water, ventilating and cooling a building, depending on the technology. They work very quietly and are virtually maintenance-free. Heat pumps can indeed reach a very high energy efficiency and are typically labelled with an energy efficiency label ranging from A+ up to A+++. As regards the hot water energy efficiency class, most heat pumps on the EU market are labelled with an energy efficiency class B to A+.

Closed-loop heat pumps: ground source heat pumps or brine/water

Closed-loop heat pumps are the most common type heat pumps in new buildings, and the most efficient. They use a closed loop of pipe containing a water and anti-freeze solution to extract heat from the ground or groundwater; they are often referred to as ground-source, geothermal or “brine/water” heat pumps. The heat is transferred to water for distribution in the building. The heat can be extracted from the ground or ground water using vertical collectors in boreholes or loops of pipes laid horizontally below the surface of the ground.

Open-loop heat pumps: water/water

Open-loop heat pumps use the almost uniformly level temperature of water. The water from the source is pumped through the actual heat pump itself where its heat is extracted.

Air-source heat pumps: air/water

Air-source heat pumps extract environmental heat from the air. They are particularly suitable for installation in existing buildings and can be installed indoor or outdoor. They are easier and less costly to install as no boreholes or horizontal pipes are necessary.

Benefits

- ✓ Using renewable heat from the surroundings;
- ✓ Highly energy efficient;
- ✓ Can provide space heating, cooling and/or hot water;
- ✓ Suitable for different building contexts, especially in new builds;
- ✓ Reducing CO_2 emissions, near zero if fully powered by renewable electricity (e.g. wind power or photovoltaics).

2.1.2.2 Gas Heat Pumps

Highly efficient renewable heating

A gas heat pump is a heating appliance which uses the renewable energy stored in the soil, groundwater or the environment for heating purposes. It then combines this environmental heat with high efficiency gas-fired condensing technology. In this way, renewable energy can be used relatively easily for heat supply to new and existing buildings. A gas heat pump is typically labelled with an energy efficiency class ranging from A to A+, whereas gas heat pumps equipped with controls (package label) can reach an even higher efficiency class A++.

There are three types of gas heat pumps: a gas-fired compression heat pump, a gas-fired adsorption heat pump and a gas-fired absorption heat pump.

Gas-fired compression heat pumps

A gas-fired compression heat pump operates like a refrigerator in reverse: a refrigerant extracts low-temperature heat from the environment, which causes the refrigerant in the system to evaporate; the refrigerant is then compressed by a natural gas engine; heat is released in a condenser and is transferred to the water circulating in the heating system.

The gas-fired compression heat pump efficiency is increased thanks to heat recovery from the engine and exhaust gas. Gas-fired compression heat pumps are especially suited for commercial buildings – such as hotels, hospitals or schools – and large housings to produce heating, cooling and domestic hot water.

Gas-fired adsorption heat pumps

A gas-fired adsorption heat pump captures the heat from the environment (soil / solar) and stores it in refrigerant liquid water. This water is then captured by environmentally friendly mineral zeolite, which releases even more heat. This heat can be used directly for heating purposes.

To allow a new heating cycle, water captured in zeolite is vaporised by gas-fired heat as a second step. Then the process can start all over again. Gas-fired adsorption heat pumps are most efficient in low temperature heating systems. They use a natural refrigerant (water) and are easy to maintain (no compressor needed).

Gas-fired absorption heat pumps

A gas-fired absorption heat pump draws in the heat from the environment at low temperature and releases it to the water circuit of the heating system at high temperature. It uses a natural refrigerant – such as ammonia with zero ozone depletion potential and zero global warming potential – inside a closed cycle operated by a thermal compressor.

Compact gas-fired absorption heat pumps are most efficient in low temperature heating systems, but are especially suited for existing, retrofit installations with high temperature distribution systems, such as radiators. They are mainly used in industrial or commercial buildings, as well as residential homes to produce heating, cooling and domestic hot water.

Benefits

- ✓ Links efficient technologies of condensing boiler and heat pump;
- ✓ Use of existing energy infrastructure;
- ✓ Maximising use of fuel and renewable energy;
- ✓ Suitable for low and high temperature heating systems, for new and existing buildings;

- ✓ Use of 100% renewable energy, if fully powered by biomethane.

2.1.3 Hybrid heat pumps

Hybrid heating?

Hybrids refer to an appliance or a system of appliances which combine at least 2 different energy sources and whose operation is managed by one control. Among the hybrid systems, many combinations are possible. For example, condensing boilers can be combined with a solar thermal installation plus a hot water storage tank. Or an electrical / gas heat pump (inclusive drinking water heat pumps). Or a biomass boiler. Or a ventilation with or without heat recovery. Among the hybrid appliances, the most common product is a hybrid heat pump, which combines an electric heat pump with a condensing boiler. The hybrid heat pump's master control manages the operation of the boiler and heat pump. Most hybrid heat pumps are labelled with an energy efficiency label ranging from A+ to A++, whereas the hot water energy efficiency classes for combi's ranges from A to A+.

Introducing renewable heat and hot water anywhere

Hybrid heat pumps can be installed in almost any building, regardless of its energy demand. For a lot of existing buildings, a simple switch from a gas or oil boiler to renewable heat is not possible. Relying exclusively on a heat pump or solar thermal collectors – delivering low-temperature heat – is often not possible, as most existing buildings are not equipped with an adequate low-temperature heat transfer system. Especially when the outside temperature drops, the hybrid's ability to switch to a high-efficiency boiler can maintain higher flow temperatures for the central heating system to keep the house warm.

An example to illustrate this: a hybrid heat pump will deliver the bulk of a building's heating, unless the heat pump is not able to work efficiently. During the few really cold days of the year, the boiler will cover this peak heat demand.

Convincing consumers to give up on their familiar and reliable boiler – even when it is old – and switch to lesser known renewable heat technologies is often a major challenge. A hybrid heat pump can help to overcome this hurdle, as it offers the reassurance of e.g. the condensing boiler as a back-up.

Helping the grid manage more renewable electricity sources

An increased market share for hybrids offers an opportunity for the heating sector to do its part to help balance a grid with a growing share of variable sources of solar and wind power. Such balancing can happen as 'load shedding' when switching from the heat pump to the fuel boiler, at times when electricity demand is high and the grid is stressed. Or balancing can happen as 'peak absorption' by switching from the boiler to the heat pump, when renewable electricity is abundant and power prices are down. Another possibility is using cheap renewable electricity to produce hot water as a form of energy storage.

Benefits

- ✓ Reducing running costs and improving overall system energy efficiency;
- ✓ Reducing primary energy consumption;
- ✓ Combining several energy efficiency measures with best practice technologies incorporating renewable energies;
- ✓ Ensuring security of supply and avoiding peak consumption.

2.1.4 Biomass boilers

Heat from biomass

Biomass is any material of organic origin. Biomass can be used in heating, and wood is the form that is most widely used for that purpose. Wood is carbon neutral as a renewable resource: when burned, the same amount of CO_2 that was absorbed by the tree during its growth is released. One of the most efficient ways to use wood for heating are central heating biomass boilers, which can provide high comfort efficiently, while reducing the climate impact of heating (greenhouse gas emissions). Modern heating systems use biomass in the form of pellets, wood chips or split logs.

- **Wood pellets** are small, standardised, cylindrical pieces made from natural, untreated wood. To produce pellets, the wood chips occurring in the sawmill are first dried, then cleaned and pressed into pellets in matrices. They require smaller storage spaces than split logs or wood chips as they are denser.
- **Wood chips** are manufactured in various ways. Coniferous wood log pieces that occur in the sawmills and are not suitable for any other processing are crushed directly.
- **Split logs** should be dried to reduce the moisture content of wood and increase boiler heat output. They are easy to produce but require manual feeding of the boiler. Split logs can be used in wood gasification boilers to ensure low emissions.

Efficient central heating with biomass

Wood-based central heating systems use a sustainable and flexible energy. They can supply an entire house with heat throughout the year. Moreover, they can easily be combined with solar thermal systems. Most biomass boilers currently on the market are labelled with energy efficiency class of A+.

Pellet boilers central heating systems, which are operated with wood pellets are particularly convenient: pellets are kept in a storage room or tank and supplied to the boiler by means of either a suction or screw conveyor system. The systems are fully automated and can be modulated in a power range of 30 to 100 %.

Wood gasification boilers are used to burn split logs efficiently. The individual stages of wood combustion (wood gasification and wood gas combustion) occur separately. This local division – in conjunction with a sufficiently dimensioned heat exchanger surface area – ensures particularly low emissions, low flue gas temperatures and high boiler efficiency. An induced draft fan ensures the correct air supply. The secondary air supply is then responsible for complete combustion. The use of a buffer tank increases the ease of operation significantly.

Wood chip boilers work on the same principle as pellet boilers: The wood chips are transported automatically from a storage room into the boiler by means of a screw conveyor or similar device. An electronic control system regulates the combustion process and constantly optimises it. The output range of wood chip-fired central heating systems ranges from 30 kilowatts to several megawatts. This allows heating of apartment houses and entire business establishments.

Benefits

- ✓ Efficient use of renewable sources;
- ✓ Using locally available fuel;
- ✓ Carbon neutral fuel;
- ✓ Heating technology for all output levels.

2.1.5 Combined Heat and Power (Cogeneration)

More than just a heating system

Combined heat and power generation (CHP) produces both heat and electricity in one single appliance. By using the primary energy source economically in this way, cogeneration of heat and electricity not only contributes to an overall reduction in energy consumption, but it also contributes directly to the protection of the environment. Currently available CHP appliances are mostly labelled with an energy efficiency label ranging from A+ to A++ and are thus amongst the most efficient appliances on the market. Moreover, as regards the hot water energy efficiency class, most appliances are labelled with a label ranging from A to A+.

This technology is available for large scale but also for small-scale production of heat and power (micro-CHP and mini-CHP) for commercial and public buildings, apartments and individual houses. Small scale CHP generates electricity at the time of day and time of year when heat demand is at its greatest, thereby coinciding with the times when demand on the electricity grid is at its peak.

Europe is a global leader in micro-CHP engine and product technology, with innovation and manufacturing centres in several countries including Germany, the Netherlands and the UK.

Current state of technology

There are different CHP technologies: internal and external combustion engines (Otto engines and Stirling engines), steam expansion engines and fuel cells. A range of micro-CHP appliances are commercially available in Europe, mainly internal combustion engines and Stirling engines. Fuel cell technology is currently under large scale demonstration phase and will be commercialised in the very near future.

The process heat released by the motor is used for space heating and for domestic hot water. The electricity produced is used as required and any excess power fed into the electric grid. Decentralised cogeneration of heat and power is a highly efficient way of supplying both space heating and electricity.

The fuel used, e.g. natural gas, drives a combustion engine with a power generator coupled to it, thus producing electricity. In the future, it is entirely conceivable that renewable energy sources such as biogas, biofuels, wood pellets and bioethanol will be used.

The right solution for every requirement

Consumers have a choice of different CHP solutions from outputs of just a few kW to several hundred MW. Micro-CHP units with power outputs of up to 5 kW are used for detached and semi-detached houses, while mini-CHP units of up to 50 kW have been developed for small apartment blocks and business premises. No district heating network is required for these smaller CHP units. Industrial premises and larger housing estates including hospitals and schools use larger CHP units or block cogeneration plants with outputs starting at around 50 kW. In these applications, CHP systems can supply up to 100 % of the heat and 80 % of a building's power requirements. In future, many block cogeneration plants working together as a "virtual power station" will help smooth out voltage fluctuations in the public power supply.

Benefits

- ✓ Allowing the supply of both heat and electricity from a single energy source/appliance;
- ✓ Reducing carbon emissions by generating electricity at the point of use – avoiding the system distribution losses associated with central power production;

- ✓ Allows fuels to be used more efficiently;
- ✓ Generating economic savings by reducing imported electricity and selling surplus electricity back to the grid;
- ✓ Enhancing security of supply by reducing reliance on centralised power production.

2.2 Solar Thermal Systems

Solar thermal technology harnesses the energy of the sun to heat water for domestic use or for space heating. And solar thermal technologies can be used also for cooling. Solar thermal systems collect heat and differ from solar photovoltaic (PV) systems, which generate electricity.

How it works

Solar collectors convert sunlight into heat and produce hot water for your home use. In larger systems, they can also help to heat the house. Thanks to a solar thermal system, a house can reduce its energy consumption by half and reduce CO_2 emissions significantly. Most solar systems work in combination with a heater, for example a condensing boiler or a heat pump, which helps the solar thermal system when heat demand is high.

How is a solar system composed?

A solar heating system is composed of:

- solar collectors (one or more), which are usually installed on the roof of the building;
- a hot water tank, to store the water heated by the system;
- a circuit with a fluid (frost and heat resistant), which delivers solar heat from the collectors to the hot water storage tank;
- a heat exchanger, to transfer heat from the circuit to the hot water storage tank.

There are two types of solar collectors: flat-plate collectors are the most common. Vacuum tube collectors – a heat pipe in an evacuated glass tube (vacuum) – can achieve high yields and temperatures. Because of their higher efficiencies, they require less surface area than flat-plate collectors.

Solar energy can be used to produce hot water and to top up a space heating system. In the latter case, the size of the collector surface is usually increased by a factor of about 2 to 2.5. The saving on fuel is somewhere between 10 % and 30 %, depending on the insulation levels of the building. In low energy buildings, solar systems can attain savings up to 50 %. Where solar heat is used to assist a space heating system, either a second storage tank (buffer store) or a combination storage can be used. Stratified tanks or cylinders are also available.

Where can you use a solar thermal system?

Solar thermal systems for hot water production and space heating are suitable for a great variety of residential and commercial buildings, in both retrofitting and new-build projects. Moreover, solar collectors can provide hot water for both open-air and indoor swimming pools. Some systems operate on the thermosiphon principle, using a heat-insulated storage tank above the collector; these are most common in southern countries. Solar assisted industrial process heating is still in its early stages, but the potential is enormous.

Solar cooling

Solar thermally driven cooling systems – so-called solar air-conditioning – have a great potential, as the highest need for cooling is ultimately related tothe sun's presence. Moreover, the widespread use of solar cooling could make an essential contribution to lowering the electricity demand peaks caused by traditional air-conditioning systems.

Benefits

- ✓ It introduces renewables within any heating system both in existing and in new buildings;
- ✓ saves energy;
- ✓ solar heat is available and free for everybody: low maintenance and operations costs;
- ✓ long lifespan;
- ✓ easy to use;
- ✓ reduces CO_2 emissions.

2.3 Water Heaters

Water heaters are appliances to provide water at the temperature that a person decides. Domestic hot water can be used for many purposes, for example cleaning and cooking. The production of hot water makes up an important share of the overall energy consumption for heating purposes (between 10 and 20%) and this share increases in well-insulated buildings. Different appliances reach different energy efficiency classes. Amongst the most efficient water heaters are heat pump water heaters which achieve and energy efficiency ranging from A to A+. Gas water heaters as well as electric water heaters are mostly labelled with an energy efficiency label ranging from C to A.

One purpose, many technologies

The choice of a water heater depends on the type of building and on the needs of those who will be using it. For example, some water heaters are fit for one tap only, while others can provide hot water to a whole building.

The first differentiation is between on-demand and storage water heaters.

On-demand water heaters, also known as tank-less water heaters, heat water instantly - as it flows through them.

Small tank-less water heaters can be located right where the water is used and are connected to a specific tap. Larger tank-less water heaters are common in centralised systems, such as single flats or one- or two-family houses. Most of these water heaters run on gas or electricity.

Other heating appliances, called combination heaters, can provide both domestic hot water and space heat. Storage water heaters offer instantaneous delivery of hot water and provide great comfort in cases of simultaneous use, for example when two showers are running at the same time. They can heat water directly, therefore combine in the same appliance a hot water storage tank and a heating element. The heating element can be a gas or oil burner, an electric resistance heater or an air source heat pump.

In other cases, tanks are heated indirectly. This means that they are connected to an external heater, for example a heat pump, a boiler or solar collectors - or combinations of those.

Benefits

- ✓ Variety of technologies to meet hot water demand in all buildings;
- ✓ Great comfort for users;
- ✓ With solar thermal water heating, energy from the sun may cover 70% of domestic hot water needs;

- ✓ Heat pump water heaters can reduce energy consumption by 80% compared to traditional water heaters.

2.4 Smart Heating and Smart Home

Smart heating will be an integral part of the broader evolution towards ‘smart homes’, as smart appliances can send and receive information to and from the consumer, other appliances in the house and even the world beyond the building. For example, the concept of smart heating enables the operating times of the heating system to be synchronised with the presence and absence of the residents. Local weather data can also be input and used to optimise the heating operation. Using the energy more efficiently through installing intelligent heating systems will make a major difference in driving down energy consumption. According to some studies, smart heating will help to boost the overall efficiency of heating, generating energy savings of up to 15%.[7]

A smart thermostat allows consumers to adjust the heating to their needs, remotely adjusting the heating via their smart phone or tablet. A smart control system and smart thermostatic valves make sure that the heat is on only in the rooms where it’s needed. A smart heating system also enables so-called ‘remote appliance monitoring’, whereby the installer or a service company is alerted about faults, for example boiler faults or a drop-in water pressure. This information greatly helps to offer pro-active maintenance to consumers, often remedying malfunctions remotely. User-friendly interfaces of heating appliances and smart meters also inform consumers in real-time about their energy consumption, avoiding any surprises in their energy bills.

And the possibilities extend beyond much-improved interaction between consumers and their heating system. The many different appliances inside a building will be able to coordinate their operation, thanks to a central energy manager. A better coordination between the different systems in a building will lead to an optimization of its energy consumption. These different systems include heating and cooling, large appliances such as dishwashers and fridges, charging of electric vehicles, battery storage and the photovoltaic panels on the roof. For example, when the photovoltaic panels are producing a lot of ‘free’ electricity, the smart appliances in the building will adapt their operation to the availability of this ‘free’ electricity. The heating industry is cooperating with other industries to make sure that all these appliances in the building are ‘interoperable’, i.e. able to exchange information.

Smart heating and the other smart appliances in a building cannot only communicate with each other, but also with the world outside the building. Heat pumps can modulate their power consumption, depending on data about current electricity prices. A hybrid heat pump can switch from electricity to gas, when grid operators send a signal that there is a high demand on the grid. When there is excess renewable electricity on the grid, an electric hot water tank will convert this cheap electricity into hot water (so-called ‘power-to-heat’). A smart heating system can also process information about the weather forecast or day-ahead electricity prices and already anticipate what will be required to keep the building warm. A wide uptake of smart heating will play a key role in enabling higher shares of renewable electricity on the grid, as smart heating provides the flexibility to adjust electricity demand to the variable nature of more renewable electricity generation.

2.5 Hot water storage

A hot water storage tank (also called a hot water cylinder or hot water tank) is a water tank used for storing hot water for space heating or domestic use. Water is a convenient heat storage medium

[7] i.e. Institute for Technical Building Equipment in Dresden (ITG), 2017

because it has a high specific heat capacity. This means that, compared to other substances, water can store more heat per unit of weight.

How it works

Water storage tanks or cylinders can be heated directly or indirectly.

Directly heated storage tanks are a combination of a vessel and a heater, for example a burner, an electric resistance heater or an air-source heat pump.

Indirectly heated storage tanks, on the other hand, incorporate one or more internal heat-exchangers, which are connected with external heaters, like heat pumps, gas, oil or biomass boilers, solar panels, district heating or combinations of those.

A specific storage technology is the stratified storage tank, which is often used in solar systems. This technology is specifically designed to divide the water it contains into layers at different temperatures (hence 'stratified'). The upper part of the tank will contain warmer water, which can be used as domestic hot water; the lower and colder part of the tank receives the heat coming from the solar collectors. Between the cold and the hot parts of the tank lies a second heat exchanger which can – if necessary – heat lower layer of water.

Demand response

Hot water cylinders can also help provide demand response services to the grid. An efficient hot water storage tank, for instance, allows consumers to heat water with electricity, consuming the electricity when prices are lower. Energy is then stored in the tank in the form of hot water, ready to be used for washing or to heat the house when it is needed.

Benefits

- ✓ Great comfort by supplying hot water for simultaneous use, for example when several showers are running at the same time;
- ✓ Flexibility of use: a hot water storage tank provides hot water almost immediately;
- ✓ The water in the cylinder will be released exactly at the desired temperature;
- ✓ Well-insulated hot water tanks are a great way to store energy: they can be coupled with electric resistance or a heat pump, and run when electricity is most abundant and inexpensive;
- ✓ A hot water storage tank can help reduce energy consumption. This is because it takes less energy to keep water warm, once it has already been heated, than it takes to heat cold water. Hot water storage tanks are also labelled regarding their energy performance, the less energy they loss the higher is the energy class.

2.6 Surface Heating and Cooling

Heating and cooling in one system

Many new buildings all over Europe opt for a surface heating and cooling system – hot or cold water is circulated via pipes, which are permanently embedded in floors, walls or ceilings, and thus form an integral part of the building. These systems fulfil two functions at once: in winter, they heat the rooms, while in summer, they noticeably reduce the operative air temperature within a room by running cold water through the pipes. The ability to also offer cooling is gaining importance, as well-insulated buildings with larger windows need to be cooled in summer. Through their large-area installation, they ensure an even distribution of heating or cooling in the room, contributing to a pleasant indoor climate all year round.

Wide range of solutions also for old buildings

Conventional floor-heating constructions are often unsuitable for older buildings for various reasons. For example, adding underfloor heating plus insulation may increase the floor level, which can cause problems for the door height or power outlet. Or the load-bearing capacity of ceilings may pose a problem. Therefore, special surface heating and cooling systems are designed that can also be installed in existing buildings without massive interventions, be it in the wall, floor or ceiling. The variety of surface systems available on the market today ranges from wet systems (screed or plaster) to dry systems to special thin-film systems. This offers builders the best solutions for new construction as well as modernisation.

More comfort, less costs

In embedded heating systems, low system temperatures are generally sufficient (35/28˚C) – perfect for heat transfer using condensing boilers, heat pumps and solar thermal systems. The lower the heating system temperature, the higher its efficiency. This will deliver potentially large energy savings. Installing a low-temperature surface heating and cooling system can also trigger a change towards compatible low-temperature and – ideally renewable – heat generators.

In addition, surface heating and cooling also increases the cosiness and comfort. A smart control system enables residents to create a heating profile for every room, tailoring comfort levels perfectly to the needs of residents. Embedding heating systems in walls, floors and ceilings also frees up a lot of space.

Benefits

- ✓ Fully covering the thermal comfort needs all year round;
- ✓ Highly energy efficient by operating at temperature levels very close to the desired room temperature;
- ✓ Viable option for all efficient modern heating systems in residential, commercial and industrial buildings;
- ✓ Ideally combined with renewable energy sources.

2.7 Radiators

Successfully increasing the efficiency of a whole heating system is dependent on all components being optimally adjusted to each other in terms of both energy distribution and hydraulic balance. A key aspect of the installation of a heating system is the choice of heat emitters. Radiators can be integrated into any type of heating system regardless of the heating technology used.

Modern radiators with low system temperatures, in combination with state-of-the-art control technology, save energy and, in addition, create a pleasant room climate. Radiators feature a slim-line profile and minimal water content in combination with a large heat-transfer surface. Thus, the room temperature can be quickly adjusted to changing user needs. Modern thermostatic valves and hydraulic balancing valves help the heating system maintain exactly the right temperature in individual rooms and at different times.

Between modernisation and comfort

The aim in modernising an existing system is to increase efficiency by means of energy-saving operation and optimal delivery of heat through modern radiators. Alongside financial implications, visual and functional aspects are coming more and more to the forefront: radiators can serve as features in the interior decor or as mirrors, can have a specific purpose (to dry/warm up towels) or can generally improve the design of a room.

However, it is not just the performance of a radiator that determines the quality of heat delivery. Optimum heat distribution can only be achieved if the radiator is installed in the right place. The traditional place under the window is still to be recommended: incoming cold draughts are intercepted and the heat is delivered unimpeded into the room. At the same time, the position can be chosen not only with energy savings in mind, but also for reasons of design.

Importance of radiators for the energy efficiency of a modern heating system

The energy saving potential of high-efficiency heat generators – such as a condensing boiler or a heat pump – will only be realized, provided that the system temperature of the heating system is adapted. The lower the system temperature, the higher the efficiency of the heating system. Low-temperature radiators are ideally an integral part of the modernisation of a heating system. Comparing the performance of high temperature systems (80/60°C or 70/55°C) with low temperature system (45/35°C) will show the important role that low-temperature radiators can play in exploiting the energy saving potential of the entire system.

Benefits

- ✓ Highly efficient, energy saving and providing all round comfort where needed;
- ✓ Functionally and aesthetically adaptable;
- ✓ Easy to install and requiring minimum maintenance;
- ✓ Flexible and future-proof as they can be combined with all modern heating technologies and renewable energies.

3 COUNTRY HIGHLIGHTS (DE, ES, FR, IT, PT)

3.1 Germany

In 2018 alone, an increasing installation of efficient heating appliances has helped to reduce substantially the country's installed stock of old and inefficient heaters, which is the second largest in Europe. In fact, the introduction of a new generation of heaters can drastically reduce CO_2 emissions and energy consumption – starting from a minimum level of 20% per renovation of a heating system. This development is believed to positively affect the job market, providing new work opportunities to 50.000 heating installers, as well as to the 37.000 employees of the manufacturing industry. An industry generating over 15 billion Euros of worldwide turnover. While the modernisation rate is higher than in most EU countries, it will still take about 20 years substitute old heating systems with efficient and renewable ones.

What are Germany's efficient technologies of choice? Gas condensing boilers hold a leading market position and in more than three quarters of all cases they replace an old heater, bringing substantial energy savings. Electric heat pumps are the second most popular heating technology, showing gradually increasing sales trends.

Interestingly, the German solar thermal market is the largest in Europe – although new installations have been declining since 2009. Today, more than one in ten heaters is coupled with solar thermal technology. Moreover, district heating is quite common, being used by about 14 % of residential buildings. As several old systems still use coal, modernisation is needed, either via the use of individual, cleaner appliances, or thanks to the creation of small, efficient and renewable-fuelled district heating networks.

3.2 Spain

Increasing sales of efficient and renewable heating appliances are making an important contribution in modernising a large stock of old and inefficient installed heaters. Replacing each of these aging heaters with new, highly efficient ones, is supposed to bring a significant reduction in CO_2 emissions as well as energy savings.

However, considering the current renovation rate, it will take several decades to modernise such a large installed stock and attain these results, which are crucial to achieve the climate and energy targets established both by Spain and the European Union. An acceleration of the replacement rate is needed, hence the recent launch by the Spanish heating industry of a label for installed appliances. Thanks to this label, consumers will be able to compare the (in)efficiency of their installed heaters with the efficiency of modern and more efficient alternatives.

Today, condensing boilers – especially fuelled by natural gas – are the most common technology on the Spanish market. Replacing old systems with these new ones will bring energy savings in the area of 20% and even higher CO_2 emissions reductions. Gas condensing technology benefits from being easy to install and maintain, as well as from an extended gas distribution network – especially in Spanish urban areas. Even greater energy savings and CO_2 emissions reductions can be brought by installing renewable-based heaters. Among these technologies, installations of biomass boilers remain stable in 2018. On the contrary, sales of heat pumps are growing, supported by various incentive schemes at regional level.

Differently from most other European countries, the solar thermal sector has been recovering since 2017. New installations are still much lower than in the pre-crisis years, but installations have been increasing thanks to new constructions. Indeed, since 2006, the Spanish building technical code (*Código Técnico de la Edificación, CTE*) requires the installation of solar water heaters in new buildings - rather appropriate in Spain, where solar thermal can easily cover most hot water needs of a building.

3.3 France

Abundance of electricity and the resulting relatively low prices contributed to make France the largest EU market for electric heat pumps. Electric heat pumps are often used in new buildings. When it comes to hybrid heat pumps, France remains one of the largest EU markets, although installations did not grow in 2018. Gas condensing technologies account for about three quarters of the French heating market. Also, pushed by changes in the regulatory framework, biomass boilers saw a slight increase, although their numbers remain smaller than the pre-crisis peak, in 2008. Another previously declining market, solar thermal, started to stabilise in 2018, thanks to installations in collective buildings.

Accelerating the replacement of old appliances with new ones is key to reduce the greenhouse gas emissions of buildings in France. Indeed, modernising the current stock of inefficient heaters can cut greenhouse gas emissions, starting from 35% reductions per heating system, with state-of-the-art appliances. In this field, condensing technology is playing the lion's share, as most of the installed non-condensing heaters are replaced with a modern, state-of-the-art condensing boiler. However, at current replacement rate, it will take about two decades to entirely modernise the installed stock of old and inefficient heaters – hence the need to accelerate the deployment of efficient and renewable heating technologies. New installations put France within the EU average replacement speed. As a result, it will take about two decades to entirely replace the installed stock or old and inefficient heaters with new, efficient and renewable ones.

A higher replacement rate will contribute to further raising the contribution of the heating and cooling industry to the French economy, which generates a turnover of over 6 billion Euros and directly employs 23.000 people.

3.4 Italy

In 2018, an increasing number of energy-efficient and renewable-based heaters were installed in Italian buildings. Most of these appliances were gas-condensing boilers, the most common efficient technology used to replace the stock of old and inefficient non-condensing boilers. Significant adjustments in the regulatory framework have helped to accelerate this positive market development, for instance by tax reductions for energy efficiency measures and the renovation of buildings, applicable since 2008. According to the annual report of ENEA - the Italian Energy Agency – the heating sector generated a turnover of 3.8 billion EUR in the period 2014-2018 for the Italian economy, providing over 1.400 GWh/year of energy saving. Furthermore, the Italian government estimates a growth of about 115.000 employees/year for the period 2017-2030 in the energy sector, where the heating industry has a leading role.

Despite being the second EU market and the second EU manufacturing industry for energy efficient and renewable-based heaters, installations of these new appliances are still only making a dent in the installed stock of old and inefficient heaters. In addition, it is worth mentioning that prior to the application of the EU Ecodesign regulation on space and water heaters[8], the Italian market was mainly focused on traditional fossil-fuel appliances. Consequently, the vast renewal of appliances has only started in recent years. At the current replacement rate, it will take about 20 years to entirely substitute the stock of old and inefficient heating appliances. To accelerate the replacement rate, the Italian heating sector is strongly investing in communication, training and has recently launched a label for installed appliances. This label does not just aim to demonstrate how inefficient the appliances currently installed in people's cellars and bathrooms are, but also allow a direct comparison with the EU energy label of new appliances. The comparison allows people to see at a glance the efficiency gap between old and new appliances and will help them planning the replacement.

Moreover, Italy is the EU largest market for hybrid heat pumps. Hybrid heat pumps have become particularly successful in Italy due to supportive policies and the appliance's versatility which allows them to adapt to the significant weather changes present in Italy. Electric heat pumps have enjoyed very high growth rates in the past years thanks to the introduction of a special tariff in 2014, as well as other financial incentives. Solar thermal technology, on the other hand, has been decreasing since 2011, whereas the Italian government recognized the potential of the solar thermal technology and included them in the draft version of their National Energy and Climate Plan.

3.5 Portugal

In Portugal, in 2017 (no data from 2018) 144.718 heat pumps were installed, which represents a 12% increase over 2016. (Source: Heat Pumps Barometer). The most installed heat pumps were aerothermal heat pumps (99,7%).

[8] Commission Regulation (EU) No 813/2013 and Commission Regulation (EU) No 814/2013

Regarding the Portuguese buildings, 86% have a space heating equipment installed. Centralized heating solutions can be found in 12% of the buildings and 7.800.000 of the appliances (74,7% of the total heating appliances installed) are still inefficient heating appliances like open fireplaces, wood burners, electric or gas heaters, thermo-communicators, wall-mounted heaters, etc. (Source: 2011 demographic census).

The installation of heat pumps is an increasingly recurring bet in Portugal due to the diversity of functionalities: heating, cooling and domestic hot water and the current trend towards the electrification of the heating and cooling sector, as when combined with systems for electrical self-consumption, such as photovoltaic solar, they present themselves as an attractive greener solution for the consumer-producer, also complying with the new requirements for almost zero energy buildings. Economic growth and the boom in the buildings refurbishment market can also have a significant impact in this sector.

It is also important to mention that air-source heat pumps have other worth mentioning advantages over the old and efficient heating appliances, widely used in Portugal: lower fuel bills, especially when replacing conventional electric heating; lower local carbon emissions; minimal maintenance needs; the possibility to use renewable heat from the surrounding environment; highly energy efficient; suitable for different building contexts, especially in existing buildings, which is very important in the Portuguese housing market.

Regarding DHW production in Portugal, the most common appliances installed are gas instantaneous water heaters, representing 81% (source: EHI) of the market and the second most used technology is electric storage water heaters with 18% (source: EHI). As for combi systems the most common solution are non-condensing boilers, representing 91% of gas boilers (source: EHI) and 84% of the solutions in the combi system market.

Due to the energy efficiency regulations and the application of EPC (energy performance certificates) requirements for new buildings solar thermal has increased since 2006, as it is mandatory and can only be replaced for other DHW systems requiring renewable sources like biomass boilers or heat pumps.

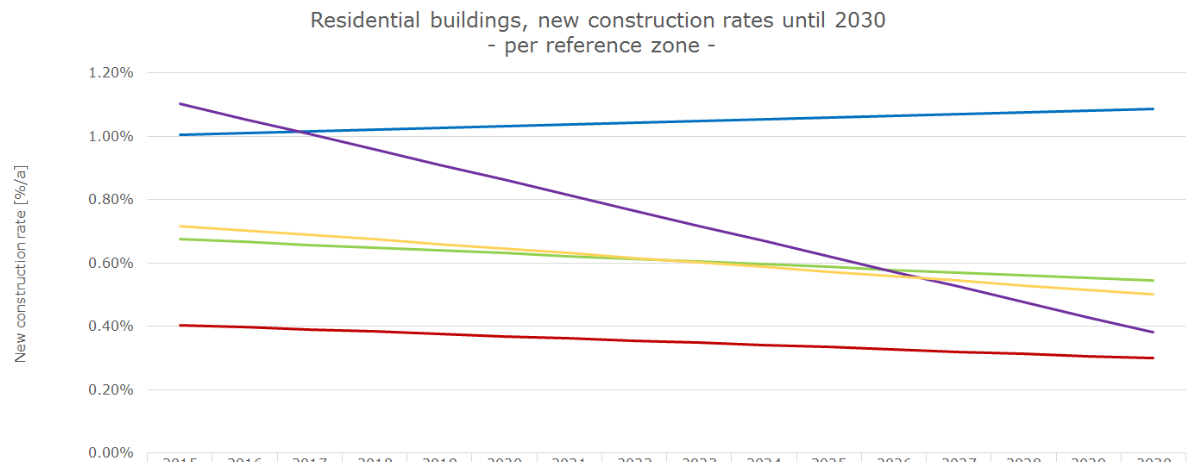
Looking ahead, at the Integrated National Energy and Climate Plan, there are plans to revise the legislative framework aiming to promote the updated of technical systems in buildings.

4 POTENTIAL ADOPTION SCENARIOS

Accelerating the replacement of old and inefficient heating systems is expected to produce significant reductions in total energy consumption and carbon dioxide emissions. To address this, a primary assumption is that the total heating system sales volume will increase by 25% from 2016 until 2020 and remain on this level until 2030 (from 7.0 to 8.8 Mio. sales/year[9]). When considering the new

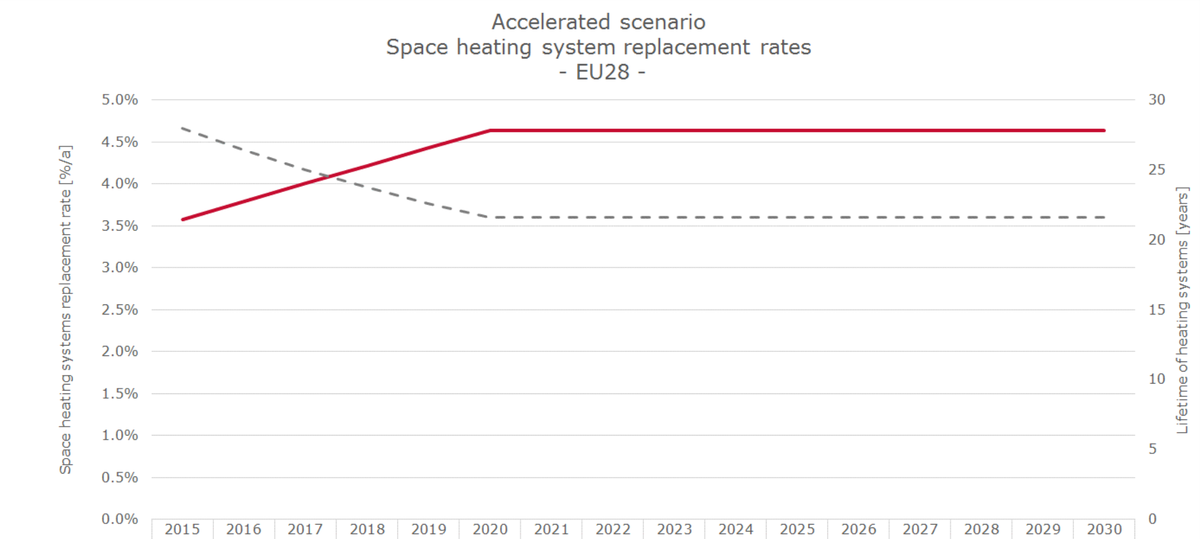
[9] Sources: EHPA, EUROHEAT, EHI, ECOFYS

construction rates for EU28 in the near future (cf. Figure 1), which is based on the prediction of the gross domestic product and the population, this equates to an increase of the heating system replacement rates of approx. 30% (3.6% to 4.6%) - as the amount of sales in new buildings cannot be varied. Consequently, this leads to a reduction of the average lifetime of heating systems from 28 to 22 years from 2020 onwards (cf. Figure 2).



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Northern	1.01%	1.01%	1.02%	1.02%	1.03%	1.03%	1.04%	1.04%	1.05%	1.05%	1.06%	1.07%	1.07%	1.08%	1.08%	1.09%
Western	0.67%	0.67%	0.66%	0.65%	0.64%	0.63%	0.62%	0.61%	0.60%	0.60%	0.59%	0.58%	0.57%	0.56%	0.55%	0.54%
North-Eastern	1.10%	1.05%	1.01%	0.96%	0.91%	0.86%	0.81%	0.77%	0.72%	0.67%	0.62%	0.57%	0.53%	0.48%	0.43%	0.38%
South-Eastern	0.40%	0.40%	0.39%	0.38%	0.38%	0.37%	0.36%	0.36%	0.35%	0.34%	0.33%	0.33%	0.32%	0.31%	0.31%	0.30%
South	0.72%	0.70%	0.69%	0.67%	0.66%	0.65%	0.63%	0.62%	0.60%	0.59%	0.57%	0.56%	0.54%	0.53%	0.51%	0.50%

Figure 1: New construction rates per reference zone, residential, 2015-2030[10]



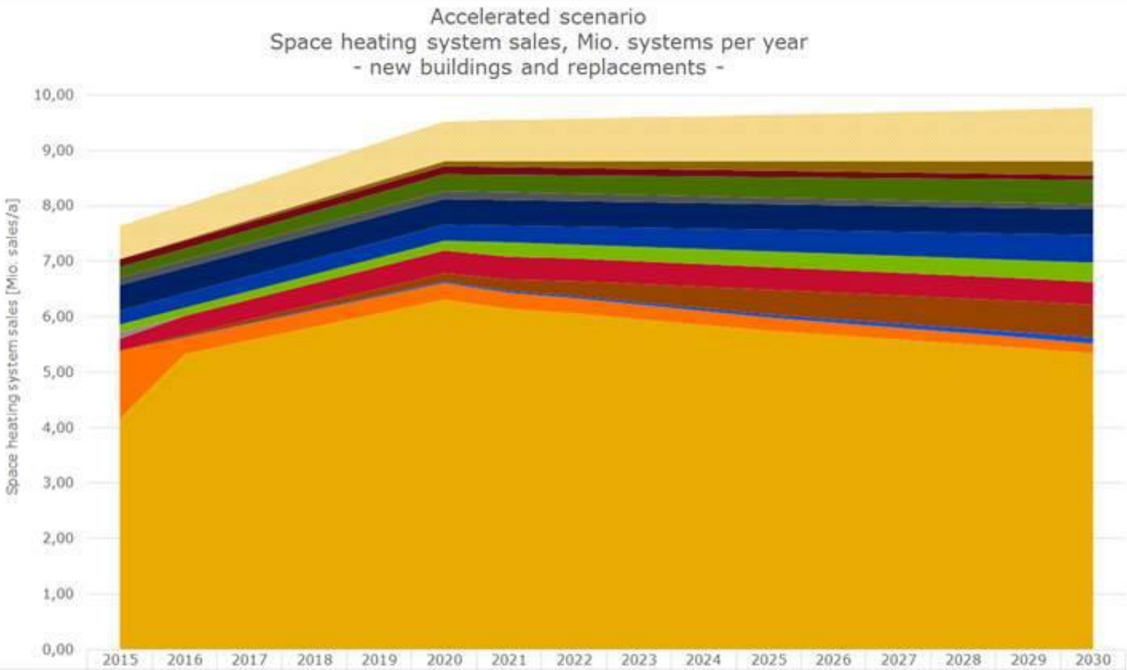
	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Replace_Rate	3.6%	3.8%	4.0%	4.2%	4.4%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%	4.6%
Lifetime	28	26	25	24	23	22	22	22	22	22	22	22	22	22	22	22

Figure 2: Space heating system replacement rates, EU28, %/a

This section aims to evaluate how an increase of the modernisation volume of heating systems (cf. Figure 2) in combination with a realistic heating system mix (cf. Figure 3) can contribute to lower energy consumption and significantly reduce emissions, thus helping to achieve the EU emission reduction targets. To understand the impact of changes in the heating system, an increase in the

[10] Schimschar, 2015

number of heating system sales alone cannot generate a complete picture. To achieve a more fine-grained analysis, one must consider the mix of different heating technologies, which will be installed. Figure 3 shows the resulting heating system sales distribution within the limits of the above-mentioned sales volume per year. All figures result from various workshops that EHI and Ecofys conducted on the potential future developments in the heating market as part of a joint study.[11]



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
ST (DHW)	0,60	0,62	0,65	0,67	0,70	0,72	0,74	0,77	0,79	0,82	0,84	0,86	0,89	0,91	0,94	0,96
mCHP+fuel cells	0,01	0,03	0,04	0,06	0,07	0,09	0,11	0,12	0,14	0,15	0,17	0,19	0,20	0,22	0,23	0,25
Coal	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,13	0,13	0,12	0,12	0,11	0,10	0,10	0,09	0,09
DH	0,19	0,21	0,23	0,25	0,28	0,30	0,32	0,33	0,34	0,36	0,37	0,39	0,40	0,41	0,43	0,44
EL	0,14	0,14	0,14	0,14	0,14	0,14	0,14	0,13	0,13	0,12	0,12	0,11	0,10	0,10	0,09	0,09
HP, air/air	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46	0,46
HP, hydronic	0,25	0,26	0,27	0,27	0,28	0,29	0,30	0,32	0,34	0,37	0,39	0,41	0,43	0,46	0,48	0,50
Wood	0,14	0,15	0,15	0,16	0,17	0,18	0,26	0,25	0,26	0,27	0,28	0,30	0,31	0,32	0,33	0,35
Oil, nc	0,11	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Oil, c	0,21	0,34	0,36	0,38	0,39	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41	0,41
Hybrids (gas+HP)	0,01	0,04	0,07	0,09	0,12	0,15	0,21	0,27	0,33	0,39	0,45	0,48	0,51	0,54	0,57	0,60
HP, gas	0,00	0,01	0,01	0,02	0,02	0,03	0,03	0,04	0,04	0,05	0,05	0,06	0,07	0,08	0,09	0,10
Gas, nc	1,22	0,30	0,30	0,30	0,30	0,30	0,29	0,28	0,26	0,25	0,24	0,23	0,21	0,20	0,19	0,18
Gas, c	4,16	5,33	5,58	5,82	6,06	6,31	6,14	6,06	5,96	5,85	5,75	5,67	5,59	5,51	5,43	5,34

Notes:
- district heating (DH) considers only new connections
- heat pumps (HP, hydronic) do not include sanitary heat pumps and heat pumps for cooling purposes

Figure 3: Total space heating system sales, million sales/year[12] [13] [14]

Figure 3 shows the heating system sales distribution, as projected by the heating industry. These estimates of potential growth and changes in the future sales volumes and product mix are also based on market developments, performance, product developments, customer acceptance and policies.

As mentioned at the beginning of this paper, the heating market is driven by customer demand. Customers often chose cost-effective solutions because of financial constraints and are resistant to new technologies that would often need larger structural construction measures. Although this means that customers will generally opt for a more efficient version of their current heating system, e.g.

[11] Ecofys, 2016: "EU pathways to a decarbonized building sector"
[12] Delta-EE, 2015
[13] The following abbreviations are used: c = condensing; nc = non-condensing; HP = heat pump; mCHP = micro combined heat and power; DH = district heating; EL = electric direct, ST = solar thermal system
[14] Note: Solar thermal system sales figures (ST (DHW)) are added for visualisation purposes although it is not a space heating system but a domestic hot water system.

replacing an old inefficient boiler with a condensing gas boiler, this still delivers significant efficiency improvements. According to the heating industry, replacing an old heat generator with a more efficient one (e.g. condensing technology) can reduce energy demand and carbon dioxide emissions by at least 25% compared to current levels.

EHI and Ecofys conducted several workshops on the potential future developments in the heating market. A major outcome of the workshops was the established need to increase replacements of old and inefficient boilers in the European Union. The following paragraphs show recent significant market trends per technology.

- **Gas, condensing boiler:**
  Gas condensing boilers show a constant growth over the last years whilst non-condensing sales dropped in 2014 to 1/3 of the sales volume of 2005. The prohibition of most of the non-condensing gas boiler systems (Ecodesign regulation) will potentially lead to even increased sales of condensing boilers from 2016 onwards, especially if the replacement of old, inefficient boilers is increasing.
- **Heat pumps:**
  In new buildings previous years have already shown an increasing electrification of heating systems and it is likely that this trend will evolve especially from 2021 onwards when nearly zero energy buildings will be introduced by the EPBD.
- **Hybrid heat pumps:**
  Hybrids are perceived as a key technology for providing decarbonised heating especially of the existing building stock. They combine the high efficiencies of heat pumps with the additional flexibility to choose the energy carrier. This is of high importance for the future energy market with higher shares of renewable electricity due to the need of flexibility options. Also heat pumps offer a certain flexibility especially on short term, as the heat can be stored in times of high energy prices. But especially in periods (typically a few weeks during the winter), when the heating demand is high but the share of renewables is moderate (due to low solar irradiation and a period of moderate wind) hybrid systems offer additional flexibility. Another main benefit is that they make maximum use of the heat pump under conditions when it can operate at optimum efficiency but allows a boiler to provide the peak heating demands e.g. under very cold conditions or fast heat up periods when the heart pump is less efficient. The heating industry is convinced that hybrids will grow significantly if the policy framework is adapted accordingly. Today hybrids represent a niche technology in sales with a high potential to evolve rapidly.
- **Biomass boilers:**
  Biomass boiler sales remained constant over the last 10 years having experienced some peaks (2006 and 2008) and dips (2007 and 2010). The demand for biomass boiler is likely to increase especially from 2021 onwards (introduction of nearly zero energy buildings by EPBD).
- **Micro combined heat and power (mCHP):**
  A micro-CHP appliance allows generating heat and electricity from a single source, close to the place it is used, on a building level. CHP systems displace grid generated electricity. This means they are significantly more efficient than power stations, because energy isn't lost during transmission and transportation leading to considerably reduced carbon emissions. Further money savings can be made through the feed-in tariff, which pays a generation tariff for every kWh or electricity you generate and an export tariff for the power you don't use

which is exported back to the grid. A moderate growth of micro combined heat and power installations can be expected if the political framework stimulates this development.

  - The sales of micro combined heat and power installations are currently limited to Western Europe with only a few thousand systems installed in 2014 (compared to about 3 million gas condensing systems).

- **Solar thermal systems:**
  Although the past years show a declining trend for solar thermal systems in most EU Member States, a sales increase can be considered due to the prescription of the Renewable Energy Directive (RED) until 2020 and due to the nearly zero energy introduction from 2021 onwards (EPBD).

Given the information and sales data provided above it can be concluded that an increase in the replacement rate is crucial to unlock the full potential of modern and efficient heating appliances in terms of energy savings and emission reduction.

5 CONCLUSIONS

The deep characterisation of available heating technologies as well as the analysis of potential adoption scenarios have shown that an accelerated replacement of heating systems in combination with future developments in low-carbon heating technologies can indeed help to reduce final energy consumption in buildings and thus contribute to reach EU energy and climate saving targets. Approximately 72 million low efficient heating systems are still installed in Europe, while sales figures for heating systems even show a decline over the last years due to the aftermaths of the financial crisis in 2008. Therefore, accelerating the replacement of existing boilers remains a strong opportunity to lower the energy consumption as well as carbon dioxide emissions in Europe.

A study conducted by Ecofys[15] on request of the European Heating Industry has revealed that the energy need of European residential buildings can be reduced by 12%, the delivered energy by 19% and that carbon dioxide emissions can be lowered by 18.5% (in 2030 compared to 2015 baseline), which translates into 39% CO_2 reductions towards 1990 levels, if the EU manages to improve the replacement rate of the installed heating stock. The scientific scenario proves that the installation of low-carbon heating systems and an accelerated replacement of old heating systems can indeed largely contribute to achieve the EU 2030 targets. The current policy framework in the EU already contains policies that can be expected to have positive impacts on the heating sector – e.g. by the Ecodesign interdiction of non-condensing boiler sales from 2016 onwards and the EPBD's implementation of nearly zero energy buildings (NEZBs) as of 2021. These policies will therefore certainly play an important role on the path to significant carbon dioxide reductions in the future.

In conclusion, the biggest contribution that Europe can make – with respect to heating systems – is to develop dedicated policies to accelerate the replacement rate of the 72 million old and inefficient heaters installed in EU homes. Consequently, the EU funded project HARP has the potential to help accelerating the retrofitting of inefficient appliances by empowering consumers to replace their heating appliances with more efficient alternatives. This bottom-up approach will be another step into

[15] Ecofys, 2016: "EU pathways to a decarbonized building sector"

the right direction benefitting consumers as well as ultimately helping to save energy and reduce GHG emissions.