EUROPEAN COMMISSION
RTD - Energy
ENER - Renewables, R&I, Ener
JRC – Energy, Transport & Climate

SET Plan Secretariat

SET-Plan – ISSUES PAPER on strategic targets in the context of Action 5

"Develop new materials and technologies for energy efficiency solutions for buildings"

CROSS CUTTING HEATING AND COOLING TECHNOLOGIES FOR BUILDINGS

1. Purpose of this document

In September 2015, the European Commission adopted a Communication for an Integrated Strategic Energy Technology Plan (C(2015) 6317 final). The Communication identifies ten priority actions to accelerate the energy system transformation that should facilitate coordinated or joint investments by individual Member States, between Member States and with the EU. These actions have been defined on the basis of the Integrated Roadmap[1] developed with stakeholders and Member States and in line with the new political priorities defined in the Energy Union. Out of the ten priorities of which some are focused on specific technologies, two are related to the development and strengthening of energy-efficient systems, namely Action 5 on the development of new materials and technologies for energy efficiency in buildings, and Action 6 on the continuation of our efforts to make EU industry less energy intensive and more competitive.

For each priority action, the services[2] of the European Commission develop an Issues Paper which will be jointly prepared by and discussed with the representatives of EU Member States and countries forming part of the SET-Plan, working together in the SET-Plan Steering Group, as well as with other stakeholder and Member State forums. These documents will serve as a starting point for discussions with Member States and stakeholders in the development of new research and innovation cooperation at European and national level, not necessarily linked to the on-going H2020 programme. Each Issues paper aims to define (a) the level of ambition (in terms of priorities and targets), (b) the modalities for the implementation and (c) the timing for achieving results and adopting expected deliverables.

This document[3] is intended to progress the implementation of Action 5. It is the second issues paper under Action 5, the first one adopted in April 2016 containing technology neutral targets for efficient solutions for buildings.

[1] https://setis.ec.europa.eu/system/files/Towards%20an%20Integrated%20Roadmap_0.pdf
[2] For this Issues Paper: DG ENER, RTD, JRC and EASME
[3] This document is a working document of the European Commission services for consultation and does not prejudge the final form of any future decisions by the Commission.

Stakeholders and Member States will be invited to take positions on the proposed targets in accordance with the guidelines set out in the paper "The SET Plan actions: implementation process and expected outcomes" and submit their positions to SET-PLAN-SECRETARIAT@ec.europa.eu by Friday 28 October at the latest. Relevant documents and material on the SET Plan and Integrated roadmap are available on the SETIS website https://setis.ec.europa.eu/ and other relevant information is available on the EC website[4].

2. Context

Energy demand for Heating and Cooling (H/C)

The total EU28 energy demand for H/C equals 51% of the total final energy demand (Fig 1.a, Annex I)

The majority of the demand for H/C is due to space heating (52%), process heating (30%) and water heating (10%) (Fig 1b, Annex I). Space cooling is currently limited, although the sector is growing fast.

Most of the energy demand for H/C is satisfied with fossil fuels, with natural gas having the lion's share (45%). Relevant amounts of coal (9%) and fuel oil (12%) are also used (Fig. 2, Annex I). District heating satisfies 8% and electricity 12% of the H/C demand. Consistently with the specific National energy mix, renewables energy is used in the form of electricity to satisfy the H/C demand. However with the exception of biomass (12%), the use of other renewables for H/C is marginal[5].

Energy demand for H/C in the individual Member States

The share of the final energy demand for H/C deviates substantially across MSs and neighbour countries. It ranges from 36% in Norway and Portugal to a distinctively high value of 68% in Slovakia (Fig 3, Annex I).

These figures are influenced on one side by the presence of energy intensive industry and space heating demands, but also by the importance of energy demand in non-H/C sectors, mainly transport.

Looking at the energy carriers used in the H/C sector in the individual MS, the share of natural gas reaches 68% in the UK, 66% in the Netherlands and 59% in Hungary. Finland, Sweden, Norway and Iceland plus Malta and Cyprus use for H/C a natural gas share lower than 5%. Poland is the country with a high share of coal (38%), followed by Slovakia (20%) and the Czech Republic (17%). On the other side, in 24 out of 31 countries the share of coal is below 10% (Fig. 4, Annex I).
District heating has particularly high shares in northern and eastern countries. Lithuania (36%), Estonia (34%) and Denmark (29%) have the highest shares. The use of electricity in H/C has

[4] https://ec.europa.eu/research/industrial_technologies/energy-efficient-buildings_en.html
[5] These figures are slightly different from those indicated in the "Heating and Cooling Strategy" COM(2016) 51 final published on 16.2.2016.. For this document, more recent consolidated figures are used.

shares above 20% in countries with high space cooling demand, which are mainly the Mediterranean countries. Exceptions are Norway (45%) and Iceland (28%).
The share of biomass used in H/C is high in the Baltic countries, Sweden and Finland: more than 28% compared to an EU average of 12%. Cyprus on the other hand has the highest share of solar energy (14%) followed by Malta (4%).

Age of the technology stock available for heating and cooling

In terms of installed capacities, the oldest heating stock is installed in Cyprus, Poland and Bulgaria and the newest in Estonia, Italy and Sweden. The age distribution by country for the EU-28 as a whole is illustrated in Figure 5, Annex I.

Policy framework

In order to achieve its targets for 2020 and 2030, the EU has put in place a comprehensive regulatory framework built around the Energy Performance of Buildings Directive (EPBD) (2010/31/EU), the Energy Efficiency Directive (EED) (2012/27/EU) and the Eco-design (2009/125/EC) and Energy-labelling (2010/30/EU) directives. With this legislative framework, the EU has set itself ambitious policy objectives which include, for instance, that all new buildings must be Nearly Zero Energy Buildings (NZEB) by 31st December 2020 (public buildings by 31st December 2018), that minimum energy performance requirements should be set for major renovations and for the replacement or retrofit of building elements, and that at least 3% of the heated and/or cooled floor area of buildings owned and occupied by central governments should be refurbished each year.

It is important to underline that as part of the Energy Union Strategy of 25 February 2015, the Commission announced the review of the Energy Efficiency Directive (EED) (2012/27/EU) and the Energy Performance of Buildings Directive (EPBD) (2010/31/EU) as one of the key strategic energy efficiency policy initiatives to contribute to moderation of demand.

Ecodesign and energy labelling requirements for space and water heaters came into force in 2015. The sale of the most inefficient boilers is now banned. Consumers are able to see efficiency ratings – both for single technologies and for packages that include the use of renewables. The transition that these measures are expected to foster should bring annual energy savings of 600 TWh and CO2 emission reductions of 135 million tonnes by 2030. At the same time, emissions of air pollutants will also be reduced.

A communication entitled "An EU Strategy on Heating and Cooling" from the Commission to the European Parliament, the Council, the European Economic and social Committee and the Committee of the Regions was published on 16.2.2016 (COM(2016) 51 final).

The new Regulation on fluorinated greenhouse gases will also accelerate the refurbishment of heating and cooling systems. Climate-friendly refrigerants offer great energy saving potentials, but require for some applications an update of existing standards to ensure their safe use. To that end the Commission has initiated the discussion of reviewing the relevant European standards.

While fully acknowledging the importance that building envelope improvements play in increasing efficiency, it is important to take into account all relevant efficient heating and cooling options. Measures on the envelope and on the heating system as such must be combined to ensure optimal outcomes and to avoid counter-productive effects. This becomes especially clear when considering the differences between Member States, and urban and rural areas.

As already mentioned, H/C is responsible for 51% of the EU's final energy consumption. As a consequence, an increased penetration of renewable technologies in the heating and cooling sector is crucial for the EU to meet its renewable target and its CO2 reduction target. The EU is progressing towards meeting both the 20% RES target and the 20% energy efficiency target set for 2020. The latest available Eurostat figures provide an overall EU RES share of 16% in 2014[6]. This overall figure is composed of a share of 5,9% of RES in the transport sector, 27,5% of RES in the electricity sector and 17,7% of RES in the H/C sector.

With the revision of the renewable energy directive, the Commission is also assessing different policy options for heating and cooling to ensure the timely and cost efficient achievement of the 27% RES target for 2030.

The accomplishment of this target poses new challenges. Given the difficulties which arise by adding more variable RES electricity to the grid, and given the slow growth in the take-up of RES fuels in transport, the 27% EU-level target for 2030 may have to be met by the still underexploited RES potential in the H/C sector[7].

A wide range of renewable heating and cooling solutions is available and scaling-up the market would reduce their price. Furthermore, research will develop novel and more efficient renewable energy solutions. The Energy Labelling Directive (2010/30/EU) states that Member State incentives for products such as heaters need to aim at the highest performance levels. In line with the G20 2020 statement about inefficient fossil fuel subsidies, the Commission is calling on Member States to focus incentives on non-fossil fuel based heating and cooling technologies.

Other benefits

Decarbonising the EU heating and cooling sector contributes to the three core objectives of the EU energy policy: Makes the EU economy energy secure, by reducing reliance on natural gas and oil imports; Makes it more sustainable, by reducing GHG emissions, environmental and societal costs of coal and heating oil; Contributes to the EU's economic growth, through reduced cost of energy imports and creating new economic and business opportunities in the EU.

3. Technologies targeted in this document

The use of renewable energy sources (RES) such as biomass, solar thermal, geothermal and aerothermal offer a safe, reliable and increasingly cost-competitive solution to all heating and cooling needs. In order to realise this potential it is necessary to exploit synergies among the

[6] EU energy in figures, Statistical pocketbook 2016, European Union, 2016

[7] Given the current progress and the fact that H/C is responsible for more than 50% of the EU final energy consumption, only an increased penetration of renewables in the H/C sector will ensure the accomplishment of the renewable and CO2 reduction targets.

renewable energy production, distribution and consumption, by investing in **"Cross-cutting technologies".** The Renewable Heating & Cooling European Technology Platform identifies with this term any energy technology or infrastructure which can be used either to enhance the thermal energy output of a RES, to enable a greater fraction of the output by the system to be used, or to allow the exploitation of RES which would be difficult or impossible to use in building-specific applications.

Heat Pumps, District Heating and Cooling (DHC) and Thermal Energy Storage (TES) all fit the definition very well, can be used in buildings, and represent the technology focus of this document.

3.1 Heat Pumps

Introduction

Heat pumps combine high energy conversion with the capability of utilising aerothermal, geothermal or hydrothermal heat at useful temperature levels.
The Renewable Energy Directive 2009/28/EC of 23 April 2009 and its Annex VII specify that the heat extracted from the environment by a heat pump (ambient heat) is considered renewable as long as a minimum Seasonal Performance Factor (SPF) for the unit is met. Heat pumps present a versatile energy technology that can provide both heating and cooling in a great variety of building contexts and applications. They can be combined with smart technologies and storage. They can provide flexibility for the electricity system and also contribute to the management of the variability of heating and cooling demand. Heat pumps have the potential to become mainstream technology in the heating and cooling sector.
However, in many Member States, their market uptake and full adoption by consumers are still hindered by higher investment and installation costs, with a market price that is often two or sometimes even three times more than competing common heating products. In addition, the installation and the coupling with other technologies (e.g. shallow geothermal systems for ground source heat pumps) is frequently complex in dense urban environments. As today most heat pump systems, especially hybrid, are customised combinations of single components, the efficiency of the overall system strongly depends on the installer's skills, technical knowledge and choice of the right components.

Objectives

The objective is to develop the next generation of cost efficient heat pumps for new and renovated buildings. The aim is to accelerate their market uptake, improve their characteristics according to the market need and drastically reduce their cost to make them fully competitive with conventional heating solutions.
Increasing the demand for heat pumps and speeding up mass production requires:

- Standardized systems -with smart hydraulic layouts and standardized connector pipes- easy to be coupled with other systems harnessing renewables, in particular with geothermal energy sources. Standardized systems require standardized controls with energy monitoring and energy management with self-learning capacities and demand-response enabling elements. These controls allow integration of on-site renewable energy and switching to extra heating sources.

- Increased integration level to reduce the number of connectors to the building (inclusion of pumps, three way valves, pressure vessels), with an increased use of standardized, pre-fabricated components.
- Development of high capacity heat pumps for simultaneous production of hot water and cold water for heating/cooling the buildings.
- Remote monitoring for failure detection and preventive maintenance.
- Further improve the performance of heat pumps using ''natural'' instead of synthetic refrigerants
- Compact design with a minimum footprint.
- Modular design to include hot water storage tank in an inexpensive and simplified installation.
- Simplified design and installation by the installer.
- User-friendly interface and non-disturbing operation (low noise level)

3.2 District heating and cooling (DHC)

Introduction

District heating supplies 8% of the EU's heating and cooling. In 2012 the main fuel was natural gas (40%), followed by coal (29%) and biomass (16%). District Heating can integrate geothermal, solar thermal and waste heat sources, as well as renewable electricity. It can offer flexibility to the energy system by cheaply storing thermal energy, for instance in hot water tanks or underground.

Currently about 6000 District heating systems operate in Europe with varying levels of efficiency. High shares of the population are served by district heating in the Scandinavian and Baltic countries, while the percentages decrease drastically in Southern Europe. In Eastern Europe, the use of district heating is also widespread, but in some countries (e.g. in Romania), the systems are old and in need of modernisation. The district cooling is still not a widespread technology and many countries lack DC systems. The highest district cooling uses were registered in Sweden and France (in 2012).

In some countries, district heating is seen as an attractive option for companies and consumers and as a means of improving energy efficiency and renewable energy deployment. Elsewhere, however, due to lack of investment or unfavourable price regulation, old systems exhibit low performances and record negative consumer perceptions. Some Member States are making efforts to modernise and expand old systems – others, where the technology is hardly known, are building new ones. District heating and cooling can also contribute to air quality objectives, especially if it substitutes or avoids domestic heating by solid fuel's combustion.

Synergies between waste-to-energy processes and district heating/cooling could provide a secure, renewable, and in some cases, more affordable energy in displacing fossil fuels.

As for other solutions, the deployment of DHC differs widely between MS (from just a few systems to covering more than 60% of heat demand in North and North-Eastern Europe) which has a major impact on the set of measures that result in optimal improvements. Furthermore, it has been shown that the share of DHC as well as the potential for new grids differs between urban and rural areas[8]. As stated in the Issues Paper on Energy Efficiency in Buildings, "any approach that would seek to exploit the untapped energy efficiency potential would fail unless these differences were adequately considered."

Objectives

The decarbonisation of DHC networks requires the integration in the system of much higher shares of RES and waste heat; the reduction of the end-user connexion costs and the development of low-temperature heating networks.

Low energy buildings should also be integrated in existing District Heating and Cooling and smooth the transition to next generation networks.

Increasing the demand and use of DHC as well as speeding up mass utilization requires:

- Large scale demonstration of Smart Thermal Grids
- Demonstration of Booster Heat Pumps for DHC
- New solutions for circulation systems in buildings to save energy (pipe, ducts, pumps, new generation of liquids, …)
- Improved, highly efficient substations for both present and future lower temperature networks
- Optimised integration of renewable energy sources, and waste heat, in DHC systems and enhancement of thermal energy storage at system level
- Low temperature space heating systems
- Intelligent control of heating of buildings and peak shaving
- Minimization of losses in heat networks and intelligent control and metering of the network performance
- Increase waste heat collection from the commercial sector through simplification of connection to the grid (plug & play)

3.3 Thermal Energy Storage (TES)

Introduction

Thermal energy storage addresses the key bottleneck against the widespread and integrated use of renewable energy sources, as the renewable supply does not always coincide with demand for heating or cooling. Numerous technologies in sensible, latent or thermochemical form can time-

[8] EU-funded research project STRATEGO at http://stratego-project.eu/

shift renewable energy supply to periods of greatest demand, each of them characterised by different specifications and specific advantages.

Objectives:

Performance improvement of the thermal energy storage technology can be found in improved materials for the system, improved system concepts and operational characteristics. The performance improvement can be broken down into an increased energy efficiency (heat out/heat in) from 60% now to 75% in 2025, increased system lifetime from 25 to 30 years and reduction of operational & maintenance cost from 5% to 3% of investment costs.

The state of the art of thermal storage density at system level (the volume taken in by all components in a prismatic-shaped box) is around 60 kWh/m^3 for the zeolite system[9]. The density at material level for zeolite is 180 kWh/m^3, with a theoretical potential of about 230 kWh/m^3. With further material development of salt hydrates and composite materials, both the material storage density and the system level storage density can be increased. The potential for salt hydrate material level storage density is currently at about 800 kWh/m^3. For thermal storage based on phase change materials (PCM), the improvements will be found in materials improvement and cost reduction. Further improvement for the storage density at system level is also expected for these materials.[10]

Research and Innovation Priorities relevant to Thermal Energy Storage:

- Next generation of Sensible Thermal Energy Storages Development
- Improving the efficiency of combined thermal energy transfer and storage
- Increased storage density using phase change materials (PCM) and thermochemical materials (TCM)
- Improvements in Underground Thermal Energy Storage (UTES)
- Optimised integration of renewable energy sources in DHC systems and enhancement of thermal energy storage at system level
- Energy storage in the thermal mass of buildings and integration with demand response services[11]

[9] EU-funded research project COMTES at http://comtes-storage.eu/

[10] Further technology development is supported by the Public Private Partnership for Energy Efficient Buildings activities under H2020 http://ec.europa.eu/research/industrial_technologies/energy-efficient-buildings_en.html

[11] EU-funded research project Real Value

Targets by 2025:

Heat Pumps: Reduction by 50% of the equipment and installation costs of the next generation for small and large size heat pumps compared to 2015 market prices Development of prefabricated, fully integrated cost-effective 'plug in and play' heat pump systems. **District heating and cooling** Increase to 25% the share of RES and waste heat in DHC networks without jeopardising the quality of the service provided to the consumers. Decrease of the DHC substations reference cost for residential buildings by 15% compared to the 2015 prices. **Thermal Energy Storage** Improvement of 25% of performance (energy efficiency, system lifetime, O&M) of above ground and underground energy storage compared to 2015. Increase of 200% of storage density at the *system level*, from the current state-of-art of 60 kWh/m^3 [12]

Monitoring strategy:
Monitoring will be done by analysing results of R&I actions and market survey.

[12] This value is achieved for the zeolite system in the EU-funded research project COMTES at http://comtes-storage.eu/

List of Stakeholders to be consulted

- Energy efficient Buildings association (European construction technology platform)- ECTP
- Buildings Performance Institute Europe (BPIE)
- The European Alliance for Companies for Energy Efficiency in Buildings (EuroAce)
- European Heat Pump Association (EHPA)
- Federation of European Heating, Ventilation, and Air Conditioning Association (REHVA)
- The European Association for the Promotion of Cogeneration (COGEN Europe)
- Construction Product Europe (CPE) (http://www.construction-products.eu/).
- Renewable Heating & Cooling Technology Platform (TPRHC)
- Euroheat & Power (Association representing the District Heating and Cooling and Combined Heat and Power sector)
- Association of the European Heating Industry (EHI)
- European Insulation Manufacturers Association (Eurima)
- PU Europe, European Polyurethane Insulation Industry
- Eurovent (European Committee of Air Handling & Refrigeration Equipment Manufacturers)
- European Solar Thermal Industry Federation (ESTIF)
- European university association (EUA)
- European Builders Confederation (EBC)
- European Energy Research Alliance **(**EERA**)**
- European Geothermal Energy Council (EGEC)

ANNEX I

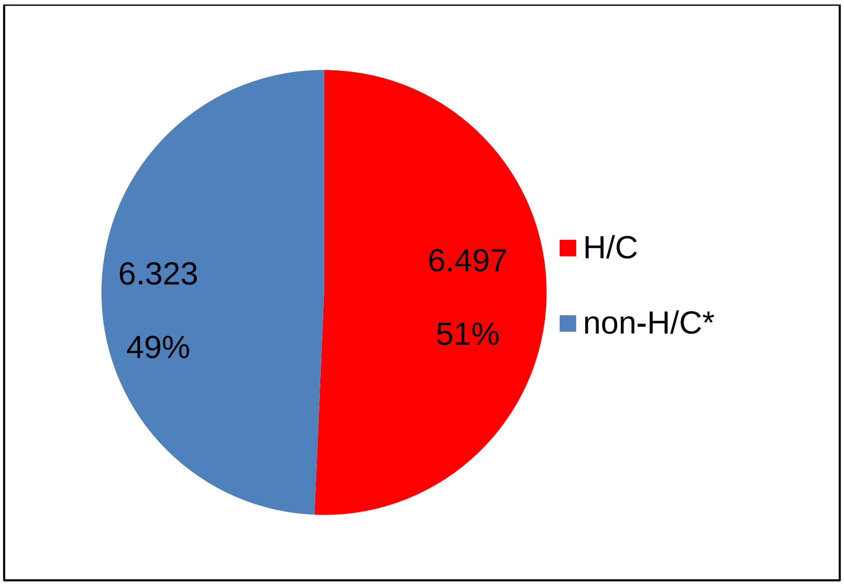

Fig.1a Total EU Final energy demand, year 2012 [TWh, %]

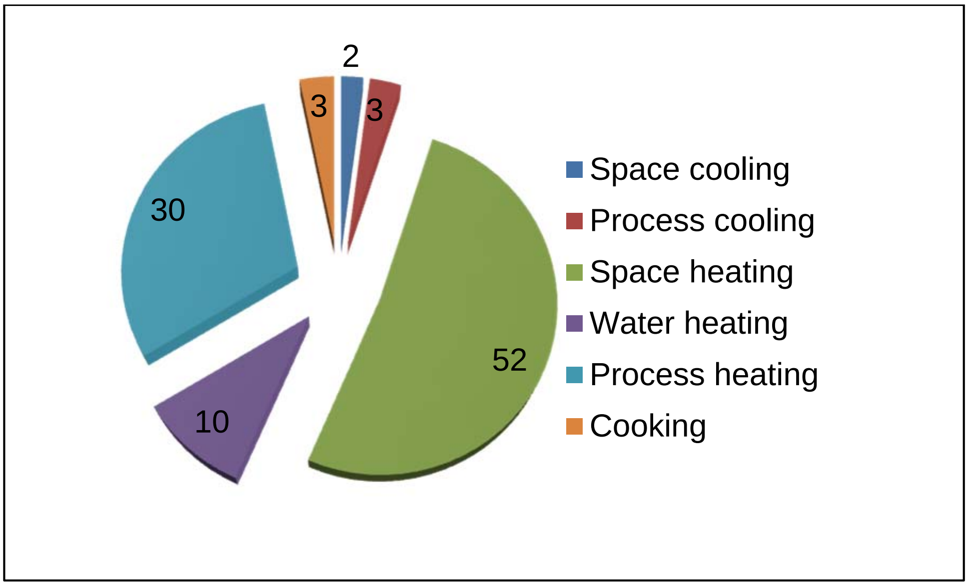

Fig.1b EU Final energy demand for H/C in sectors of use, year 2012 [%]

Source: Tender ENER/C2/2014-641 "Mapping and analyses of the current and future (2020 - fuel deployment (fossil/renewables)".
This tender study was coordinated by Fraunhofer ISI, in a consortium with Fraunhofer ISE, IREES, Observ'ER, TEP Energy Gmbh, and EEG - Vienna University of Technology. Reports are available at: https://ec.europa.eu/energy/en/studies?field_associated_topic_tid=All&page=2

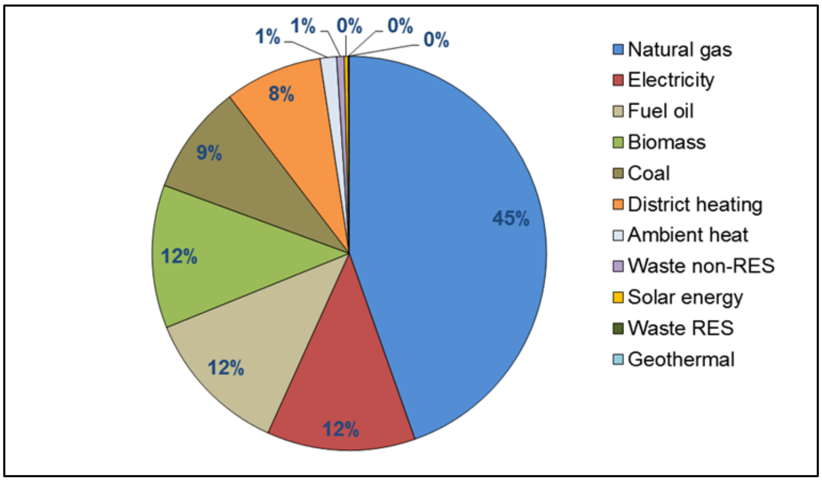

Fig 2: EU Final energy demand for H/C by fuels (%)

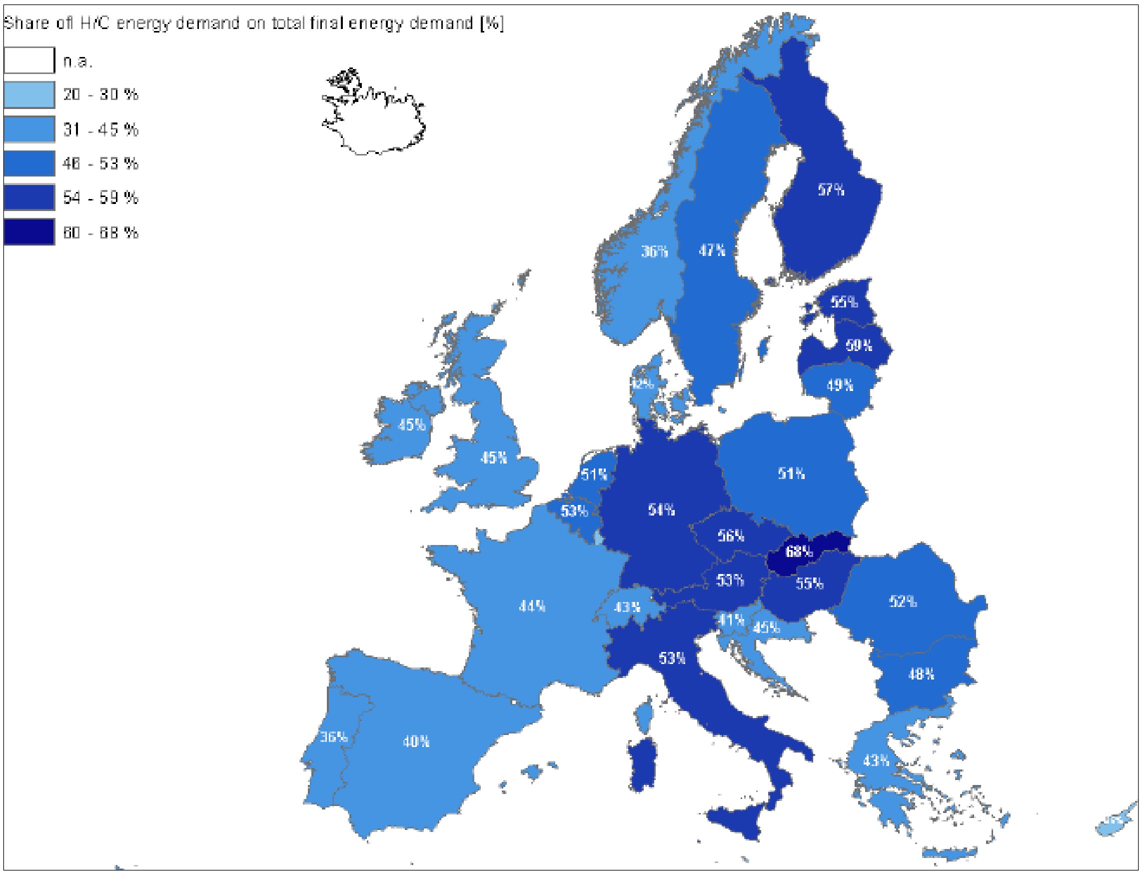

Fig 3: Energy demand for heating and cooling as a share of total final energy demand (year 2012)

Source: Tender ENER/C2/2014-641 "Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)".

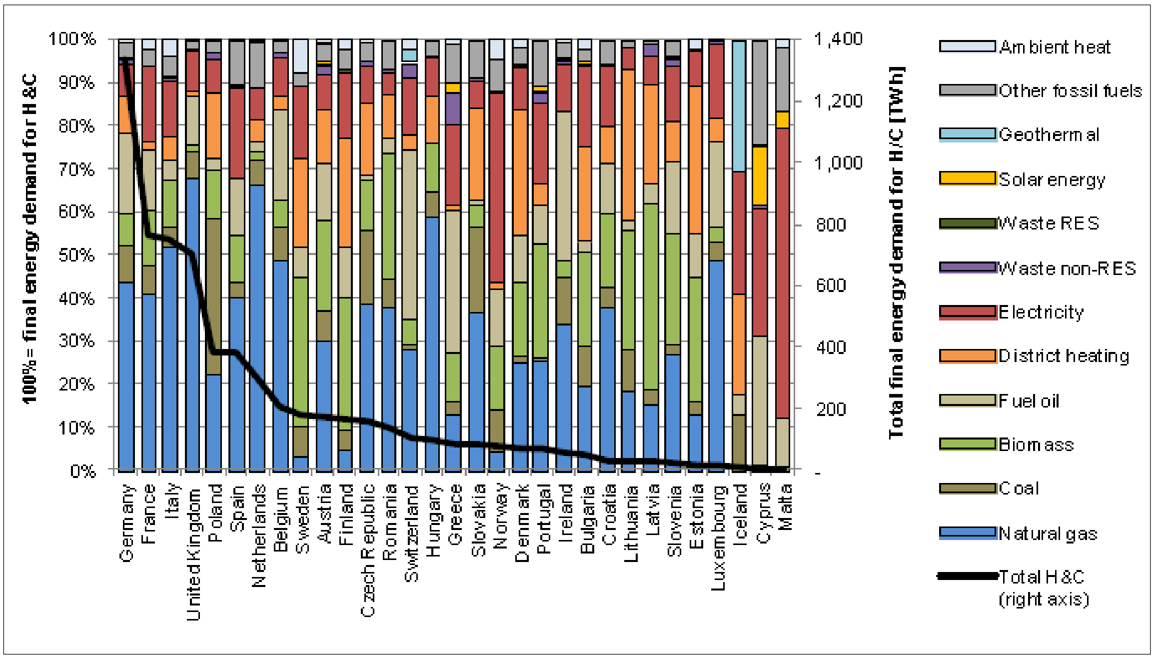

Fig 4: Energy carriers used for heating and cooling in the EU28+3 (year 2012)

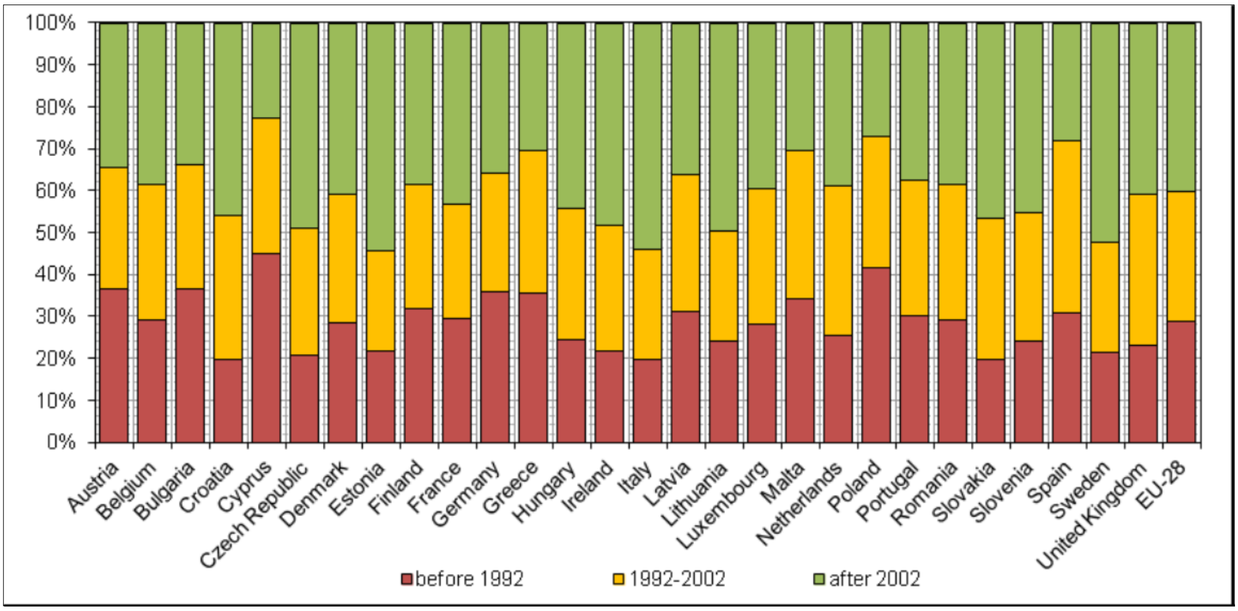

Fig 5: Age of the heating technology stock (related to installed capacity) by country for EU-28.

Source: Tender ENER/C2/2014-641 "Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables)".