THE LEGACY OF HEAT ROADMAP EUROPE 4

Scenarios, recommendations and resources for decarbonising the heating & cooling sector in Europe and complementing the strategic long-term vision of the EU

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2050
Heat Roadmap Europe
A low-carbon heating and cooling strategy

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ABOUT HEAT ROADMAP EUROPE 4

The aim of Heat Roadmap Europe 4 (March 2016 – February 2019) was to create the **scientific evidence** required to effectively support the **decarbonisation** of the heating and cooling sector in Europe and **democratise** the debate about the sector.

Since heating and cooling are inherently local, but represent the largest single sector of the European energy system (Figure 1), this has required highly localised data through energy mapping; national modelling and Heat Roadmaps, bottom-up European-wide technology and stock knowledge, and guidelines at all levels. This has been achieved through the collaboration between the 14 project partners, and with the help of 11 Advisory Board organisations. Local authorities from 10 European cities and regions have joined the City and Regions Interest Group and received tailored advice for low-carbon heating and cooling solutions.

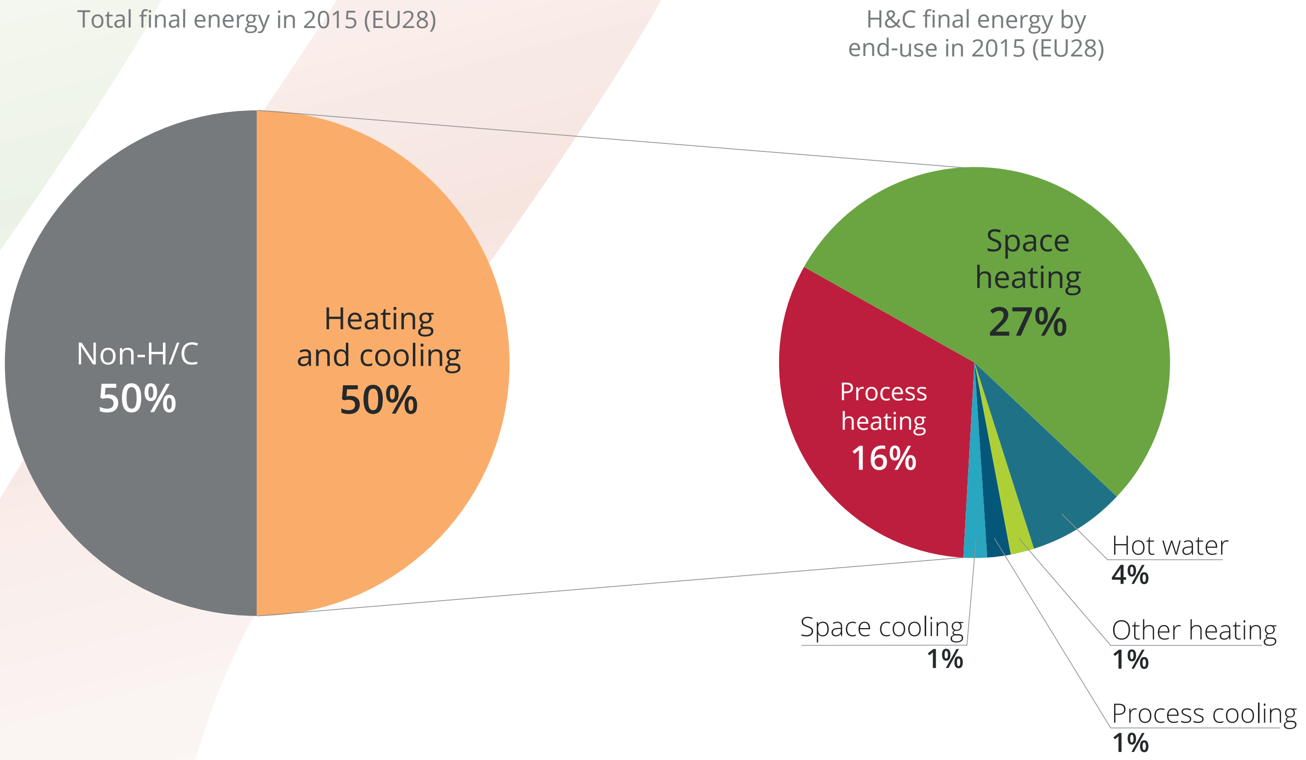


Figure 1: Total final energy in 2015 (EU28) and heating & cooling final energy by end-use.

HRE 2050 SCENARIOS – SUPPORTING EU'S VISION OF CLIMATE NEUTRALITY

The Heat Roadmap Europe 4 (HRE4) project developed comprehensive energy scenarios for 2050, also known as "Heat Roadmaps", for the **14 largest EU countries** that represent **90% of EU's heat demand**. The Roadmaps are developed based on the profiling of heating and cooling (H&C) demands, end-user savings identification, high geographic resolution maps of H&C demand and supply, and entire energy system models using an hour-by-hour and optimisation approach. The Heat Roadmaps and scenarios include transport, electricity and industry, and focus specifically on the H&C sector. This approach also helps the integration of renewable energy into the electricity sector by using heat pumps, district heating and large thermal storage, while still increasing ambitions with regards to end demand savings in buildings.

Three 2050 scenarios for each one of the 14 countries have been produced as a means to compare the implications of current policies to more ambitious decarbonisation strategies:

- the **Baseline (BL) 2050 scenario**, based on JRC-EU-TIMES modelling, which represents the development of the energy system under agreed EU policies as of March 2018;
- the **Conventionally Decarbonised (CD) 2050 scenario**, which represents the development of the energy system under a framework that encourages renewables, but does not focus deliberately on feasible infrastructural changes within the H&C sector; and
- the **HRE 2050 scenario**, which represents a redesigned H&C system, considering the cost-effectiveness of different types of energy efficiency, excess heat and renewable sources, as well as better integration with the other energy sectors.

The HRE scenarios show that is possible to significantly further reduce CO_2 emissions **using already-existing technologies**, while still saving money, as compared to a silo approach to decarbonising the energy system. **Fossil fuels can be reduced by about 10 PWh** compared to 2015 and **CO_2 emissions by 86%** compared to 1990, which substantially lowers the dependency and need for importing fossil fuels to the EU (up to 90% less oil, around 60% less natural gas and 40% less coal).

KEY RECOMMENDATIONS – REQUESTED ACTIONS FROM POLICYMAKERS

Based on the data, knowledge, methodologies, and scenarios developed and made available by the HRE project, it is clear that the European Union should focus on implementing change and **enabling markets for existing technologies and infrastructures** in order to take advantage of the benefits of energy efficiency in a broader sense and for the H&C sector specifically.

Typically, decarbonisation of the energy system is done in a silo-approach, usually only using electrification and some degree of refurbishment. In the **HRE scenarios**, reductions in the primary energy supply are created by combining several energy efficiency measures in the form of further **end-use savings, district heating and cooling grids** and the use of **renewable and excess heat sources** (for urban areas). This is combined with electrification using **heat pumps** efficiently, both at an individual building scale in rural areas, and in the form of large-scale heat pumps in district heating and cooling grids. Like in other decarbonisation scenarios, further electrification of the energy system happens through electric vehicles and the production of "green" gasses using hydrogen-based and carbon sources. The combination of **electrification, thermal grids and energy savings** has benefits across the whole energy system and for the integration of renewable energy capacities (Figure 2).

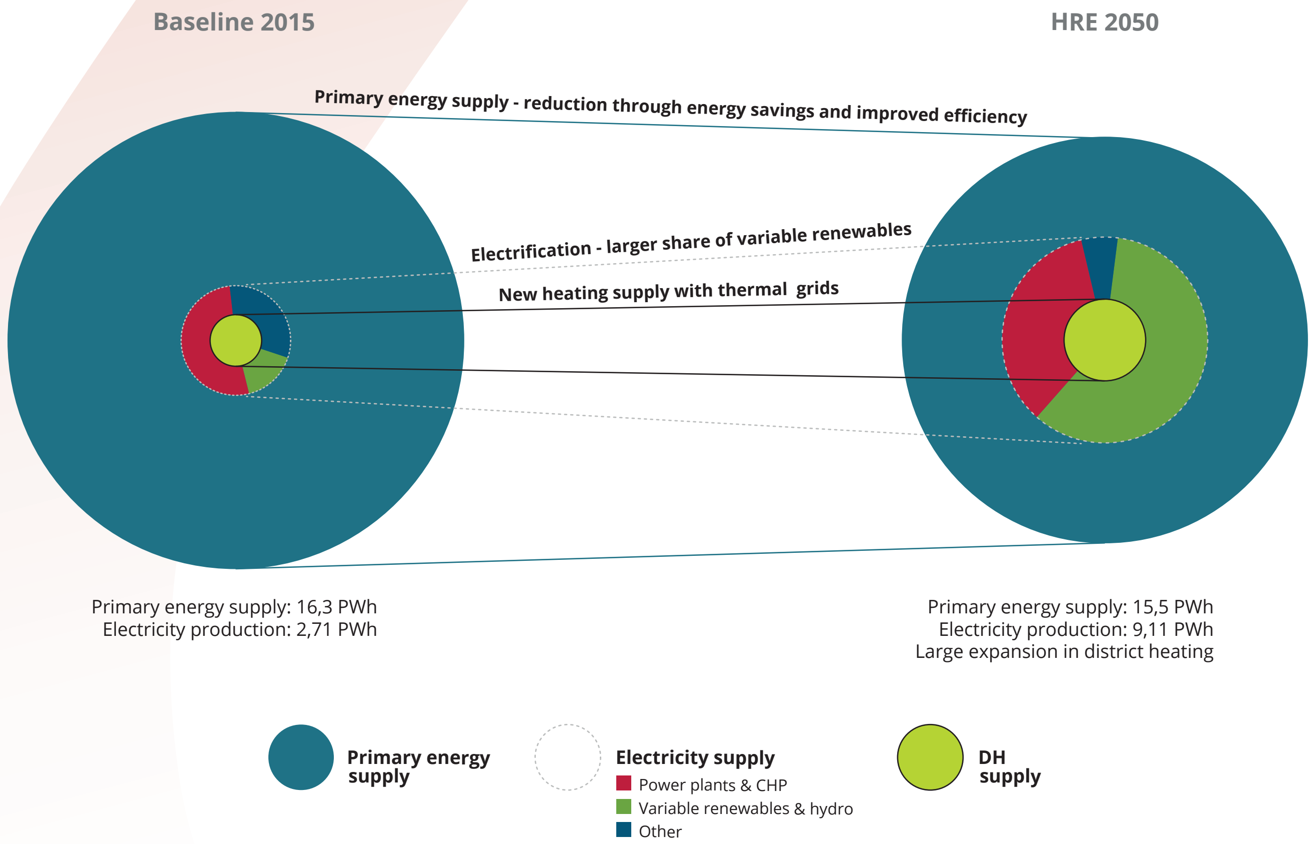


Figure 2. Illustration of the energy system changes implemented in all HRE Scenarios towards 2050 with regards to primary energy supply (PES), electrification and new thermal grids.

Decarbonisation possible with existing technologies

Europe can already **reduce its CO_2 emissions** by 4,340 Mton or **86% compared to 1990** by using mature **technologies which are already existing** and in use within the H&C sector today. HRE4 proves that decarbonisation in line with the European commitments under the Paris Agreement is not only possible, but that by the roll out of comprehensive **energy efficiency** measures and **coupling related sectors**, this transition can be done cost-efficiently to accelerate an economically and socially feasible low-carbon energy system (Figure 3).

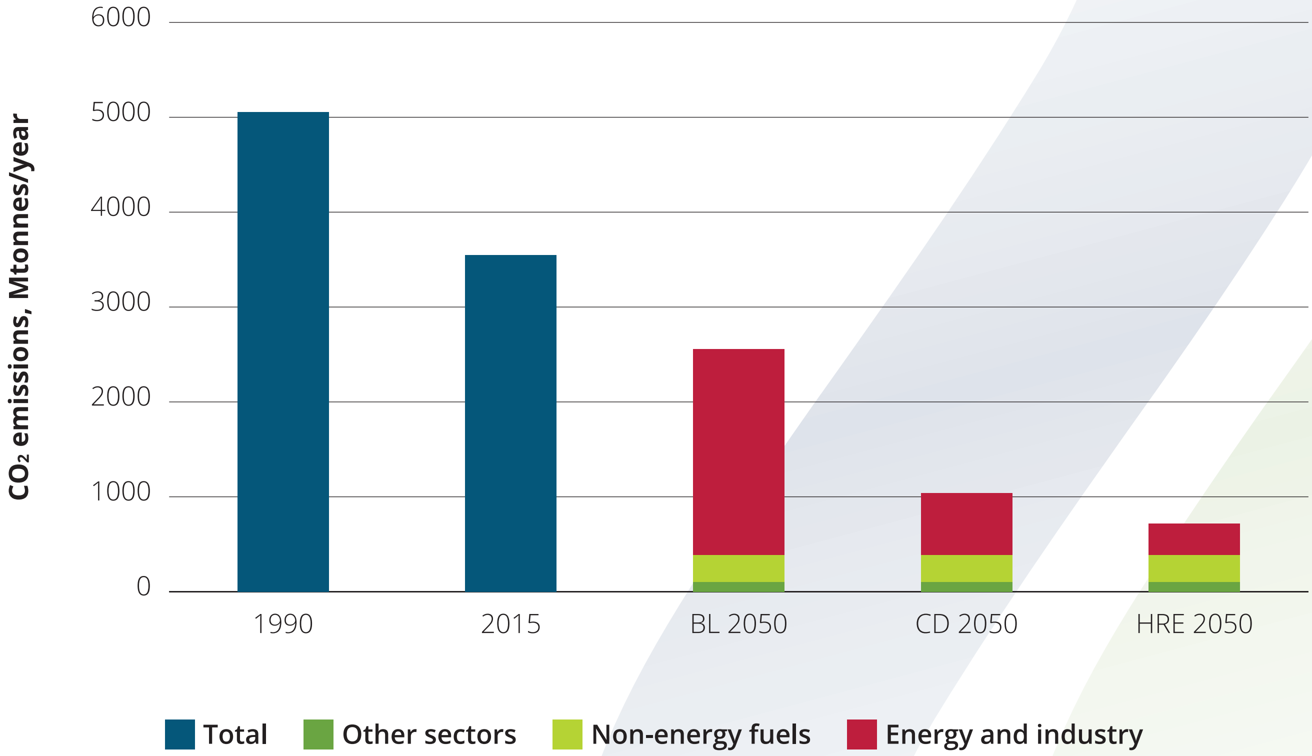


Figure 3. Historical, current and future CO_2 emissions for the 14 HRE4 countries.
See page 2 for more explanation on the BL 2050, CD 2050 and HRE 2050 scenarios.

Energy efficiency and decarbonisation in the H&C sector is achieved with the use of already-existing technologies and methods (i.e. ambitious renovations of the existing building stock; 3rd generation district heating and cooling grids; efficient heat pumps; energy recovery; and better utilisation of the potential synergies between the energy sectors). The design of this scenario represents one approach and is deliberately chosen to show that using existing technologies, this pathway also enables full decarbonisation. The potential to decarbonise is not hindered by a lack of technical development, but rather by an ethical, political and organisational failure to implement the proposed approach.

Energy efficiency imperative on both sides to reduce energy system costs

Energy savings are required on both the **demand and supply side to cost-effectively reach decarbonisation goals**. HRE4 shows that the majority of recommended savings in primary energy demand can be achieved by more efficient supply options. More specifically, almost 30% of the decrease in energy needs is driven by the end user savings with the remaining 70% by the improved heating and cooling supply system.

Though an integrated approach to the H&C sector does require more investments to establish energy efficient technologies and infrastructure than a focus only on demand side efficiency, overall this synergetic manner actually **reduces energy system costs by ~6%** (67,4 billion €) annually (Figure 4).

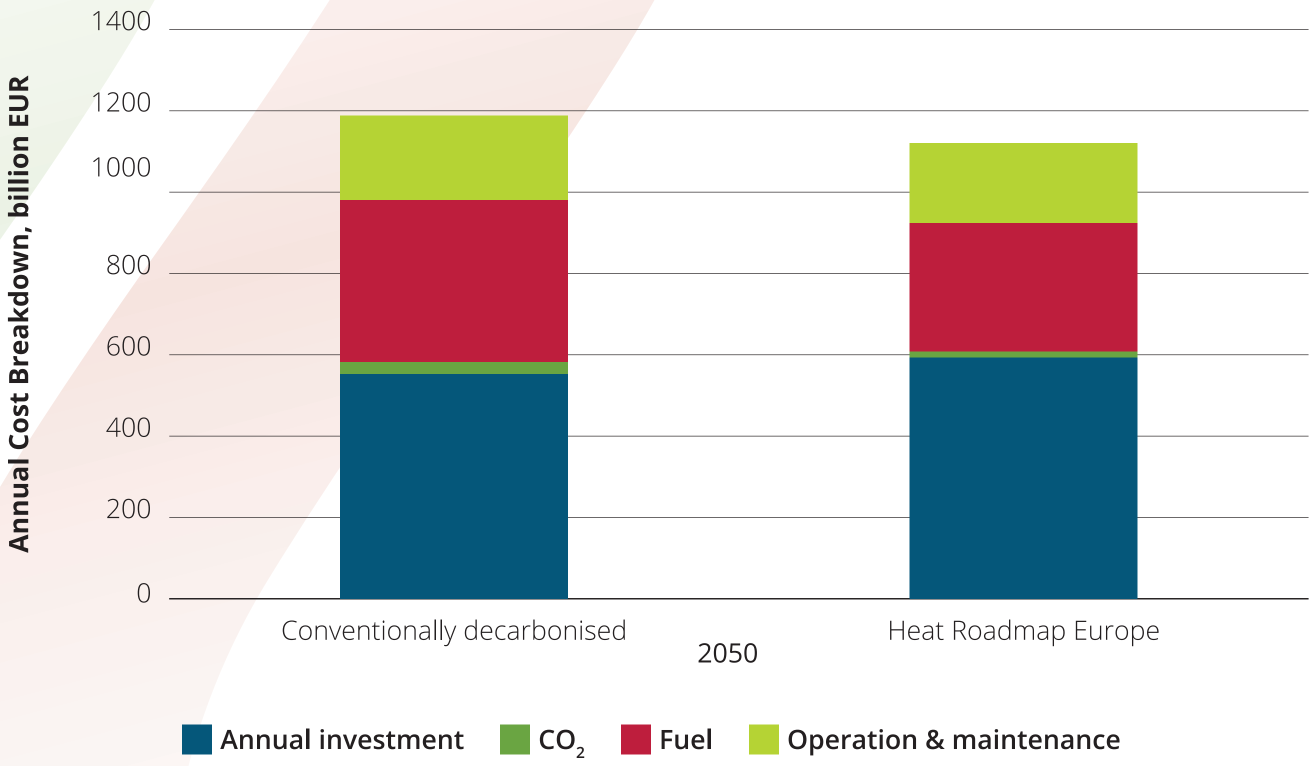


Figure 4. Annual total energy system costs for the decarbonised 2050 scenarios.

At least 30% end-use savings in space heating vital to make decarbonisation achievable

In combination with a more energy efficient supply side, end-use savings in delivered energy are vital to efficiency, decarbonisation and affordability. The analysis in HRE4 took into consideration service, residential and industrial heating and cooling demands, and the respective potential for reducing these demands through energy saving measures (Figure 5).

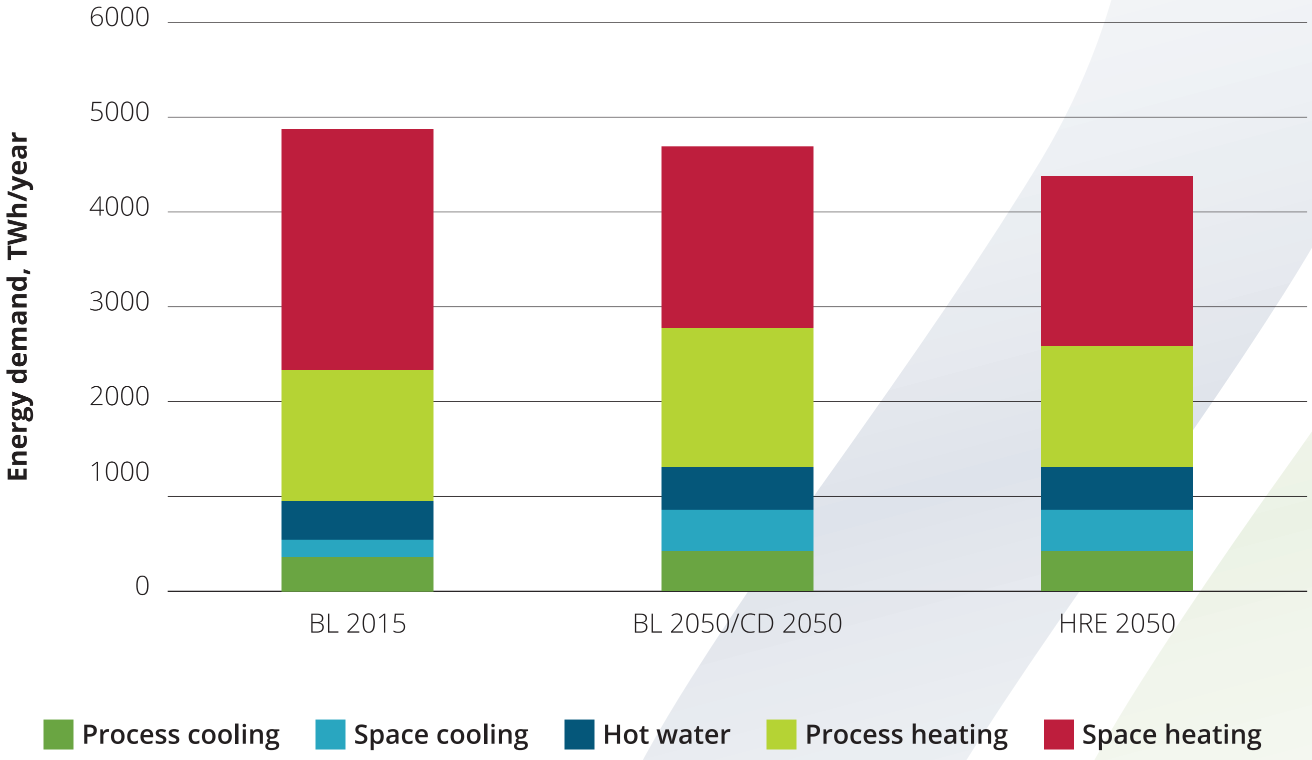


Figure 5. Heating and cooling demands reductions in the baseline (BL) and decarbonised (CD) scenarios and in Heat Roadmap Europe 2050.

While savings in the built environment and industry were generally found cost-effective, this is particularly true for space heating in existing buildings, where **higher renovation rates and depths are needed**. With the current policies and targets, a 25% reduction in total delivered energy can be reached in 2050, also considering an increased amount of buildings. This already represents an ambitious target for many countries, when compared to the historical developments that have taken place, and would require an annual refurbishment rate of 0.7-1% towards 2050. This implies that ambitious targets that currently exist are joined by concrete policy tools that ensure their implementation.

However, HRE recommends an even more ambitious target of **at least 30% savings** for space heating in buildings, which would require a higher **refurbishment rate of 1.5-2%**, and **deeper renovations** when they occur [1]. If end-use savings are not implemented, decarbonisation becomes both technically more limited (especially in rural areas) and is likely to come at a higher cost.

HRE finds that all countries should have a higher ambition level than the current EU-level target would lead to. Especially Belgium, the Czech Republic, Hungary, Italy, the Netherlands, Poland, Romania and Spain should have much higher energy savings targets (Figure 6).

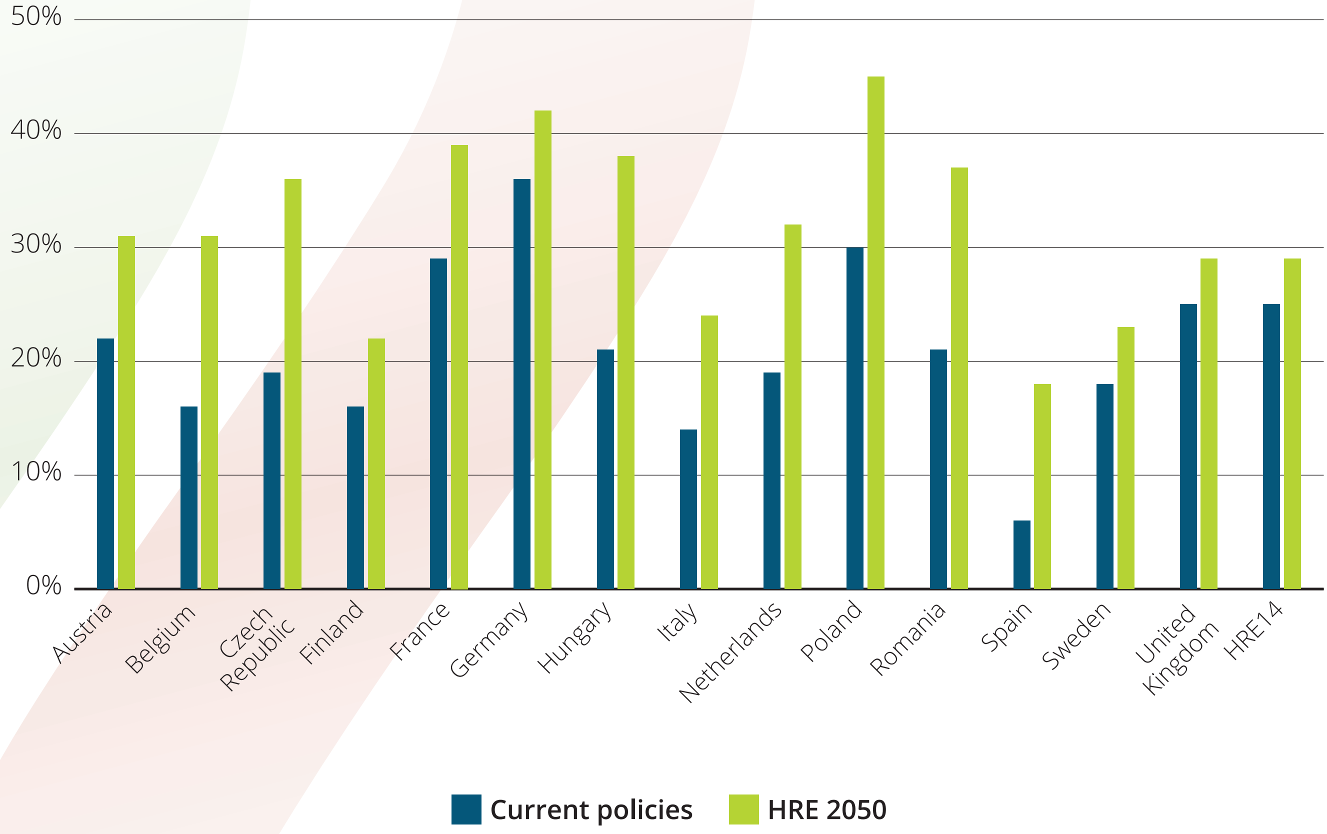


Figure 6. Savings in delivered space heating demands from 2015.

1 Harmsen R, van Zuijlen B, Manz P, Fleiter T, Elsland R, Reiter U, et al. Report on cost-curves for built environment and industrial energy efficiency options. Heat Roadmap Europe Deliverable 4.2 & 4.3; 2018.

Investment initiative needed to quadruple thermal grids in European cities

The **expansion of thermal grids** is crucial to redesign the energy system and enable better integration of renewable energy and excess heat sources. District heating can cost-effectively provide **at least half of the heating demand in 2050** in the 14 HRE countries, expanded from about 12% of the heating market today in the 14 countries. While there are differences from country to country, going beyond half towards 70% of the heat market in the 14 countries targeted by HRE, on the whole can provide additional energy efficiency and strategic benefits. (Figure 7). The cost of expanding district heating is mostly determined by the population density and urban fabric of the area, and not necessarily the geographical climate[2].

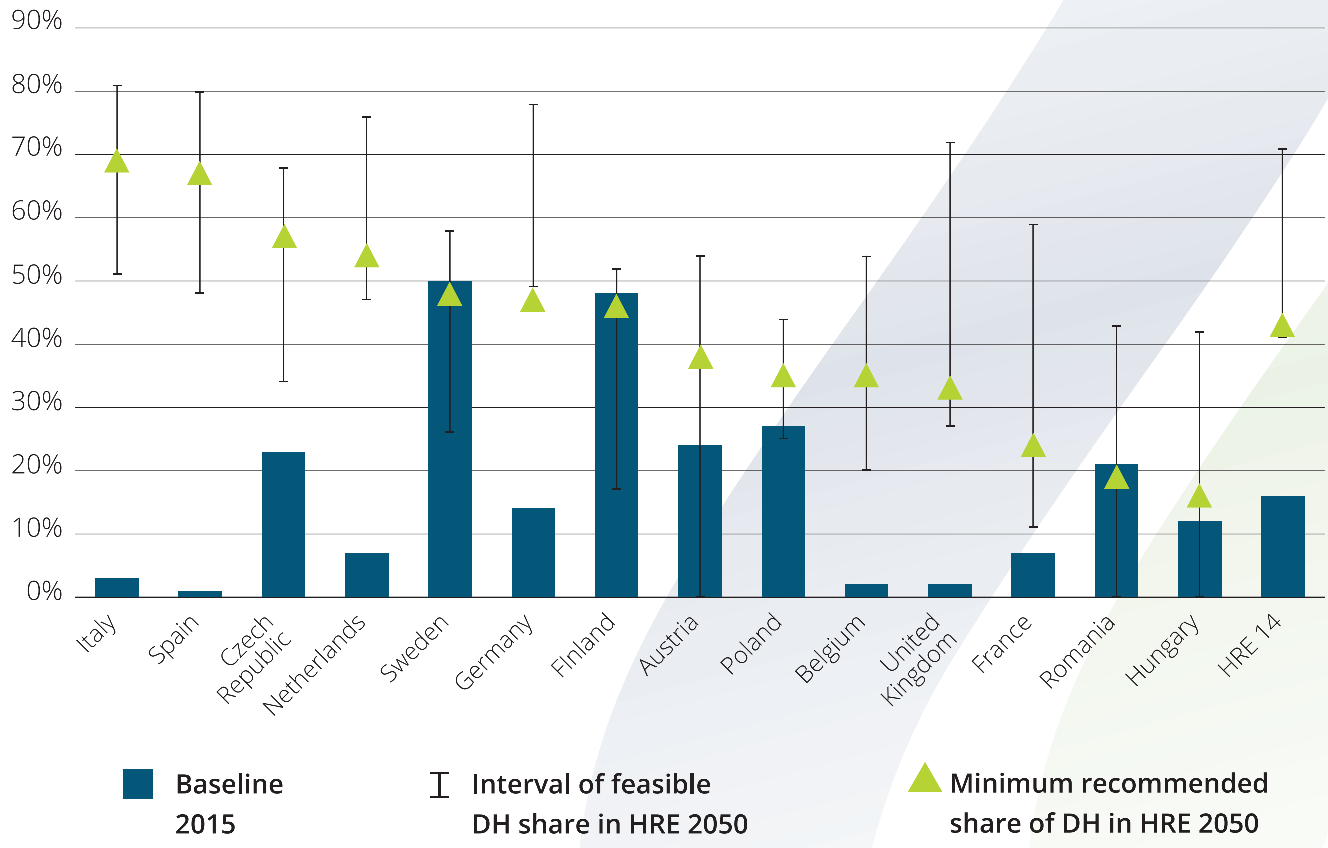
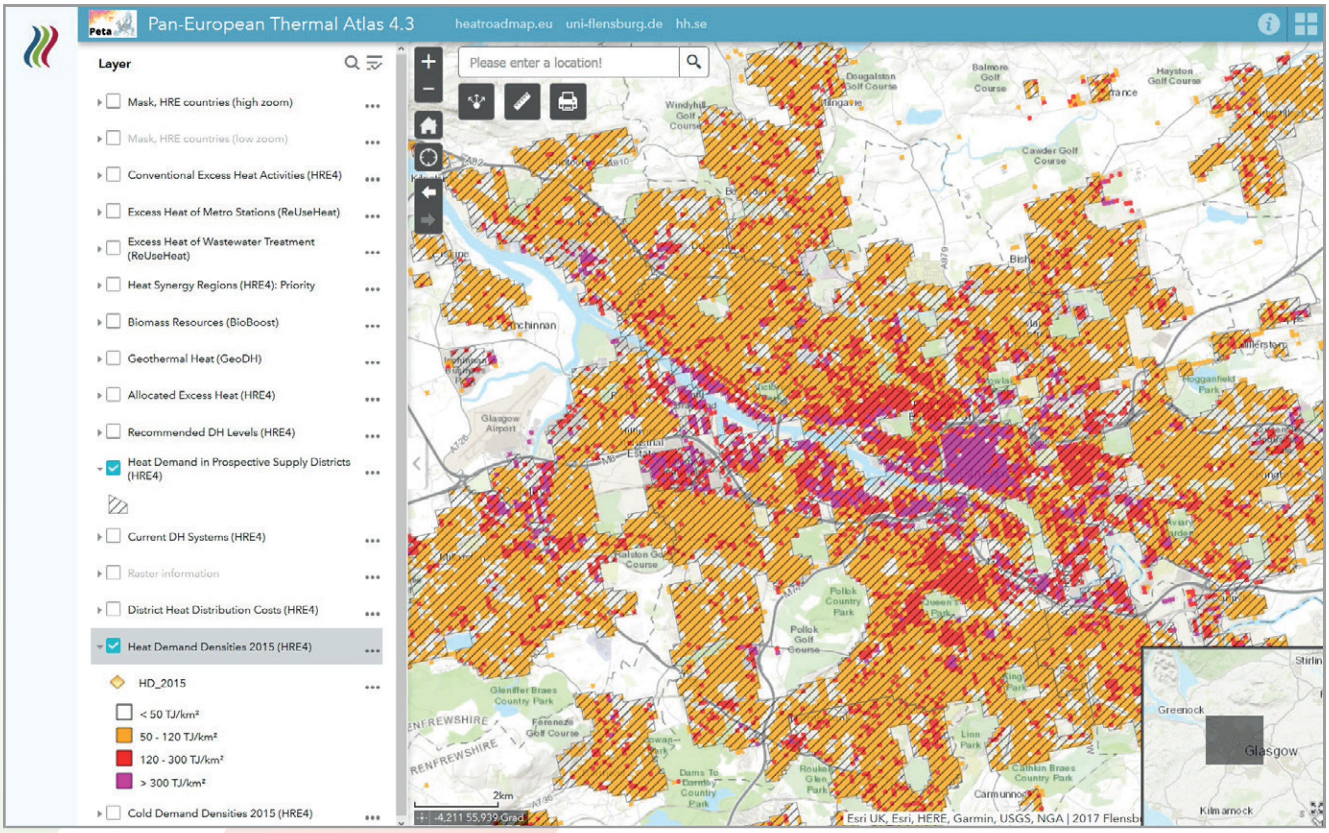


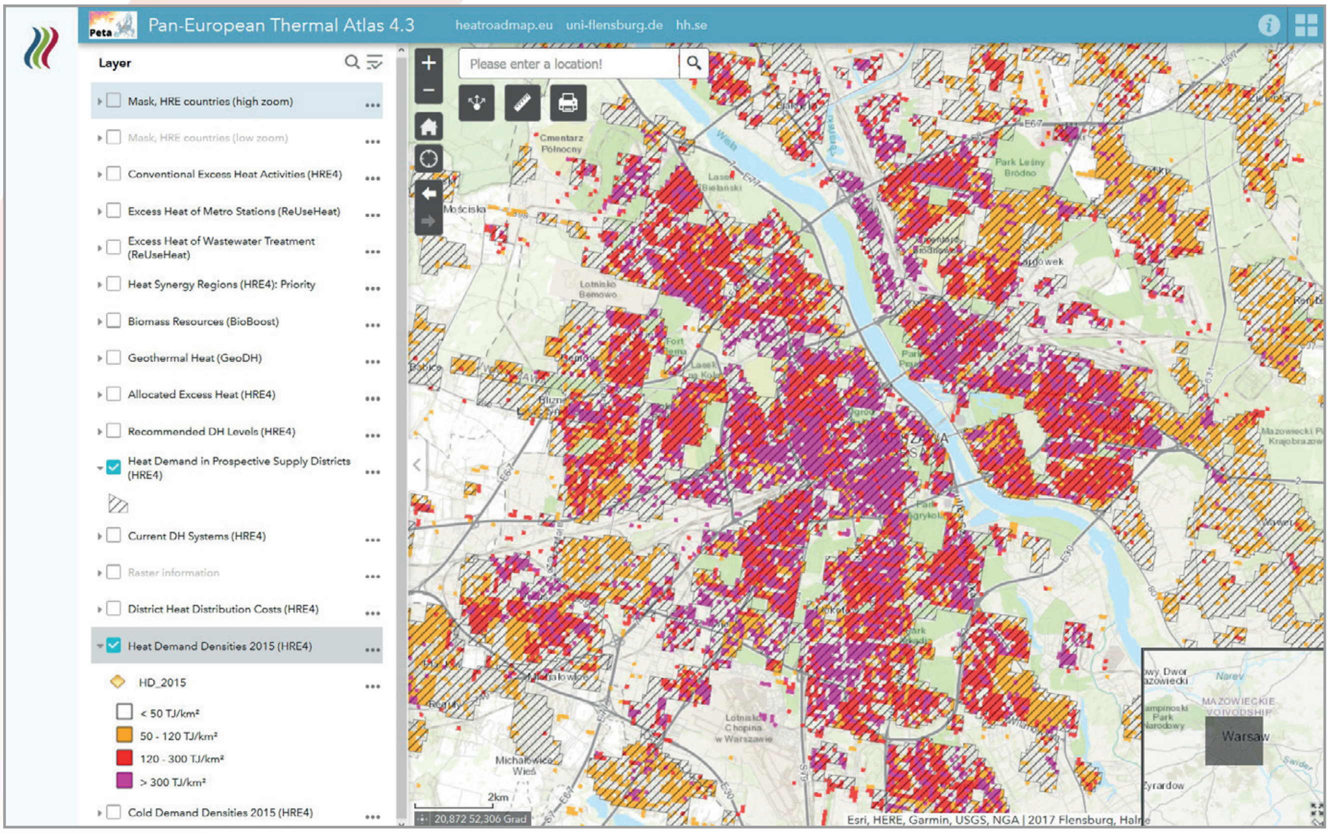
Figure 7. Baseline share of district heating in 2015 and the minimum recommended level of district heating share in HRE4.

This expansion requires **thermal grids to be recognised as an important infrastructure in the Energy Union**, as well as to be targeted in relevant EU and country-level policies, in particular those which enable city or regional planning and development processes, as well as the financing of district heating infrastructure.

2 Persson U, Möller B, Wiechers E, Grundahl L.
Map of the heat synergy regions and the cost to expand district heating and cooling in all 14 MS.
Heat Roadmap Europe Deliverable 2.2; 2017.



Peta zoom on Glasgow: heat demand densities and prospective heat supply districts.



Peta zoom on Warsaw: heat demand densities and prospective heat supply districts.

Enable the diversification of the heat production and storage to gain synergies between energy sectors

Future **production and storage units** for district heating **should be more varied and versatile** (Figure 8) to integrate low-carbon sources and enable flexibility. Production facilities include biomass boilers, various renewables, different types of excess heat, and the use of combined heat and power (CHP) and large-scale heat pumps. Overall CHP covers 25-35% of the heat generation. These units operate only in response to the needs of the electricity markets, which means the heat is created as an unavoidable by-product of flexible electricity production. Since this heat is otherwise wasted, its use contributes to the overall energy system efficiency and plays a large role in reducing the resource demand of the energy system.

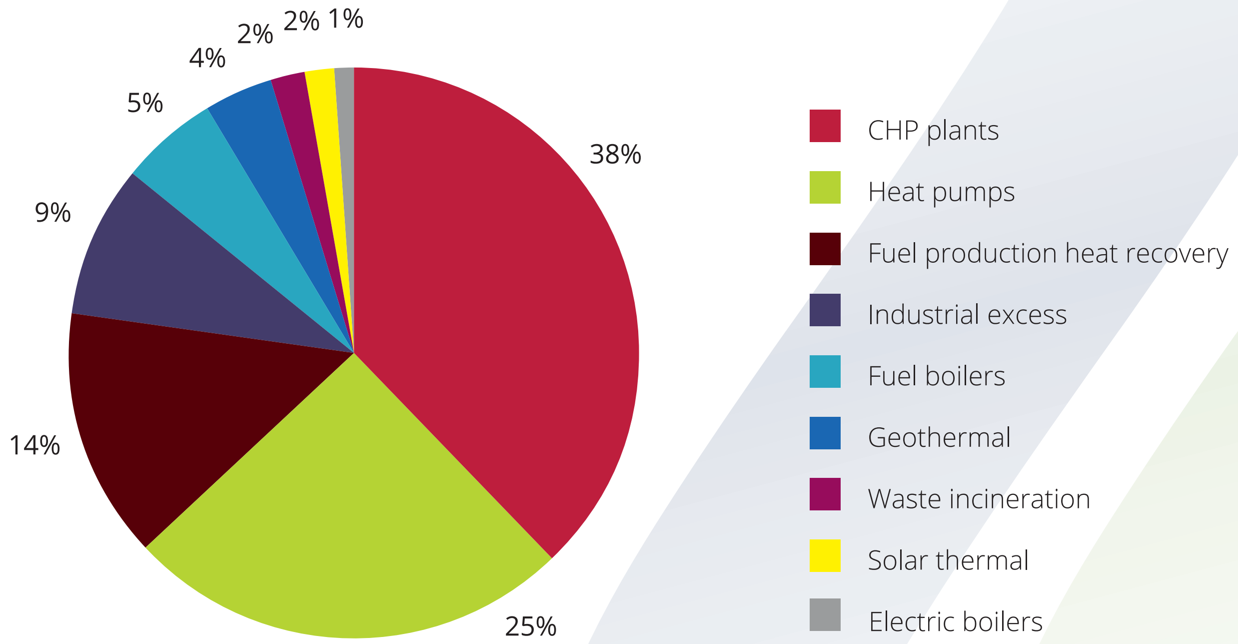


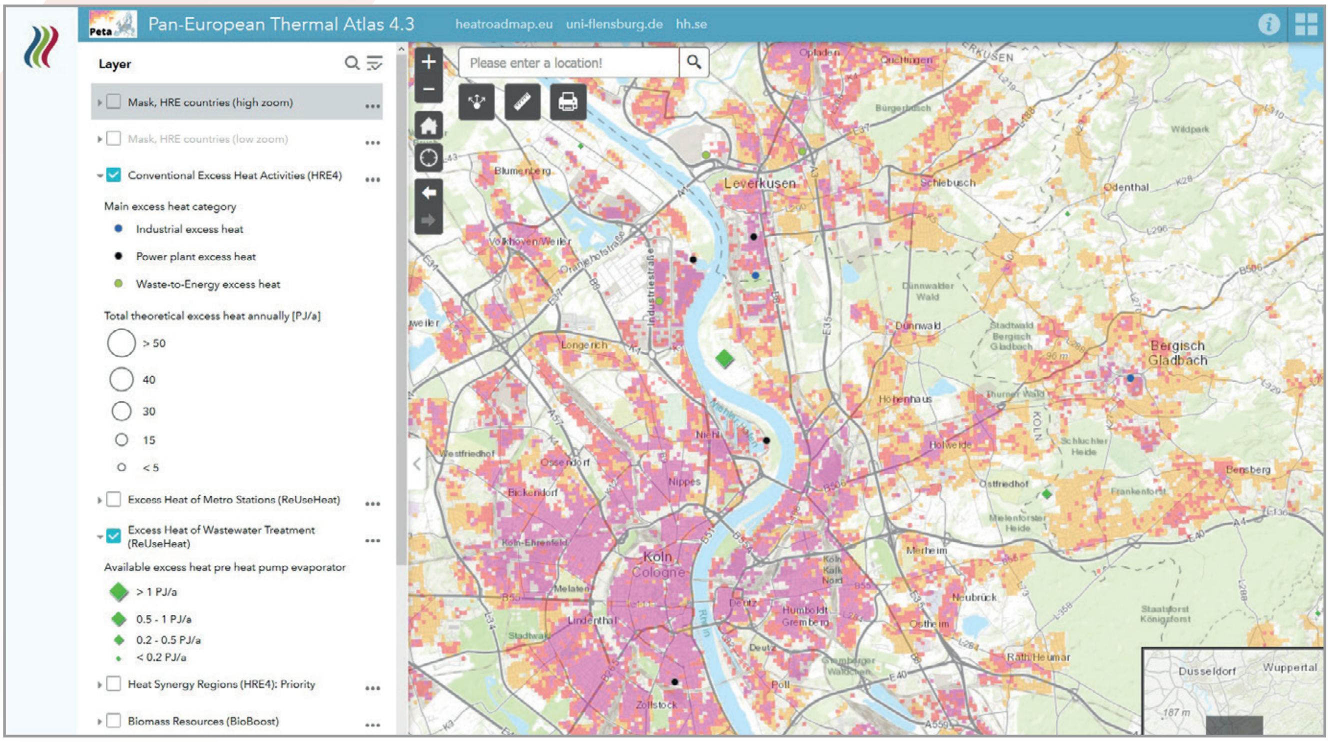
Figure 8. District heating source shares in HRE 2050 combined for all the 14 countries.

Large heat pumps providing 20-30% of the thermal demand are using mainly renewable energy and the remainder from excess heat (25%) and other renewable sources such as geothermal and solar thermal heating (5%). Renewable sources such as deep geothermal energy and solar thermal heating can only be exploited to their full potential in the energy system if district heating is present, and are a valuable resource for district heating systems that do not have obvious sources of industrial excess heat. Heat-only-boilers should become a back-up production unit since the capacity of boilers can cover the peak demands over the year. However boilers should not produce more than 10% of the district heating demand corresponding to times with peak demands or low production from other sources.

Thermal storages – being many times cheaper than electrical ones – can increase the flexibility potential. In fact, storages for district heating represent a key role to provide the flexibility required in future energy systems with an increased amount of non-controllable energy production. The most important thermal energy storage to consider should cover on average 2-8 hours in larger cities and 6-48 hours in smaller cities. These types of **short-term storages are crucial** to balance the electricity grid as well as to handle the more diverse production of heat and fluctuating local low value heat sources. Seasonal storages may be relevant to locally increase the coverage of excess heat which is otherwise wasted in the summer period from e.g. industry or waste incineration, implement solar thermal, or serve as sources for efficient heat pump operation.

Political attention required to integrate at least 25% excess heat sources

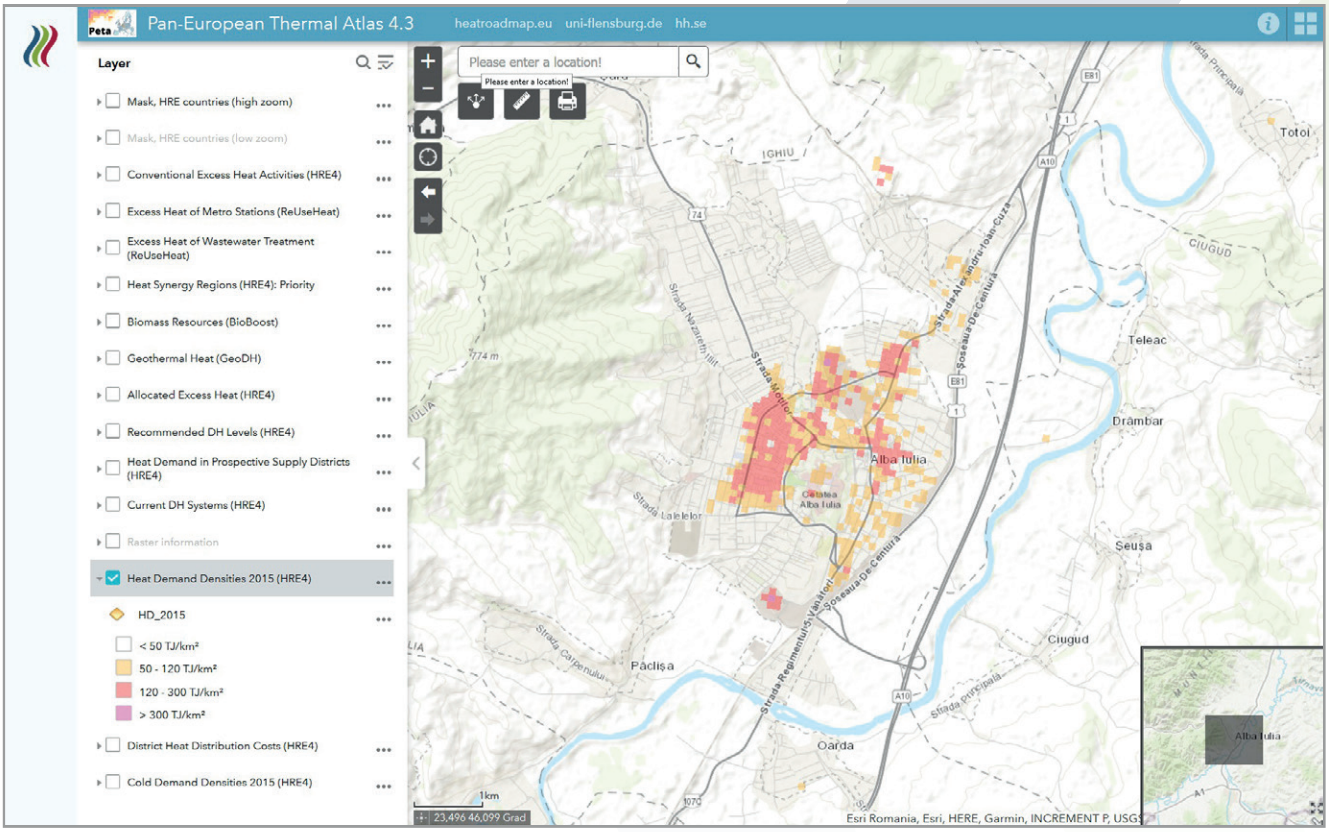
In the past, excess heat has been politically neglected. **Excess heat recovery** from various industrial processes, power production and commercial facilities is key to an efficient and resilient H&C sector, and has the potential to support local industries, economies and employment. These sources could potentially cover **at least 25% of the district heat production**. In order to maintain, exploit and increase this potential, a concerted change in planning practices is necessary to ensure that they are within geographic range and fairly distributed among different potential district heating areas and cities. This applies to local industries, waste-to-energy facilities, and future biogas or electrofuel production sites. In many cases, further sources of excess heat may become accessible through heat pumps, for example data centres, sewage treatment facilities, underground metro stations and other types of **non-conventional excess heat**. Such lower-temperature sources are not included in the analysed scenarios portrayed here, which means that the included analyses of both industrial excess heat and large-scale heat pumps actually are likely to be on the conservative side, as compared to the real potential.



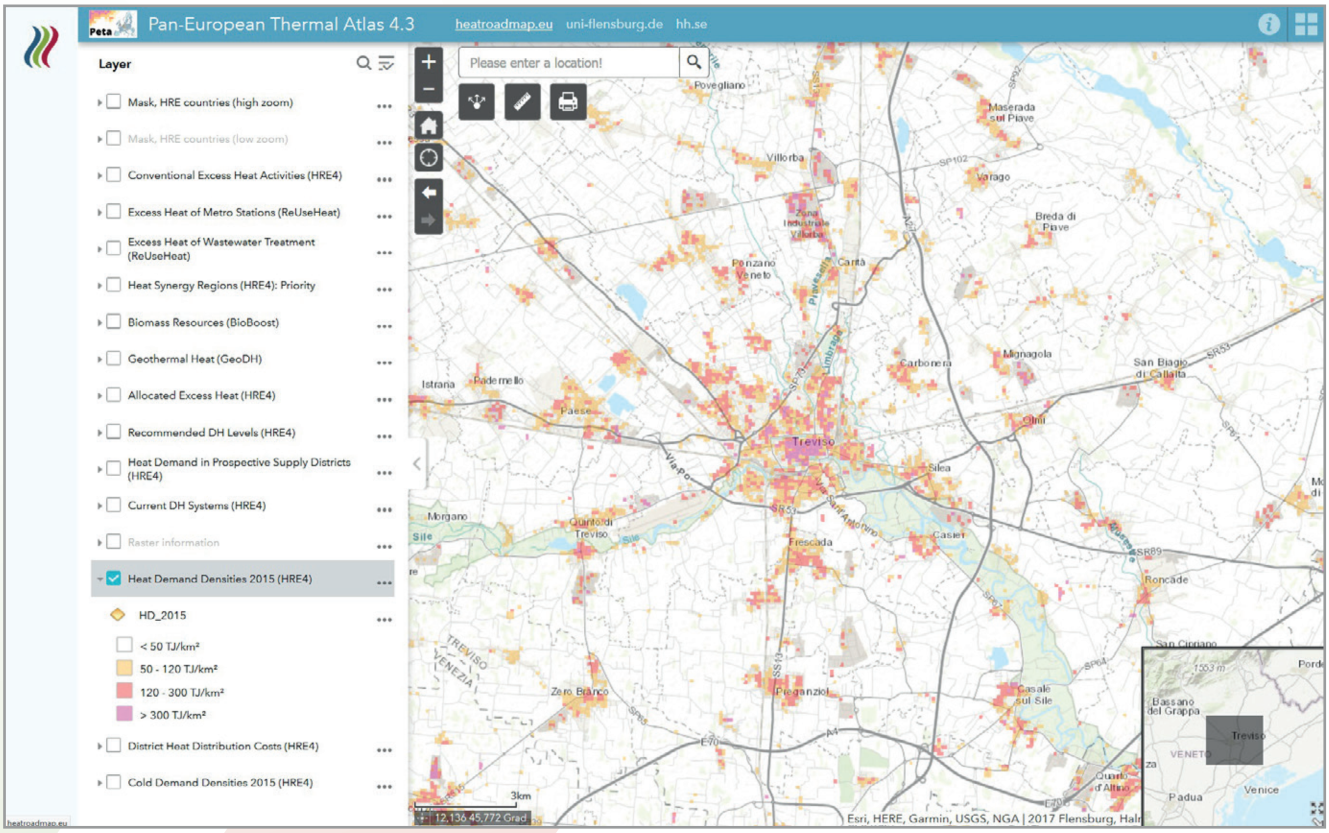
Peta zoom on Cologne: conventional excess heat activities and excess heat from waste water treatment.

Individual heat pumps cover up to half of the heat demand in an efficient energy system

Individual heat pumps will be key to enabling resource efficiency and electrification in areas where district energy is not viable, and should provide **about half of the heat demand** depending on the local conditions for the built environment. Since the investment required to unlock their potential is high and often borne by building owners, focus should be on policies and implementation strategies that encourage **switching from individual boilers and inefficient electric heating** to more efficient alternatives in non-urban areas. The policies should be targeted at areas not suitable for district heating, in order to ensure the overall energy efficiency, flexibility and decarbonisation of the system. The policies should also be combined with targeted measures for energy savings as this improves the efficiency of the heat pumps and reduces the peaks in the electricity grids in cold periods. The small individual heat pumps are in practice likely to be combined with solar thermal and biomass boilers as part of the supply in some areas in Europe. However, heat pumps reduce the dependency on fuel boilers in a bioenergy-scarce decarbonised future and increase the use of fluctuating renewable electricity sources. Thermal storage in combination with these are important, but the flexibility is limited compared to the district heating system with thermal storage, large scale heat pumps or combined heat and power.



Peta zoom on Alba Iulia: heat demand densities.



Peta zoom on Treviso: heat demand densities.

Thermal sector facilitating the pathway towards a 100% Renewable Energy Union

HRE4 shows how an energy system transition can facilitate the integration of **at least 87% renewables** in the electricity, industry, and heating and cooling sector. The HRE 2050 scenario does not hinder but rather enables the possibility of further implementation of renewables by decarbonising also the remaining fossil fuel use which primarily is allocated to transport, industry and flexible CHP (Figure 9).

The modelling shows that an energy system with a strategically decarbonised H&C sector can support a similar amount of wind capacity as a conventionally decarbonised energy system. At the same time up to 30% more of the electricity produced by the installed variable renewable energy capacity can be functionally absorbed and used in the energy system due to the enhanced flexibility in the H&C sector.

The suggested redesign of the European energy system represents a first step that can enable a deeply decarbonised energy system. Extending the HRE designs to use a **Smart Energy Systems** approach to include transport and electrofuels could provide a **pathway towards 100% renewable energy** to fully decarbonise the Energy Union.

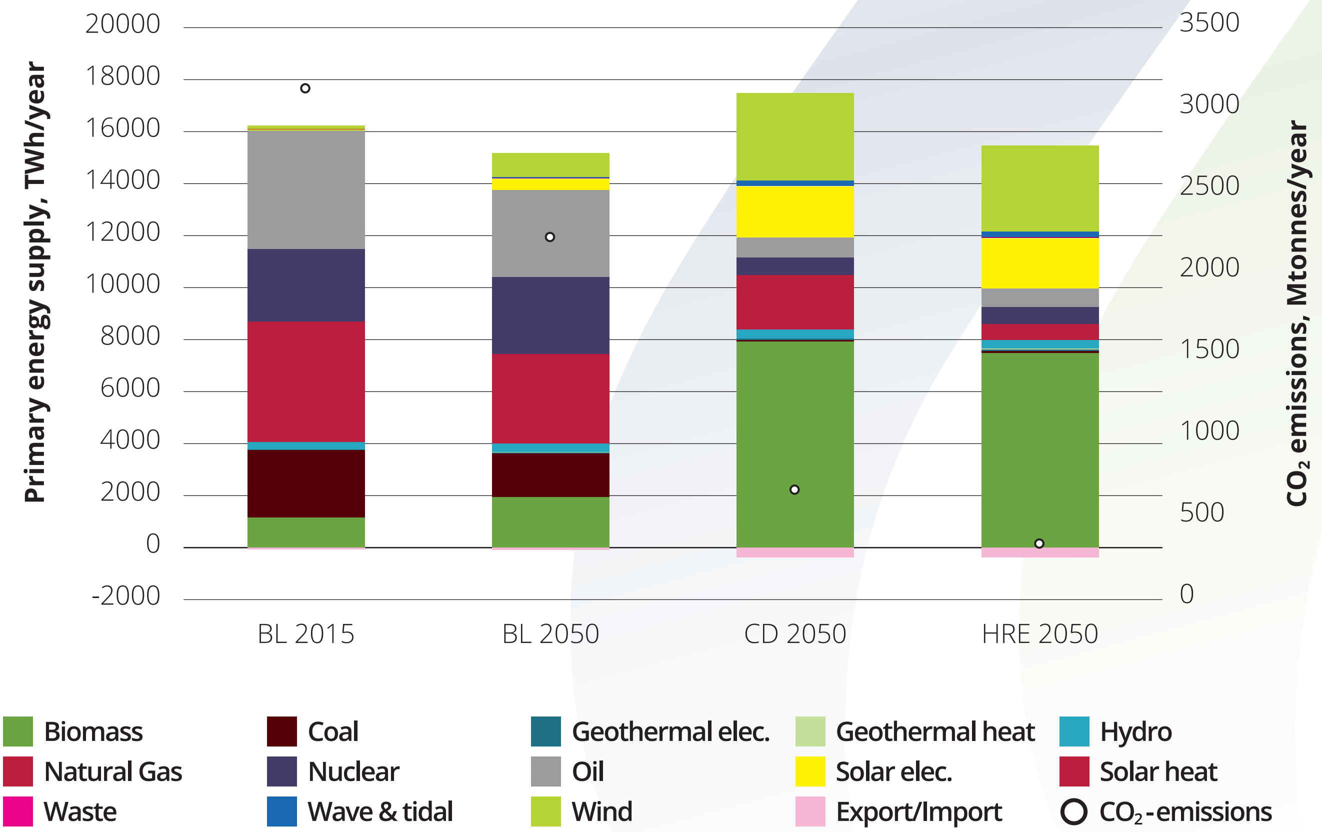


Figure 9. Primary energy supply currently, in the BL 2050, CD 2050 and HRE 2050.

KEY RESOURCES FOR POLITICAL AND TECHNICAL DECISION-MAKERS

HRE4 provides a range of new information to empower the decision processes and improve the foundation for political and technical choices on the most cost-effective and affordable pathways towards a decarbonised energy system. The use of tools, methodologies and datasets that are specific to the H&C sector are necessary in order to coherently model, analyse and design the H&C system within the energy system. However, the secondary purpose of the development and distribution of the freeware tools, methodologies, analyses, results and local geographical data developed in HRE is also to support a transparent discussion, and to provide new capacity and skills for lead-users in the energy transition.

These include among others, **detailed profiling of the present H&C demands** by subsector, **cost-curves** for reducing the H&C demand in buildings and industries, and complete **energy system model datasets** which users can modify to investigate for themselves the likely impacts of alternative scenarios.

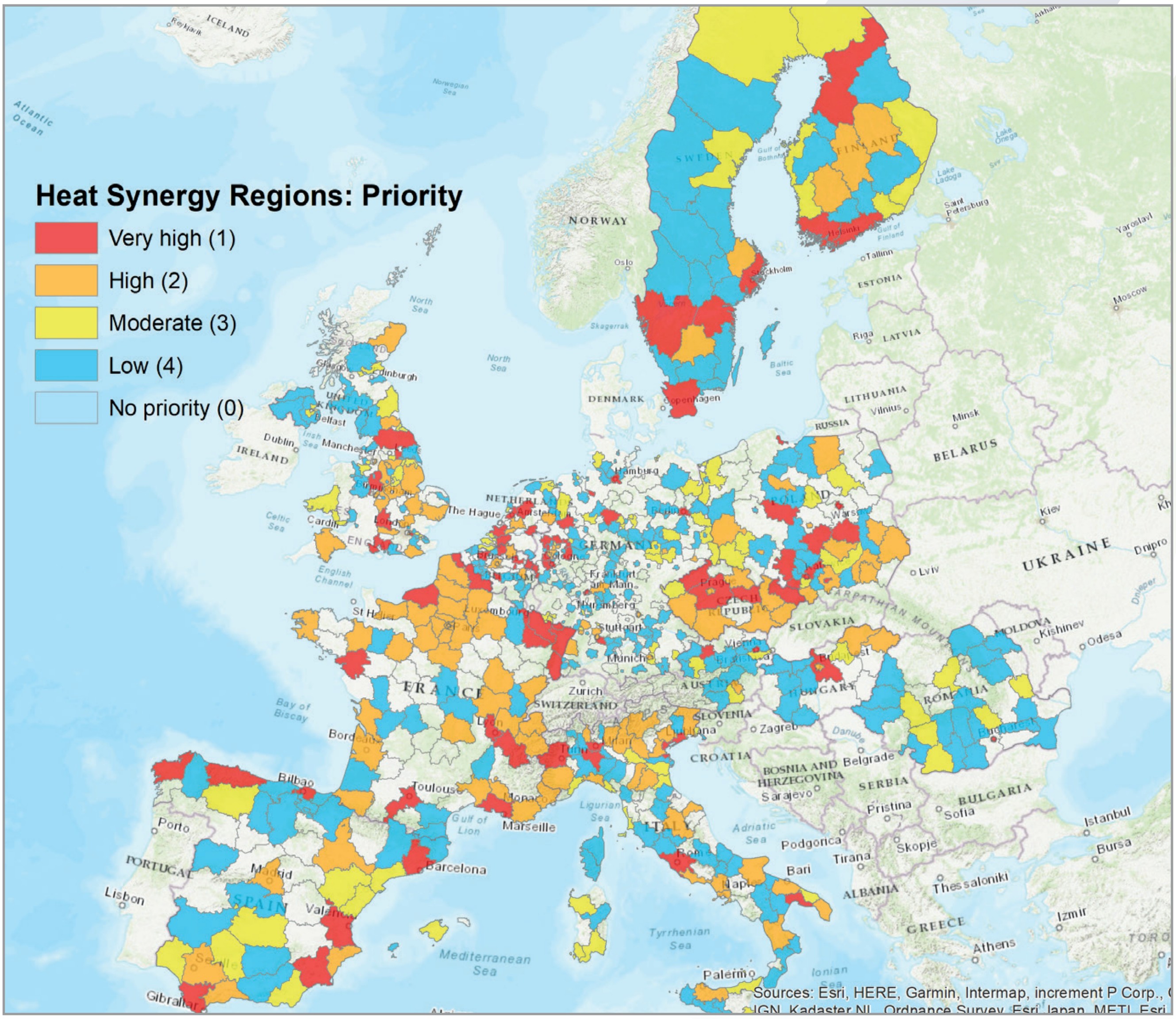
Two outcomes stand out in particular as major results building upon the knowledge gathered from the other HRE analyses: **The Pan-European Thermal Atlas** and the **energy system scenarios** of the 14 HRE countries. Additionally, **Guidelines for Lead Users** at European, national and local/regional level, as well as **Business Strategies** and business cases to encourage market uptake are the outcomes that could help implement the HRE recommendations in practice.

The Pan-European Thermal Atlas (*Peta*)

www.heatroadmap.eu/peta

Peta represents a publicly-available, interactive online portal to support planners, investors and policymakers by presenting and quantifying H&C possibilities (geo)graphically for all 14 HRE countries. The following features are included, amongst others:

- Heating and cooling **demand densities**, each on a hectare level.
- **Renewable** heat resource potentials such as geothermal, solar thermal and biomass.
- Pinpointed potential **excess heat** from conventional sources (e.g. from waste incineration, power plants, and industrial processes) and non-conventional (e.g. waste water treatment and underground metro stations).
- Existing **district heating areas** and prospective **heat supply districts**, including the cost of establishing network infrastructure and indications of the recommended shares of district heating.
- Heat Synergy Regions highlighting the overlap of demands and identified excess heat – indicated as an "excess heat ratio", i.e. the ratio between conventional excess heat and heat demand within a given region.



Heat Roadmaps

www.heatroadmap.eu/roadmaps

The main Heat Roadmap Europe report describes the development and findings of the modelled HRE 2050 decarbonisation scenarios including the methodologies used, different energy demands, different energy supply technologies, their role within the wider energy system and how these compare with alternatives[3]. Country-specific results such as the recommended balance between energy savings and district heating are included in the 14 individual country reports. Collectively, these 1+14 reports hold the title: Heat Roadmap Europe – Quantifying the Impact of Low-carbon Heating and Cooling Roadmaps.

3 Paardekooper S, Lund RS, Mathiesen BV, Chang MP et. al.
Heat Roadmap Europe 4 : Quantifying the Impact of Low-Carbon Heating and Cooling Roadmaps. Heat Roadmap Europe Deliverable 6.4; 2018.

Three level-specific policy guidelines

www.heatroadmap.eu/project-reports

The HRE4 project identifies **three main pillars**, which are especially critical to address in order to facilitate the transition towards a future low-carbon H&C system. These are closely linked. Hence, in many cases policy recommendations cover more than one of them. Figure 10 below sketches the pillars as well as interconnections between them.

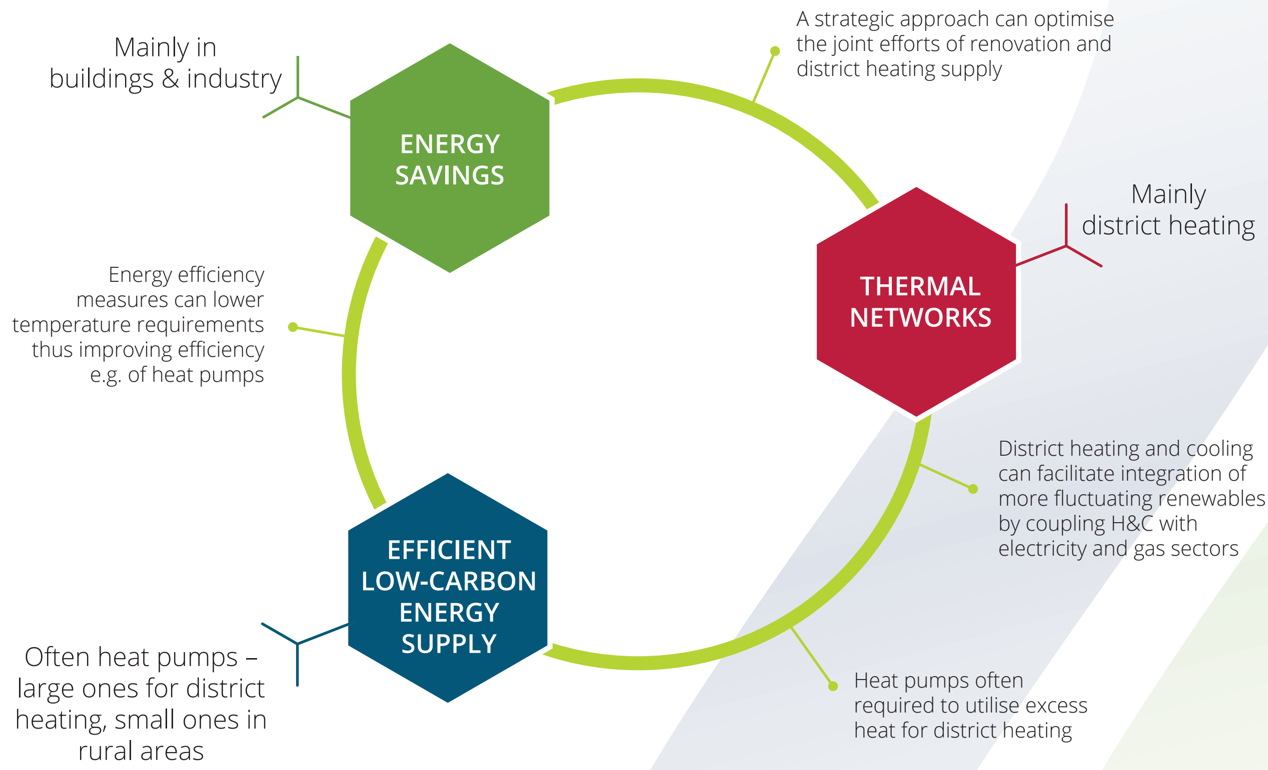


Figure 10. The three HRE "pillars", including examples of linkages between them.

The publication "**Guidelines for the Energy System Transition (The Energy Union Perspective)**" encompasses key messages and recommendations based on the overall HRE4 project targeting policymakers at European level [4].

4 Trier, D., Rothballer, C., Stiff, G., & Mathiesen, B. V. (2018). Heat Roadmap Europe 4 - Guidelines for the Energy System Transition The Energy Union Perspective. PlanEnergi. Heat Roadmap Europe Deliverable 7.17-E.

The following combined and complementary efforts are recommended at EU level:

- **Raising awareness** about relevant H&C solutions among policymakers, businesses and individuals and formulating a common narrative for all Europeans that the decarbonisation of our society is not only possible, but **cost-effective and affordable with existing technologies** available on the market today and can prove profitable for our local economies.
- Setting up frameworks to improve qualifications and the number of **skilled professionals** supporting decarbonisation solutions.
- Requiring **integrated energy planning** facilitated through **sector-specific targets** and regular **evaluation** of the status across all energy sectors and at all governmental levels.
- **EU policies, directives and the EU financial framework need to coherently support energy savings** on both the demand and supply side to cost-effectively reach the decarbonisation goals.
- Investments in the establishment and **expansion of thermal grids in urban areas** need to have high priority in **public funding and support programmes.** Ensuring **certainty (predictability) for investors**, avoiding “stop-and-go” measures.
- **Removing administrative barriers** for stakeholders to establish district heating and cooling and enabling the use of an increased share of renewables in H&C as well as recovered excess heat.
- **Building Heat Synergy Regions** to combine renewable energy potentials and excess heat sources beyond their political boarders in order to optimise and create the most sustainable and low-carbon energy infrastructure.
- Improving feasibility of a sustainable energy system directly and indirectly by introducing a **CO_2 taxation**.
- All **fossil fuel subsidies should be stopped** immediately, including also indirect support such as incentive schemes for gas and oil combustion boilers.
- **Fossil fuel boilers should be phased out**. Expiry dates should be set combined with banning the installation of fossil fuel boilers in new buildings. This should go hand in hand with stronger support for alternatives (e.g. renewables and sustainable excess heat) and thus potentially avoiding increased costs for end-consumers.
- **Expiry dates for fossil fuel power production** should be set to avoid investments in new (long-lasting) fossil-based capacity and provide certainty for the power industry to invest in sustainable solutions in the long-term.

Refer to the **Guidelines for more detailed messages** related to each HRE “pillar” including explanations of the context regarding why this is important as well as how the raised points apply to policymakers, how the HRE outputs can be used, and how to apply the outputs to policies.

Guidelines similar to the EU level report only aimed at national and local/regional policymakers respectively may also be of interest to get an insight in the country-specific recommendations and the ones suggested for other governmental levels.

Business strategies for an integrated energy system

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The report **"Business strategies and business cases to encourage market uptake"** is another useful tool which outlines the identified barriers to deployment, business strategies, and gives examples of extant business cases with replicability potential in relation to the most important solutions recommended by the HRE4 project [5].

Below are presented possible business strategies for key HRE4-related technologies on how to increase their market share, based on the Heat Roadmaps and a series of market uptake dialogues organised through the HRE4 project:

1. **Sell an integrated service, not only components**

   Providing a service rather than merely selling a piece of technology or a renovation measure itself, can prove to be a business opportunity for companies related to energy-savings measures, H&C supply units and district energy by overcoming a main economic barrier, namely the large up-front investment costs for consumers (in order to achieve lower operation costs in the long-term).

2. **The keyword is "easy"**

   The companies selling the service/unit should make interaction with them as straightforward as possible. Customers with an initial interest in a given solution should easily locate the relevant companies. It should be simple for them to evaluate the benefits of the offered service/unit and the customers should be guided through the process in a clear manner – ideally by a single point of contact. Interactions should take up only a minimum of a customer's time, so that it is not experienced as an administrative burden to engage/be engaged in the process.

3. **Collaborate on a common decarbonisation strategy**

   By engaging in a common decarbonisation strategy together with local authorities and other stakeholders, relevant businesses can secure their role in the future decarbonised energy system and make sure that the process is structured across different stakeholder groups.

4. **Engage in partnerships**

   Energy technology providers whose products and/or services are perhaps not economically feasible (enough) to be implemented as stand alone should be encouraged by the findings of HRE4 to explore the integration of other components or even cross-sectorial elements to develop a future-orientated business case.

For more information on barriers and solutions, together with their applicability in the 14 HRE4 countries, please refer to the report.

5 Trier, D., Kowalska, M., Paardekooper, S., Volt, J., De Groote, M., Krasatsenka, A., ... Mathiesen, B. V. (2018). Heat Roadmap Europe 4 - Business Cases and Business Strategies to Encourage Market Uptake: Addressing Barriers for the Market Uptake of Recommended Heating and Cooling Solutions. PlanEnergi. Heat Roadmap Europe Deliverable 7.16.

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