Guidelines for the Energy System Transition

The Energy Union Perspective - Heat Roadmap Europe

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Publication date:
2018

Document Version
Publisher's PDF, also known as Version of record

2050

Heat Roadmap Europe

A low-carbon heating and cooling strategy

Guidelines for the Energy System Transition

The Energy Union Perspective

Deliverable 7.17-E

Project Number:	695989
Project acronym:	HRE
Project title:	Heat Roadmap Europe: Building the knowledge, skills, and capacity required to enable new policies and encourage new investments in the heating and cooling sector.
Contract type:	H2020-EE-2015-3-MarketUptake

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 695989.

Deliverable number:	D7.17-E
Deliverable title:	Final HRE guidelines for local, national, and EU lead-users
Work package:	WP7
Due date of deliverable:	31 August 2018
Actual submission date:	M33 - 30/11/2018
Start date of project:	01/03/2016
Duration:	36 months
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Dissemination Level of this Deliverable:	PU
Public	*PU*
Confidential, only for members of the consortium (including the Commission Services)	*CO*

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Deliverable No. D 7.17: Public report.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 695989. The sole responsibility for the content of this document lies with the authors. It does not necessarily reflect the opinion of the funding authorities. The funding authorities are not responsible for any use that may be made of the information contained therein.

Preface

The findings of Heat Roadmap Europe 4 (HRE4) proves that a common and coordinated effort of all Europeans for the transition to a low-carbon future in accordance with the Paris Agreement is not only possible, but cost-effective and affordable with existing technologies available on the market today. Therefore it would be an ethical, political and organisational failure, if the European Commission, its Member States as well as regional and local governments together won't be able to ensure the change required to keep global warming significantly below 2 °C compared to the pre-industrial area.

In particular, current and planned policies should be aligned with the vision of a carbon emission free heating and cooling sector by 2050, as the sector corresponds to about 50% of the final energy demand in Europe and has a crucial role to play in the connectivity and affordability of the entire sustainable energy system of the future. This includes energy, environmental, economic, tax and educational policies, while ensuring that the impact of any legislation on all levels does not hinder the development towards this goal, but instead encourages and accelerates the transition.

There is no sustainable alternative for the future of Europe than a decarbonised, integrated energy system. Postponing the challenges will only make the transition organisationally more difficult and unnecessarily expensive, but will not make the challenge itself become obsolete. The emission targets required to meet the Paris Agreement must be reached sooner, rather than later in order for society to benefit from the improvements created. The scientific and technolocially neutral research initative Heat Roadmap Europe verifies how choosing the path of decarbonisation in an integrated manner will be beneficial for all governmental levels, wether if the main priorities are economic, social or environmental.

Based on the outcomes of Heat Roadmap Europe, the authors call for action from all politicians in Europe to accept their responsibility to take on their necessary role as leaders towards a fossil fuel free energy system by setting up the decisive framework which will have guided Europe to an economically feasible, socially accepted and environmentally needed low-carbon future.

Executive summary

The aim of the HRE4 project is to create the scientific evidence to support short-to long-term energy strategies and decision-making at local, regional, national and EU levels to accelerate and empower the transition to a low-carbon energy system by quantifying the impact of various options, particulary in the heating and cooling (H&C) sector. Specifically, the results are presented in terms of roadmaps and recommendations towards 2050 for the H&C sector of the 14 EU countries[1] that correspond up to 90% of the EU's thermal demand, but are also still applicable to other Member States.

These *Heat Roadmaps* [1] should not be considered as the exclusively definited and only viable future sustainable energy mix, but rather as solid, cost-effective and affordable pathway presenting how the benefits and synergetic opportunities – ready to be exploited today by taking an integrated approach in a redesign of the entire energy system – can lead to a feasible, decarbonised future in accordance with the Paris Agreement [2].

Key messages – requested actions from EU policymakers

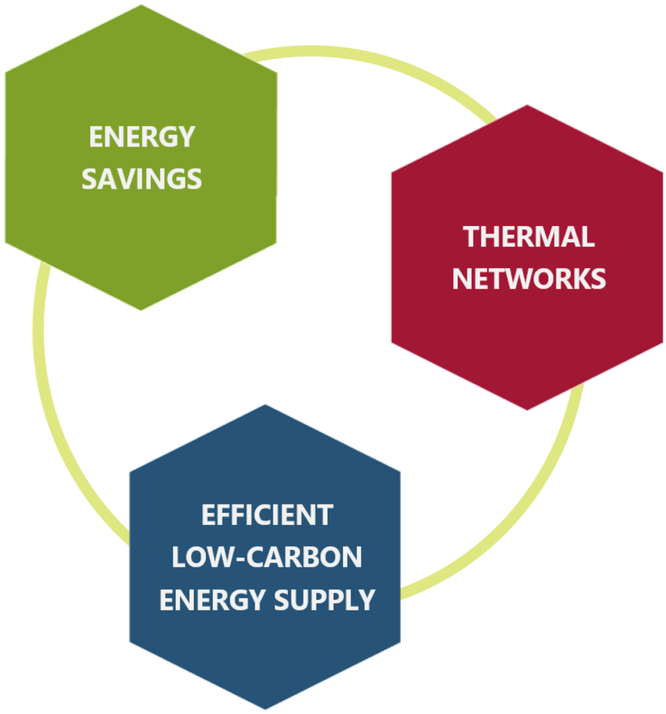
1	**Europe can already reduce its CO_2 emissions by 4,340 Mton or 86% compared to 1990 by using existing, mature technologies in the heating and cooling sector. HRE4 verifies that decarbonisation in line with the European commitments under the Paris Agreement is possible and that the coupling of sectors is essential for the most cost-efficient, and therefore economically and socially feasible low-carbon energy system.**

- By redesigning the heating and cooling sector the total costs of decarbonisation can be reduced by 6% annually compared to conventional methods of decarbonisation. In all future scenarios less financial resources are spent on fossil fuels and more on the infrastructure that delivers sustainable energy. This requires clear sectorial targets and policies that facilitate and foster a fossil fuel phase-out by 2050 and a strategic redesign of the framework conditions to enable investments for an integrated, efficient and renewables-based energy system on a local, regional, national and European level.
- H&C should be politically and technically recognised as an essential component and the most cost-effective solution that allows the integration of shares of renewable energy of up to

[1] Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, Netherlands, Poland, Romania, Spain, Sweden and United Kingdom.

87% and more, while supplying flexibility and ensuring the stability and security of an overall integrated sustainable energy system.

The three main "pillars" or focus areas – energy savings, thermal networks and efficient low-carbon energy supply to enable electrification of the energy system – are especially important for policy-makers to steer the transition holistically towards a low-carbon energy system. HRE4 shows that a mix of energy savings, establishing and expanding district H&C areas, integration of low-carbon renewable and excess heat sources together with a significant electrification of the H&C sector can create synergies which are not as exploitable if one (or more) of these components is overlooked. The cross-sectoral energy planning approach of HRE reveals further points covering all three pillars, as revealed in the subsequent key messages.



2	**Energy savings are required on both the demand and supply side to cost-effectively reach the decarbonisation goals. HRE4 shows that the majority of recommended savings in primary energy demand can be achieved by more efficient supply options. EU policies, directives and the EU financial framework need to coherently support both sides.**

- Substantial amounts of cost-effective energy savings are ready to be exploited and these are key for the decarbonisation of the energy system. Related EU directives, like the Energy Efficiency Directive and the Energy Performance of Buildings Directive, need to reflect the higher, but feasible energy saving targets of at least 30% for space heating in buildings for instance. Consequently, also the EU financial framework including financial incentives should support this higher ambition and enable the exploitation of the potential in the residential, industry and service sector alike.

- Despite common misconceptions, introducing energy efficiency measures does not necessarily make district heating unfeasible, neither for existing nor new networks. In fact, energy efficient buildings can effectively shave expensive peaks and improve the performance and feasibility of the entire (new or existing) district energy network. Respectively, policies and financial programmes should support the efficiency for district heating systems and the integration of small- to large-scale excess heat sources, as HRE4 has identified an excess heat potential in the electricity production alone corresponding to more than the heat demand of Europe's entire building stock today.

ENERGY SAVINGS

- Where district heating is not the most cost-effective solution, mainly in rural areas, energy retrofitting of buildings should consider combining such measures with the replacement of boilers by individual heat pumps. The most efficient heat pump systems are those found in new buildings and in those that have undergone deep renovation. On top of the added value in energetic savings, such efforts will also improve the comfort level for the buildings' inhabitants. Respectively, policies and financial programmes should support the massive roll-out of heat pumps in rural areas.

3	**HRE4 identifies suggested balances between decentralised heating and cooling systems being the most cost-effective decarbonisation option in rural areas, and thermal networks in dense urban areas. Those individual supplies should mainly be based on heat pumps as they can enable the flexible integration of renewables without using scarce bioenergy resources.**

- Electrical heat pumps should be implemented to a much greater extent and up to an overall market share of about half, specifically:
    - in rural areas, where individual heat pumps should replace fossil fuel boilers;
    - in urban areas, where large-scale heat pumps should make the use of low-temperature renewable and excess heat sources and replace a fossil-based district heating supply relying on boilers and/or CHP.

EFFICIENT LOW-CARBON ENERGY SUPPLY

- Increasing the share of district heating in combination with cheap thermal storages, heat pumps and CHP can stabilise the electricity grid and thus facilitating the integration of renewables, when introducing more fluctuating sources such as wind and solar.

- Several renewable energy technologies benefit – or even require – large-scale installations in order to be economically viable. To exploit the full potential of large-scale and capital-intensive technologies like deep geothermal energy and solar heating, a district heating system needs to be present since for these technologies, economy of scale is key. The future energy mix will be much more diverse than in the past. A thermal grid in place will be able to integrate small- to large-scale renewable and excess heat sources in the most cost-effective way.

- By means of detailed spatial analysis HRE shows that approximately half of the total building heat demand in the residential and service sectors is located in high density areas. Some countries have higher or lower shares, depending largely on their level of urbanisation. Combining cost calculations with the overall system modelling reveals the scientific evidence supporting the conclusion that more than half of European countries' heat demand can cost-effectively be supplied with district heating in 2050. Furthermore, the spatial components of HRE and in particular its Pan-European Thermal Atlas (*Peta*) online mapping tool can even pinpoint where these new or expanded networks can feasibly be located.

THERMAL NETWORKS

4	**Excess heat recovery is key to an efficient and resilient thermal sector, and has the potential to support local industries, economies and employment. The identified quantities of excess heat across Europe are with 2.4 PWh/y (8.7 EJ/y) immense and thus need to be addressed through policies, regulations and finance that enable integration into the energy system.**

Small to large-scale excess heat sources could cover at least 25% of the district heat production considering their location. This requires a concerted change in planning practices to ensure that they are within geographic range and fairly distributed among different potential district heating areas and cities. This is the case for local industries, waste-to-energy facilities, future bio-, green gas or electro fuel production sites, and potentially also data centres, sewage treatment facilities and other types of non-conventional excess heat.

Further sources of excess heat, for example that which requires heat pumps to be upgraded, should be investigated. These lower temperature sources are not included in the analysed HRE scenarios, which means that the analysed of both industrial excess heat and large-scale heat pumps are likely to be on the conservative compared to the real potential.

Administrative and financial barriers to use (low-temperature) waste heat should be suitably removed, but of course giving priority to sustainable excess heat sources free of fossil fuels or other negative environmental impacts.

5	**District heating and cooling in cities and towns is the least-cost and most-efficient solutions for reducing emissions and primary energy use. Through a thermal grid H&C can be completely decarbonised using renewables, large heat pumps, excess heat and CHP. Therefore, investments in the establishment and expansion of thermal grids in urban areas need to have high priority in public funding and support programmes.**

The HRE recommendations correspond and support all aspects of the EU Energy Union including energy security, strengthening the internal energy market, prioritizing energy efficiency, identifying viable options for the decarbonisation of the economy, and enhancing research, innovation and competitiveness.

- The presented solutions of the HRE scenarios recommend the shift towards a more capital-intensive heat supply, however, with much lower operational costs due to a heat supply mainly based on renewables and excess heat. With this shift fossil fuel imports which currently amount to a value of about € 50-65 billion for natural gas alone, could be phased out and economically be replaced by local added value chains of energy efficiency and renewable energy throughout Europe.

- With the comprehensive energy system modelling approach of HRE4 it was analysed how a reduced consumption of fossil fuels can be achieved in order potentially to eliminate the dependence on imported oil and natural gas for heating purposes in Europe and the uncertainty related to future fuel prices.

- The decarbonisation of the H&C sector will open the market for locally based heat sources and thereby increase the security of supply and making the countries more resilient to geopolitical changes, while enabling the implementation of increased amounts of fluctuating renewables.

- The restructuring of the thermal energy system will create and maintain local jobs related to energy efficiency and renewable energy products and services. Moreover, the redesign would significantly strengthen the competitiveness of industries, nationally as well as internationally.

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

The ambitious long-term climate and energy targets of the EU must be translated into adequately ambitious short-term actions through policies that facilitate the energy transition in the electricity, thermal and transport sector. Cross-sectorial, complementary efficiency and renewable targets applied at all governmental levels will be essential for realising a sustainable low-carbon society. Integrated management, knowledge transfer, holistic energy planning tools, open business models with broader forms of collaborations and incentives are some of the most important aspects that need to be carefully addressed, since in most cases the barriers faced are political, regulatory and organisational rather than technical. Among the key recommendations can be mentioned several action points:

- A horizontal integration of energy/climate targets (into all sectors such as electricity, heating and cooling, transport etc. incl. their subsectors) combined with vertical integration of targets (throughout governmental levels) should be applied. Besides this, it is important to ensure not only targets, but actual policy implementation and realisation, with regular reporting and evaluation cycles on progress and impact.

- It is recommended to increase the target to at least 30% savings for space heating in buildings by 2050 compared to 2015 which requires higher annual refurbishment rate at 1.5% to 2%, and deeper renovation of existing buildings that anyway undergo a renovation. The EPBD should reflect these ecomically feasible findings.

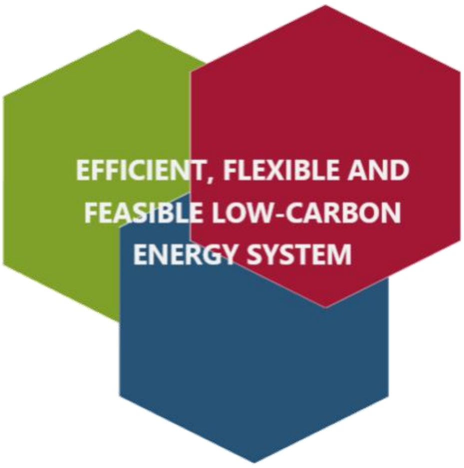
- Policies such as the RED should incentivise flexible interaction for prosumers to help balance electricity grids and not maximise self-consumption which in some cases will be counterproductive for the overall energy system.

- An investment initiative – both at EU level and at national level – for comprehensively and fast expansion and establishment of systematically new district thermal infrastructures in urban areas and roll-out heat pumps in rural areas should be initiated. This financial framework has to be aligned with policies reflecting the reduced role and appliance of natural gas and an increased importance of electricity grids.

- More support is also needed to ensure implementation and higher energy saving targets and higher energy saving targets for both deeper renovation of the existing building stock and investments in industry. Stronger price signals (e.g. energy obligation schemes or taxes), together with information-availability (e.g. smart meters), communication (e.g. “nudging”), as well as the proper education of craftsmen and citizens, will be crucial drivers.

7	**HRE recommends a complete decarbonisation of H&C by 2050 and shows how this can be done. Contributions from all energy sectors have to support the implementation of such decarbonisation targets to ensure the most cost-effective and socially acceptable pathway. The targets should also be reflected in directives such as the EED, RED, EPBD and EU ETS[2].**

- To remove barriers the following complementary measures for the recommended key actions have been identified:
    - Raising awareness 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 much more profitable for our local economies.
    - Setting up frameworks to improve qualifications and the number of skilled professionals.
    - Removing administrative barriers for stakeholders to establish district heating and cooling and excess heat recovery[3].
    - Requiring integrated energy planning, implementation and regular evaluation of status across all energy sectors and at all governmental levels.
    - Improving feasibility of a sustainable energy system directly and indirectly by means of 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.



[2] Referring to the Energy Efficiency Directive [3], Renewable Energy Directive [4], Energy Performance of Buildings Directive [5] and EU Emissions Trading System [6] respectively.
[3] In some cases, even small industries would need the same level of approval as an electricity production utility if they are to enter an agreement on selling their low-temperature excess heat.

- The EU Emission Trading Scheme (ETS) today does not reflect actual costs of emissions. A decision to ensure a minimum price level (increasing over the years) would serve as a safety net to make investments in RE solutions and energy efficiency more certain. Increasing the amount of allowances put in the Market Stability Reserve (MSR) until a certain lower price level is reached could be combined with the present MSR and ETS cap reduction plans. This additional MSR action will only come into force, if the cost of allowances becomes too low.
- In general, all public financing should be cross-checked, if they counteract or support the short- to long-term energy efficiency, renewable energy and emission reduction targets and activities of the EU and its Member States.

HRE resources available to support the energy transition

The HRE 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. 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[4], and complete energy system model datasets which users can modify to investigate for themselves the likely impacts of alternative scenarios. HRE has the aim provide a transparent approach to democratise the debate on how future energy systems can and should be structured.

Guidelines for the energy system transition with a *local/regional* and *national* approach respectively are also available, and may be useful to get an insight into variations of these recommendations from either perspective. All project reports are available on the HRE website. 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.

- The Pan-European Thermal Atlas (*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 demands, each on a hectare level.
    - Renewable heat resource potentials such as geothermal, solar thermal and biomass.
    - Pinpointed potential excess heat sources e.g. from waste incineration, power plants, data centres and industrial processes.
    - Existing and prospective district heating areas including the cost of establishing network infrastructure and indications of the recommended shares of district heating.

[4] The cost-curves shows the cost of reducing the demand depending on how ambitious the target is, i.e. what are the cost of measures, when "low-hanging fruits" have been exploited and further savings are required.

    - Heat Synergy Regions highlighting the overlap of demands and identified excess heat – indicated as an "excess heat ratio", i.e. the ratio between excess heat and heat demand within a given region.

- The development and findings of the modelled HRE 2050 decarbonisation scenarios including methodologies used, different energy demands, different energy supply technologies, their role within the wider energy system and how these compare with alternatives [1]. 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.*

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1. Introduction

In Europe, there is a clear, long-term objective to decarbonise the energy system. The Heat Roadmap Europe 4 (HRE4) project, co-funded by the European Union, seeks to enable new policies and prepare the ground for new investments by creating more certainty in relation to the changes that are required.

HRE4 provides new capacity and skills for lead-users in the heating and cooling (H&C) sector, including policymakers, industry, and researchers at local, national, and EU levels. This is done by developing the data, tools, methodologies, and results necessary to quantify the impact of implementing more energy efficient measures on both the demand and supply side of the sector.

The results of HRE4 show how a complete decarbonisation of the European heating and cooling sector is technically feasible and economically viable, and can be achieved with proven technologies already used today. The "Heat Roadmaps" representing decarbonisation pathways for 14 EU countries[5] towards 2050 (covering approx. 90% of the EU heat demand) show how this can be done, and all the available HRE outcomes such as guidelines and interactive tools can help stakeholders facilitate this transition. This report emcompasses *key messages and recommendations* based on the overall HRE4 project targeting policymakers at European level such as DG ENER, DG CLIMA, DG REGIO, MEPs etc.

The overarching "pillars" of HRE (see section 2) identified to be the main focus areas each represent one section headline. These sections include key messages related to the topic 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.

> The development and findings of the HRE scenarios including methodologies used, different energy demands, different energy supply technologies, their role within the wider energy system and how these compare with alternatives are described in the report
> *Quantifying the Impact of Low-carbon Heating and Cooling Roadmaps* [1]
>
> Guidelines similar to this report only aimed at national and local/regional policymakers respectively may also be of interest to the readers of this report to get an insight in the country-specific recommendations and the ones suggested for other governmental levels.
> *Guidelines for the Energy System Transition – The National Aspects of the HRE 2050 Scenario and Associated Policy Recommendations* [7]
> *Guidelines for the Energy System Transition – Recommendations for Local and Regional Policymakers* [8]

[5] The HRE4 project especially focuses on those fourteen EU countries with the highest H&C demands (around 90% of the EU's total demand): Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, the Netherlands, Poland, Romania, Spain, Sweden and the UK.

2. Three main pillars to decarbonise the H&C sector

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 the recommendations cover more than one of them. Figure 1 below sketches the pillars as well as interconnections between them. Examples for each of these pillars (hexagons in Figure 1) district heating (DH) or district cooling (DC) in urban areas – fed by renewable energy (RE) or excess energy, building renovations to improve energy efficiency (EE) and heat pumps (HP) for space heating and domestic hot water in rural areas.

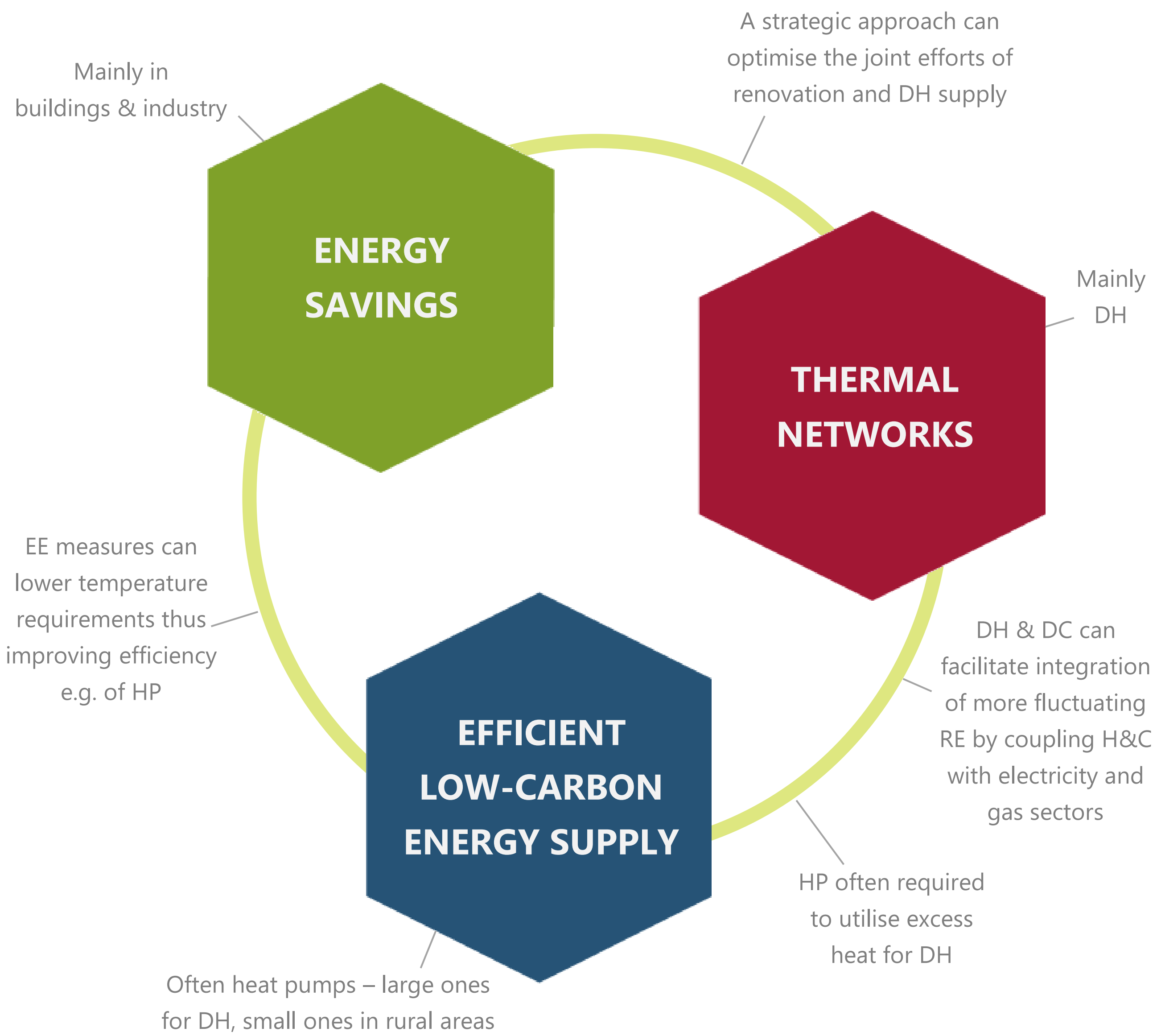

Figure 1. The three HRE "pillars", including examples of linkages between them.

The "Heat Roadmaps" of each of the 14 countries are commonly referred to as the HRE 2050 scenario. They should not be considered as the exclusively definited and only viable future sustainable energy roadmap, but rather as solid, cost-effective and affordable pathway presenting how the benefits and synergetic opportunities can lead to a feasible, decarbonised future in accordance with the Paris Agreement. One aim is to democratise the debate on how future energy systems can and should be structured.

Detailed energy system modelling has been used to take into account short-term hourly interactions of demand and (renewable) supply and including both challenges such as balancing requirements, and opportunities such as cross-sector links, while also looking at the long-term developments of the overall energy system and its demands towards 2050. This makes it possible to consider the connections between demands and supplies for heating, cooling, electricity and transport to optimise the overall system. HRE 2050 shows 86% decrease in CO_2 levels compared to 1990. The remaining fossil fuels are primarily in transport, industry and flexible CHP. In this context it should be mentioned that HRE 2050 does not hinder but rather *enables* the possibility of further implementation of renewables[6].

1	**The holistic HRE approach – which jointly considers electricity, heating, cooling and transport – reveals synergies between (and within) these different sectors and shows that decarbonisation is indeed possible and affordable with existing, mature technologies.**

The cross-sectoral energy planning approach of HRE reveals the following:

- Increasing the share of district heating and cooling, including cheap thermal storages, helps to stabilise the electricity grid when introducing more (non-dispatchable) variable renewable energy (VRE).
- Substantial energy savings in different sub-sectors are possible, feasible and recommendable for each of the targeted countries.
- An integrated approach considering the energy demands for transport, electricity, heating and cooling as a whole can release larger savings as a result of synergies.
- Even without including the significant health-related and climate change-related costs [9, 10], decarbonisation can be achieved at lower costs than "conventional decarbonisation"[7]

[6] See section 4.4.

[7] The HRE 2050 scenario (one per country) can be compared with the 2015 situation, a baseline development towards 2050 and the "Conventionally Decarbonised scenario" (CD 2050). CD 2050 represents an energy system targeting 80% reduction in EU CO_2 levels compared to 1990 levels and assumes encouragement of RE but without the same focus on savings and a redesigned H&C sector as in HRE 2050, cf. [1].

only, while reaching even greater CO_2 reductions. However, it requires a massive changeover of the current system design and framework conditions to support it.

These results should subsequently encourage policymakers to choose their own prioritisation – economic feasibility, environmental impact, quality of life, etc. – but nonetheless it is expected to reach the same conclusion regardless of priorities: that remains no reason to delay pushing this development forward.

The results of the baseline scenario showing the path towards 2050 with current policies is included in the report below. Furthermore, it contains a description of the energy modelling tools that can be further used – even beyond the HRE4 project. This provides a basis for understanding how markets will likely develop under current policy, and which markets need further development of their framework conditions in order to contribute to full decarbonisation.

Baseline scenario of the total energy system up to 2050 [11]

For users who want to evaluate, elaborate or adjust these models themselves, the freeware and baseline scenario input files are publicly available, presenting hourly energy system models for each of the 14 countries for both 2015 and 2050.

Hourly energy system models for each of the 14 MSs for the business-as-usual scenario [12]

The following sections represent the main findings and associated policy recommendations covering these three complementary pillars based on the complete energy system modelling of each of HRE's 14 target countries.

Just like the integrated energy system approach covers the challenges and opportunities in a holistic manner, the points raised in the following text should not be considered applicable only to a single pillar, but rather something that builds upon each of them, reinforced by the interconnections.

A key point derived from the results of HRE is that the presented decarbonisation roadmaps require *combined* efforts of energy efficiency measures, an efficient low-carbon H&C supply with increased electrification and a significant deployment of more district H&C. These synergetic effects will not be realised to the full extent possible if policymakers fail to take the potentials of all pillars and their linkages into account.

While national governments may wish to push for a sustainable development they will often be concerned with risking (short-term) reduced competitiveness for the country's industries if hard taxation and/or sustainability criteria are applied without corresponding support to facilitate the transition towards sustainability. Even with the aim to balance support and taxation for the involved stakeholders to steer the energy transition, some stakeholders will in most cases be affected more than others and thus oppose the change. Long-term political goals and corresponding stable frameworks ("raising the bar" continuously), can let stakeholders plan ahead and make wise (transition) decisions to avoid a cost increase. Collaboration and agreements on supranational level – for various sustainability topics – can encourage a common understanding of necessary changes and avoid that Member States (MSs) apply protectionist legislation.

2	**The reluctance of some national governments for pursuing ambitious energy and climate targets – setting nation-centric interests first – calls upon EU policymakers to show leadership by pushing for a common EU ambition level for 2050 matching the globally-required targets of the Paris Agreement [2].**

Stricter efficiency requirements applied to products related to buildings and industrial processes, can prove to be an advantage for Europe's exports[8] since sustainability requirements across *all* sectors will create improved technologies and products thus increasing the competitiveness globally in the long run where sustainable technologies and production chains are indeed the only viable option.

[8] In accordance with one of the objectives of the Energy Union – to make the EU the global leader in renewable energy and lead the fight against global warming.

3. Realising essential and feasible energy savings

3.1. Energy savings is not a single-player game

HRE identifies substantial amounts of cost-effective energy savings ready to be exploited and highlights that these are key for the decarbonisation of the energy system. It is recommended to target at least 30% savings for space heating in buildings by 2050 (compared to 2015) which requires a higher refurbishment rate of 1.5% to 2%, and deeper renovations when they occur. As a precaution, such a target could be set somewhat higher since the results of HRE show only little difference in socio-economic costs while there is an inherent risk that whatever targets are set, the savings realised may fall short of reaching these. However, when targeting energy savings objectives, it should be remembered that the goal should not be the savings per se, but rather emission reductions. Hence, the extent of savings should be balanced with alternatives such as RE-based supply as illustrated in Figure 2.

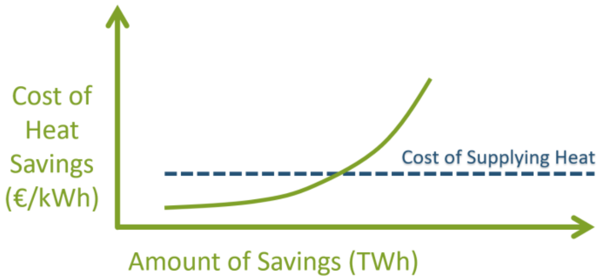

Figure 2. Illustration of the principle that savings should be realised to a certain extent, until it becomes more relevant to apply a decarbonised heat supply.

3	**Energy efficiency is required on both the demand and supply side to cost-effectively reach decarbonisation goals. To meet its greenhouse gas emission reduction target by 2050, the EU needs to combine energy efficiency measures with the decarbonisation of the energy supply.**

Decarbonising Europe's building stock is not an "either/or" decision between energy efficiency and the deployment of renewables, but needs a system focus on both. The balancing of necessary investments to achieve demand reductions vs. a decarbonised energy supply should be optimised.

Cost of savings should be balanced with cost of decarbonised supply. It is important not to promote one over the other in an unbalanced way, among others in relation to EPBD. Building performance assessments and similar sets of rules as well as the EU framework on cost-optimality calculations for nearly-zero energy buildings must consider systemic measures and individual measures, efficiency and renewables, and onsite and offsite energy solutions equally. This means for example that primary savings through using waste heat and through a more efficient building need to be compared on a non-discriminatory basis while taking into account more than just one individual building. Similarly, individual RES solutions like PV panels should not be considered as energy savings as it is the case, when using a purchased energy approach. On the contrary, RES onsite and offsite must be treated in a non-discriminatory way that reflects the actual contribution to a better performing building.

When considering the contribution of sustainable energy sources, be it RES or excess, the use of primary energy factors (PEFs) has a key influence on the way this happens. They are crucial in policies implemented in relation to both the EED and to EPBD. It must be ensured that methodologies in general reflect the real energy mix and it is worthwhile to consider seasonal variations in the use and supply of energy.

Similar to the case of PEFs, also other indicators must treat all options in a fair manner. The smartness readiness indicator[9] should consider heat and electricity equally e.g. in a way that *demand side management* and *demand response* solutions are included[10].

> By investigating the energy savings potentials – including their sub-sectors, type of savings and associated costs – HRE4 has evaluated how the costs increase as the energy efficiency ambition-level rises. This is graphically represented as "cost-curves" which naturally vary from country to country. The information can be used when developing national scenarios targeting a certain savings potential. The same methodology is applied across all countries, which makes the cost-curves of different countries directly comparable. This can be used to identify suitable policymaking and other solutions from third countries which may have a potential for replication. The report below describes how to relate investments to delivered energy savings.
>
> *Cost-curve Guide for Lead-Users* [13]

3.2. Ensuring the implementation of savings

By investigating the potential and corresponding cost of a wide range of concrete energy savings measures (sub-groups within residential, tertiary and industry) it has been analysed to which extent these can be implemented economically including a comparison with alternative means of covering demands (e.g. supplying more RE instead of implementing some of the savings). The results show that in some countries the ambitious policies passed on since the 2010 EPBD[11] are already enforced

[9] Article 8 of the 2018 EPBD states the following: "The [smart readiness] rating shall be based on an assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance."
[10] See also section 4.5 regarding consumer flexibility.
[11] Directive 2010/31/EU on the energy performance of buildings.

in national laws meaning that the baseline scenario includes roughly the same level of savings as in the Heat Roadmaps. To achieve these savings the focus needs to shift from encouraging ambitious policy targets towards ensuring *implementation* to the extent of complete achievement of these goals. It is vital that defining the goals does not become a pretext for inaction.

4	**While Belgium, the Czech Republic, Hungary, the Netherlands, Poland and Romania need to significantly enhance their current legislation on energy efficiency, other countries already-passed policies that would lead to a substantial, cost-effective reduction in residential heating demand. Therefore, the latter group should focus on the effective implementation of these policies.**

HRE4 finds that in Belgium, the Czech Republic, Hungary, the Netherlands, Poland and Romania there is a need to significantly improve/upgrade current legislation to increase their energy savings efforts, while (as in all countries) keeping a focus on supporting policies to ensure that the expected savings are reached in practice. Regular follow-up evaluation on the progress and impact on legislation and support schemes is important to ensure that expected targets are met.

Considering the lifetime of buildings compared to other investments, planning is needed for 2050 in which the development of built area quantities including types of demand, renovation rates, and uncertainty of compliance should be taken into account. Once investments have already been made for "low-hanging fruit" in energy efficiency renovations, the remaining savings potentials will have higher investment costs, and therefore need to be made attractive for end-users to invest in them. It is relevant to distinguish between refurbishment *rates* of 1.5%-2% per year and refurbishment *depth*.

5	**Supporting deeper thermal renovation of buildings that will anyway undergo a renovation could avoid an important missed opportunity. Financial incentives should be combined with increased awareness and education of related companies and craftsmen.**

Stronger price signals (e.g. energy obligation schemes or taxes), together with low-cost financing schemes for decarbonisation investments, information-availability (e.g. smart meters), communication (e.g. "nudging"), as well as the proper education of craftsmen and citizens, will be crucial drivers to ensure realisation of the necessary savings to reach the decarbonisation goals across Europe. These are not technical barriers but can all be addressed if the political will and required efforts are put into the processes.

> The Heat Roadmaps use the abovementioned cost-curves for each of the 14 countries highlighting to which extent energy savings should be applied in the context of various energy system configuration alternatives. The report below can support policymakers by presenting the costs and benefits of targeting various (sub-)sector-specific efforts relevant to establish suitable frameworks to steer a development towards recommended savings levels.
> *Cost-curves for heating and cooling demand reduction in the built environment and industry* [14]

3.3. Feasible heat savings potential in industry

By assessing the cost of heat savings depending on penetration level and sectors, HRE4 finds that energy savings in industry are highly cost-effective from a socio-economic perspective, and since industries often benefit from economies of scale (e.g. larger equipment, greater demands and/or higher annual full-load hours than in the residential or tertiary sector) the result is smaller investment costs for industrial heat savings than in residential buildings.

The extent of heat savings in industry tends to be more limited than in buildings because the temperature levels of many industrial processes cannot easily be lowered (and some savings have already been implemented). However, energy efficiency measures with small investment costs compared to the reference technology have been identified e.g. increased paper recycling and a shift from blast furnace steel to electric arc steel. Efficiency standards and financial incentives for process heat savings should be ensured to realise this potential.

> Specific industrial savings categories, including the potentials and cost levels per kWh saved, is described in section 3.4 of the report mentioned above:
> *Cost-curves for heating and cooling demand reduction in the built environment and industry* [14]

Working towards a circular economy approach to the energy sector, could result in an even larger share of savings by recycling resources, both in materials and energy.

6	**Efficiency standards and financial incentives should better reflect the highly cost-effective potential for energy savings in industry and the service sector from a socio-economic perspective. Excess heat should be regulated, as the quantities of energy losses are contradicting not only the climate targets, but also enable the affordability of the decarbonisation of the economy in Europe.**

3.4. Energy savings and district energy combined

Introducing energy efficiency measures does not necessarily make district heating and cooling unfeasible, whether for existing or new networks. In fact, energy efficient buildings can effectively shave peaks and improve the performance and feasibility of the entire (new or existing) district energy network. With new or renovated energy efficient buildings, a new network can be designed for low temperatures whereas an existing network peak demand can be reduced, while/or additional consumers can be connected to the same grid. In district heating, the relatively small number of hours per year with peak demand are often the most expensive – in terms of OPEX and/or CAPEX (since the capacity required may have few full-load hours per year).

7	**Energy efficiency measures in buildings and district energy can be seen as complementary solutions, not in opposition to each other as commonly thought.**

Not only are low-temperature district heating networks in general more efficient, but they are also better equipped to take advantage of a wider variety of heat source input options – e.g. low-temperature excess heat with or without the need of applying heat pumps.

3.5. Energy savings and individual heat supplies

Similar to the synergy effects highlighted in 3.4 above, the combination of energy efficiency in buildings and an energy efficient individual supply can contribute to the overall efficiency and decarbonisation of the heating/cooling systems more than either one on its own. One example is the replacement of a boiler by a heat pump. Heat pumps run very efficiently in new buildings and in those that have undergone deep renovation. In all other cases, a proper assessment of the energy demand is necessary for a proper heat pump system design. If the operation temperatures of the heating system are low enough, the necessary energy can be provided by a heat pump. If not, energy efficiency measures should be applied to the building envelope and the heat distribution system before installing the heat pump. In general, heat pumps run most efficient (expressed as the COP/SCOP[12]), if the difference between energy source and the needed supply temperature of the building is as small as possible. Optimising the building envelope and/or the heat distribution system can in some cases be a requisite to make the building "heat pump ready" and thus enhance the technologies application area – on top, it will improve the comfort level of inhabitants.

[12] The coefficient of performance (COP) represents the efficiency of a heat pump – as an annual average also referred to as seasonal coefficient of performance (SCOP).

4. Ensuring an efficient, low-carbon energy supply

4.1. Electrification of H&C is a key piece of the puzzle

Electrical heat pumps should be implemented to a much greater extent – both individual ones in rural areas where thermal networks are not feasible and in urban areas where they can make the use of low-temperature renewable and excess heat sources possible.

8	**Where decentralised H&C systems are more feasible than centralised thermal networks, individual heat pumps should be promoted, since they can simultaneously contribute both to direct decarbonisation and to the flexible integration of renewables.**

The results of the Heat Roadmaps show that a too uniform energy transition focusing only on few solutions (such as full electrification without integrating district heating) would not result in the most cost-efficient future energy system configuration. All the "players on the field" should be considered as possible contributors of the (optimum) energy mix, and energy system modelling should fully take into account specificities of the H&C sector – only then can potential synergies be obtained. Revealing these opportunities requires knowledge on the various demands, available sources and costs of infrastructure – all in high spatial resolution – as well as detailed energy modelling in a short timewise resolution combined with a long-term horizon. Such a combination of mapping and modelling is essential to analyse the heating and cooling sectors but should be expanded to other parts of the energy system in the future.

The Pan-European Thermal Atlas (*Peta*) is a public online interactive portal to support planners, investors and policymakers by presenting and quantifying the possibilities in a (geo)graphical manner for all 14 HRE countries in terms of, among other features: a) H&C demand densities on a hectare level and b) various heat sources to decarbonise the H&C sector, such as geothermal sources, solar district heating potentials, residual biomass resources and excess heat from waste incineration plants, power plants and industrial processes respectively. More information on *Peta* can be found directly in the online map or in the report
Maps Manual for Lead-Users [15]

The details regarding the underlying methodology which the maps are based on is described in
Methodology and assumptions used in the mapping [16]

4.2. A sustainable supply is required for all future demands

Not only a conversion of the existing energy demands is required. Targets and corresponding planning should reflect the future supply needs taking into account the increasing demands following economic growth and increased electrification for heating, cooling, transportation – e.g. electric vehicles (EVs) and industries such as datacentres. A renewable electricity capacity to cover 100% of the existing electricity demands would therefore not be enough.

By profiling the energy demands it is shown how important H&C is when aiming for a decarbonised energy system. With a final energy demand (FED) of 6,350 TWh in 2015 (22.9 EJ), H&C accounts for around 50% of the EU28 FED.

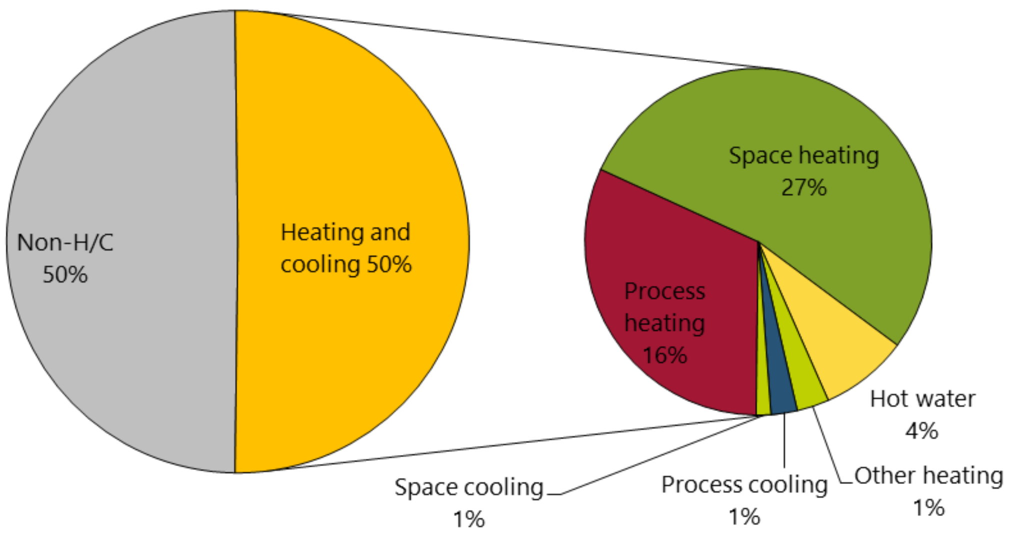

Figure 3. H&C demand in 2015 in the EU28, by end-use, compared to total final energy demand [17].

HRE4 presents a wide extent of freeware data for anyone to use for further analyses. This includes the descriptions of profiling the 2015 energy demand for H&C developed by calculating energy balances for all 28 EU countries. Besides the report including a methodology and summary of main results, the 2015 H&C profiles for all EU28 member states are freely available for download as interactive spreadsheets.

Profile of heating and cooling demand in 2015 [17]

Besides this, the scenarios of current policies are presented towards 2050 (i.e. targets and measures concerning RE H&C and energy efficiency, which have already been agreed or implemented at the latest by the end of 2016). These are described in:

Baseline scenario of the H&C demand in buildings and industry in the 14 MSs until 2050 [18]

> A guide for how lead-users can utilise the demand data for 2015 and 2050, technology datasheet, and FORECAST tool is described in the report
> *FORECAST Guide for Lead-Users* [19]

The use of biomass in boilers and CHP plants should not be considered an "easy-fix" solution to cover all the decarbonisation demand. In the future there will be an increased demand for biomass as it will have to cover several fossil-based demands of today such as bioplastics and biofuels for transport. For any biomass demand purpose, strict national and European sustainability rules will be crucial to ensure that it is sourced in a sustainable and effective manner, preventing deforestation and other harmful effects.

4.3. Carbon taxes and investor security

Across all pillars a consistent and reoccurring argument from various stakeholders is that an adequate carbon tax is needed to make the recommended decarbonisation solutions economically feasible and to accelerate their deployment in the medium to long run. If state revenues from such increased carbon taxation is fed back to the same stakeholder groups in the form of support for decarbonisation solutions, it can minimise the overall negative economic impact on the affected companies/end-users. This way the focus can be on the support scheme(s) and common goal(s) rather than what may be a (general) negative impression of increased taxation.

As a simultaneous and important step, all fossil fuel subsidies should be stopped immediately since these are directly counterproductive to the agreed climate targets.

For all the additional capacity needed as explained above (section 0) what is needed for investors is *certainty*. Feed-in tariffs could prove efficient to ensure stakeholder engagement (i.e. continuous RE capacity deployment) even when the RE shares are increased and electricity prices become harder to predict. The price of EU ETS allowances does not in itself provide the certainty for investors to promote new RE capacity. The dilemma of applying feed-in tariffs (to ensure that investors get a minimum price) or not can be boiled down to who should cope with the uncertainty of future energy prices – investors or MSs. Allocating the entire risk to investors may result in additional overall cost of the energy transition (included by investors to cover the risks) and/or to prolong the required changes.

In many cases the feasibility of converting from the fossil-based status quo to a low-/non-carbon alternative is simply not incentivising enough (if even positive) to realise the transition in practice. One example is the widespread use of natural gas boilers used for space heating which is recommended to be phased out (along with inefficient direct electric heating). Though taxation is a strong mean to encourage sustainable choices for the industry, residential and service sector, it cannot stand alone as the only mean promote the energy transition but should rather be considered as one part of a complete package towards decarbonisation.

A starting point for the abovementioned example is to ban the installation of fossil-based heat supplies in new buildings and phase out the ones in existing buildings. This measure – together with increased fossil fuel taxation – could go hand in hand with support for the shift to alternatives (e.g. subsidies or tax discounts). In order to minimise the impact of those who are used to their fossil fuel demand (e.g. natural gas) and associated costs, the economic incentives to shift to alternatives could be implemented simultaneously in order to keep a similar level of expenditures for the consumers.

On a European level, the EU ETS[13] today does not reflect actual costs of the damaging effect of emissions (and obviously distinguish between those polluters covered by the ETS and those who are not). At the same time industries are granted with free quotas allowing for continuous fossil fuel-based production. There is a need to plan for the phase-out of this fossil fuel demand already now. Defining long-term plans including a continuous increase in emission taxes could be a signal to investors showing what is considered a sustainable path forward and what is not, thus providing a more solid foundation for decision makers.

Though the ETS can play a key role in the energy transition, it is important to avoid the shift of CO_2 emissions from ETS to non-ETS sectors. Whereas the (typically centralised) electricity production required for these heat pumps are covered by the ETS, the residential use of fossil fuels (e.g. gas boilers) are not. This represent an unfair advantage favouring fossil fuel-based heat supply. Taxation should cover also emissions beyond ETS to promote decarbonisation outside urban areas.

Due to the following two points, carbon taxation and pure market mechanisms cannot be entrusted with the task of ensuring the energy transition alone:

- Other barriers must be overcome, e.g.:
    - removing unnecessary administrative burdens
    - educating skilled professionals e.g. in terms of renovation measures as well as HP installations and service checks of these
    - raising awareness about relevant H&C solutions among policymakers, businesses and individuals
    - facilitating access to financing schemes
- Broad market mechanisms will have a smaller impact as the RE share is increased. As the RE share increases in some countries/regions while others will lag behind, the price of ETS allowances will not be enough ensure an appropriate continuous push towards decarbonisation. To reach ambitious targets, milestones should push the threshold

[13] In short also referred to simply as "ETS".

continuously. Emission taxation therefore needs to follow this development by having a local aspect.

Though the ETS cannot stand alone, it may prove to be one of several effective tools if the price of emission allowances is high enough. A decision to ensure a minimum price level (increasing over the years) would serve as a safety net to ensure a minimum price threshold, thus making investments in RE solutions and energy efficiency a more certain venture – a critical point to engage investors and convince them to contribute.

9	**Increasing the amount of allowances put into the Market Stability Reserve (MSR) until a certain lower price level is reached could be combined with the present MSR and ETS cap reduction plans[14]. Thereby, this additional MSR action would only come into force if the cost of allowances becomes low enough.**

4.4. Renewable energy requires and offers flexibility

With the increasing integration of VRE, the positive role which the heating and cooling sector can play to augment grid flexibility becomes increasingly important and apparent. The use of renewable electricity in the heating and cooling sector can help balance the electricity grid when more VRE is introduced. Individual heat pumps in rural areas in combination with smart controls and large-scale heat pumps in district heating networks can play an important role in this connection when operated at times of surplus electricity thus providing a demand response potential to stabilise the grid and to allow more renewable electricity in to the energy mix.

Thermal storages – being several 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.

10	**To provide the flexibility required when increasing the share of wind and PV power, thermal storage is important in combination with individual heat pumps. However, the potential for grid flexibility and cost-effectiveness to integrate fluctuating RE becomes even greater by using district energy together with large-scale thermal storage, heat pumps and CHP.**

[14] See the EU Directive 2018/410 of 14 March 2018.

Avoiding the release of harmful refrigerants with high global warming potential factors (GWP) to the ambient is critical to realise the positive climate effect of heat pumps. In the HRE 2050 only low-GWP refrigerant heat pumps are used.

4.5. Flexibility from decentralised consumers and prosumers must be valued

In order to create new business models, which facilitate connections between the thermal and electricity sectors, the provision of demand side flexibility must become more interesting in an economic sense. This may be achieved by offering variable electricity tariffs to end-users or aggregators, among other solutions. Heat pumps can shift electricity consumption by absorbing its surplus in times of low demand through storage in a hot water tank, or in some cases within the building envelope itself. Giving this grid-flexibility service a true economic value would accelerate the technology deployment as more individuals and enterprises seek to profit from heat pumps and/or thermal storage.

Introducing many more consumers/prosumers[15] will result in a more decentralised and diverse energy system interacting across both sectors and the traditional stakeholder groups. New ICT solutions make market interactions with smaller consumers manageable. One example could be the use of local storage options (thermal or electric) to act as buffers to reduce peak demands for the electricity grid and the inherent dimensioning or capacity upgrade criteria to cope with this, when introducing large quantities of electric heat pumps (besides EVs etc.) The financial benefits for the prosumers should be structured to reflect the needs of the overall system. In some cases, the feasibility of electrical storages for individuals lies only in the avoidance of taxes. Household batteries should for example be able to respond to signals from the DSO instead of only maximise self-consumption. The use of RE should not be the end goal, but a mean to reach energy system emission targets – not single household targets.

11	**Policies such as the RED should incentivise flexible interaction for prosumers to help balance electricity grids and not just maximise their own self-consumption, which in some cases would end up being counterproductive for the overall energy system.**

[15] The term "prosumer" is a contraction of the words "producer" and "consumer". It reflects a consumer who sometimes produce more energy than what is consumed.

Flexible prices could reflect the strain on network and the balancing needs besides the production costs e.g. by introducing a tariff differentiation depending on periods or the user's maximum power peak. However, it is important *not* to structure cost schemes in a way that repels the interest of building owners to install a heat pump in the first place (where this is recommended). One option is to include an electricity tax discount on some of the bills (approximately the share for heating) for residential owners where their building is registered as supplied by a heat pump.

4.6. Excess heat is often politically neglected

HRE4 identifies an excess heat amount theoretically available that could supply heat for more than the entire building stock in Europe. Therefore, the avoidance as well as usage of excess heat – when not able to avoid – should receive high(er) priority and immediate attention in local to European decision-making processes, energy planning instruments and funding lines. However, the "CO_2 free" excess heat which could be gained from polluting power plants should not prolong their lifetime. What is shown by HRE4 is the massive potential to utilise current excess heat *and* renewable heat sources which planners and decision makers can evaluate in more detail to consider where the use is relevant and where not. Tapping into the excess heat potential can in many cases only be realised by applying district heating networks, which – once established – will have numerous supply opportunities – even if one excess heat source should terminate. HRE shows that at least 25% of the district heating production could be covered by excess heat considering the location of the sources.

Large-scale (cheap) thermal storages can act as buffers to maximise the use of excess heat when the supply and demand profiles do not match. Large scale heat pumps can make it possible to utilise excess heat sources at lower temperature in district heating networks where it is not possible to apply it directly.

HRE's *Peta* mapping platform includes geographically pinpointed and categorised excess heat sources such as power production, industrial processes, waste incineration, metro stations and urban waste water treatment plants. By clicking on the specific excess heat source, more information on the selected source is presented for the user. This can be used to illustrate not only *how much* excess heat potential is present, but also *where* this potential is located, thereby assisting the decision process of where decision-makers should investigate its utilisation further. More info on excess heat sources is found in the *Peta* itself, and in the following reports representing a user guide and a methodological description respectively.

Maps Manual for Lead-Users (section 5.3.3) [15]

Methodology and assumptions used in the mapping (section 2.2.1) [16]

4.7. CHP plays a key role, but is not a “one-size-fits-all” solution

In the Heat Roadmaps, it is shown how CHP could cover around a third of the district heat generation in 2050 operating only in response to the needs of the electricity markets. The differentiation between the type of CHP as well as its timeline is important. In terms of utilisation of excess heat from electricity-only power plants and possibly comparing with alternative industrial excess heat options it is relevant to consider the following questions for all options: When is the excess heat source expected to be decommissioned? Is it worthwhile to utilise the heat until then even if it requires a follow-up plan from the beginning? What is required of both technical and administrative measures to realise the utilisation of this source? What are my alternatives?

When it comes to replacing electricity-only power plants with new CHP plants, one has to keep in mind if the demands of the future energy system match the properties of such plants (in terms of flexibility, fuel import/costs e.g. gas or biomass etc.) Experience has shown that with increased VRE capacity in the electricity network, the non-controllable electricity production will consequently cover a larger share of the electricity demand thus leaving fewer hours for feasible CHP operation. Introducing large scale heat pumps for district heating can significantly reduce the need for other heat production capacity. In many decentralised CHP plants in Denmark (with both gas engine and gas boiler installed) long periods with low electricity prices have in most hours made it unfeasible to run in CHP mode thus resulting in an increased share of boiler operation in these plants. Hence, careful planning is required to assess the need for the future CHP capacity – including the services it should supply (e.g. mainly baseload heat/electricity production or balancing power). Any energy system investment – supply units or infrastructure – should be considered together with the remaining system, which it will inevitably interact with throughout its lifetime – directly or indirectly.

It should be noted that future power-to-gas (P2G) such as hydrogen production could be established as combined heat and gas solutions where a district heating connection ensures a higher efficiency of the P2G energy conversion. District heating can prove even more relevant in case of targeting a complete decarbonisation of EU by means of 100% RE using the Smart Energy Systems approach [20] where the production of electro-fuels for transport sector plays an important role. Hence, the HRE scenarios can serve as a step towards such a goal.

4.8. Cooling demand should not be overlooked

There is a demand for cooling throughout Europe including Scandinavia. Across Europe the demand is expected to increase significantly towards 2050 and this has to be strategically addressed today. However, even in the most southern of the 14 HRE countries heat demand continue to dominate the

H&C sector. The cooling demand differ from heating by being more balanced between space cooling and process cooling and dominated by services and industry. District cooling (DC) can in some places be a cost-effective solution and has a high potential to reduce greenhouse gas emissions by replacing individual applications in households, commerce and industry. Cooling demands often offer a direct opportunity to use the extracted heat in other applications e.g. district heating thus representing yet another synergy opportunity. However, further research is needed in terms of data for cooling demands as well as the possibilities for combining cooling and heating in spatial analyses.

In general, sustainable technologies – for example using natural cooling, integrated systems such as district cooling and the integration of the cold chain – should be given far more attention and resources for data collection, research and the roll-out of sustainable solutions in order to address the growing demand well in advance.

> Datasheets for performance and cost data of space cooling technologies in the residential and service sectors, and district cooling networks is available from the report:
> *Space Cooling Technology in Europe* [21]

4.9. Inclusive transition leaving no one behind

With the energy transition comes the need to avoid that some countries, regions, sectors and/or citizens get "left behind", meaning that efforts must be made to ensure that those affected negatively (e.g. workers in fossil fuel industry) or more difficult access to modern energy technologies (e.g. poorer families/areas) are helped in contributing to *their own* transition, too (e.g. workers educated to take on jobs created in the RE sector instead or families/areas supported in installing more efficient H&C solutions). Such changes are needed, and it is critical to make sure that energy development is inclusive to avoid any growing discontent among European populations and politicians.

12	**Support to upgrading skills on different levels (energy/urban planners, craftsmen, etc.) will support a positive public opinion towards the energy transition. Labourers in the fossil fuel industry should not be neglected in the restructuring process.**

Some degree of local ownership can increase public acceptance of RE installations. One example is to include a precondition for the investor to offer a share (e.g. 20%) of the installed capacity to the municipality's inhabitants and/or the nearest neighbours. By owning a share (e.g. of a wind farm) the locals may see it as less "intrusive". An additional option is to somehow compensate the affected local environment (e.g. by financing non-related local activities, supporting cultural activities or homeless shelters, thus improving the local area).

4.10. Long-term benefits of capital-intensive transition

Following the energy transition is a general trend towards a more capital-intensive heat supply together with lowered operation expenses. Examples include solar heating and heat pumps – both in small scale units and large (DH) utility-scale – where the total cost of energy to a larger extent relates to the unit investment rather than the operation (compared to boilers). In relation to district heating, a shift from previous times' single fuel supply to many heat supply sources introduce a wide range of options for the operator to optimise the production and reduces the sensitivity associated with the fuel costs (and availability). Similarly, the use of heat pumps makes it possible to use (locally) produced electricity (from a wide range of RE sources) thus reducing the dependency (financially and geopolitically) on fuel import. This makes it possible to ensure more stable conditions for both consumers and investors in the long run thus also reducing the risk of energy poverty. The Heat Roadmaps could eliminate the dependence on imported natural gas for heating in Europe. With this in mind, establishing new natural gas-grids holds considerable lock-in risks of potentially lost investments in the future, once countries finally transition away from fossil fuels completely.

Thermal networks take the shift from operation-related expenses towards investment-related expenses further than what is possible with individual supply. Another result of a development towards a higher degree of energy infrastructure investments is the opportunity to create local jobs as a result of the need for installation and servicing the infrastructure. This applies both on sub-country level and in terms of improving competitiveness of European industries nationally and internationally. On top of this, the energy transition improves living standards by limiting emissions thus ensuring better air quality locally besides limiting the global warming.

However, in any project the administrative efforts required have to match the predicted benefits. This applies in small and large scale. Examples include the issue of a comprehensive administrative process which repels smaller industries from entering into agreements of supplying excess heat. Similarly, as a large-scale example, where establishing new district heating networks (and possibly companies) is a long-term process requiring significant financial and manpower resources. Such financial and administrative barriers could be overcome by removing unnecessary administrative burdens, by supplying access to cheap, long-term financing and by empowering local authorities to facilitate the processes required in any (small or big) project involving several different stakeholders.

13	**Frameworks for providing low-cost financing options and avoiding (unnecessary) administratively-heavy processes is an important precondition to effectively engage communities and industries. Furthermore, local authorities should be empowered to encourage and facilitate H&C decarbonisation projects.**

5. Thermal networks create synergies

5.1. District energy plays a key role in decarbonisation roadmaps

Introducing or expanding thermal networks means that numerous synergy options come into play e.g. balancing of electricity grids in a future with much more VRE, excess heat utilisation otherwise wasted and RE sources only feasible in large-scale. As a result of this, the HRE 2050 shows that district heating should be deployed to a much larger extent in most countries as it represents a feasible and effective way which can ensure the deployment of a low-carbon heat supply in large scales. By means of detailed spatial analysis HRE4 finds that approximately half of the total building heat demand in the residential and service sectors is located in high density areas which, combined with cost calculations and the overall system modelling, forms the scientific evidence leading to the conclusion that more than half of the European heat demand[16] can cost-effectively be supplied with district heating in 2050 – and showing where these networks can be located.

14	**Due to higher urban densities, district energy in cities is one of the least-cost and most-efficient solutions for reducing emissions and primary energy use. Almost all countries' Heat Roadmaps show a strong and viable potential to economically increase the current share of district energy.**

The list of benefits by increasing the share of district heating is long:

- Beyond its ability to use economies of scale to take advantage of renewables, district H&C systems can make it possible to utilise excess heat from industries and other sources, which is otherwise regarded as mere waste (and with possible negative impacts on ecosystems[17]).
- Often many different heat sources are available. Excess heat can be a cheap option with a short payback time, while other feasible alternatives can relatively easily "step in" in case this supply option is terminated.
- Because district energy is typically not strictly conditional on the availability of just excess heat or any single type of renewable source, the feasibility of establishing district energy systems is generally a solid venture and a safe investment.

[16] Based on the 14 countries included in HRE4 corresponding to 90% of the total EU heat demand.
[17] For instance, according to studies [22] of the Swiss Federal Institute for Technology the Rhine is one of the most heat-polluted rivers as a result of warm-water discharge from power plants.

- In case energy-savings targets are not met, district H&C can still supply this additional demand with renewable heat, thus increasing the certainty that overall decarbonisation goals can and will indeed be reached (i.e. representing a type of backup solution[18]).
- District energy and cheap thermal storages can represent an ideal bridge between the heating, cooling and electricity sectors, while providing flexibility for the overall energy system.
- District H&C can be completely decarbonised using renewables, large heat pumps, excess heat and CHP. In fact, several RE technologies benefit from – or even require – large-scale installations in order to be most feasible. For example, to exploit the full potential of deep geothermal and solar thermal, DH needs to be present due to the significant economy of scale for these solutions.

This leads to the recommendation that financing mechanisms, such as the Innovation Fund and the Modernisation Fund, should (more) effectively enable intelligent system integration, e.g. in the frame of district energy projects. In general, EU financing (of various kinds) could be more closely linked to those H&C options with the most emission reduction potentials.

EU market regulation should enable various ownership models, since the most suitable structure of H&C provision and distribution to achieve social, economic and environmental targets will depend on the national and local framework conditions, as well as the historical tradition and status of district energy.

Ways that identified barriers to the market uptake of recommended solutions can be addressed are described in:

Business cases and business strategies to encourage market uptake [23]

The *Peta* online mapping tool also includes a visualisation of both existing DH networks and the cost of establishing DH on a hectare level. This gives lead-users the ability to pinpoint where the most suitable areas to establish/expand DH are located. The costs are presented as annualised investment costs per unit of annual sold heat. The *Peta* platform also includes a layer showing *Heat Synergy Regions* highlighting those regions with high synergies between excess heat and heat demand (indicated by an "excess heat ratio", i.e. the ratio between excess heat and heat demand within a given territory). The purpose is to provide an overview of where these assets and demands are in balance with each other and/or could be "exported" to nearby regions. Other features of *Peta* include the cooling demand densities on a hectare level. More info on Heat Synergy Regions and cost of district H&C networks is found in:

Map of the heat synergy regions and the cost to expand district heating and cooling in all 14 MS [24]

Updated Peta atlas for each MS with the final level of district heating recommended in WP6 [25]

[18] Note that this should indeed be considered a back-up plan. It is highly recommended *not* to disregard the energy-savings perspective, as it holds the key to a cost-effective decarbonisation.

5.2. Increasing cooling demand

Cooling demands in general remain much lower than heating also in 2050 but becomes increasingly important. As opposed to heating, the cooling demands differ by being more balanced between space cooling and process cooling (around half each) and dominated by the service and industries rather than the residential sector.

Renewable cooling should be considered in long-term planning to take into account the obvious synergy options between heating and cooling (e.g. utilising excess heat from the cooling process for DH). A close collaboration e.g. with cooling equipment providers could be useful to tap into low temperature excess heat options.

5.3. A holistic planning approach optimising the energy system

As described in section 3.4 energy efficiency measures and DH should be coupled rather than seen as competitors. Energy efficient buildings with a lower demand per m^2 compared to non-renovated ones, make it possible to reach a larger number of consumers with the existing main DH network. This way a declining demand from the DH network *per building* may actually represent a business opportunity for the DH company – provided that DH is (made) attractive enough for new consumers. At the same time a more modern DH system with lower temperatures will also be better at utilising (cheap) excess heat i.e. potentially more excess heat sources available at low temperatures, and higher COP of large-scale heat pumps when they supply heat to a low-temperature DH grid.
To disregard thermal networks as a key player in the integrated energy system will result in costlier and/or insufficient decarbonisation while failing to take into account the opportunities of renewable sources and utilising excess heat from industries and power generation thus limiting the overall system efficiency.

15	**An investment initiative – both at EU level and at national level – for a comprehensive, fast and systematic expansion and establishment new district thermal infrastructures in urban areas should be initiated. This financial framework has to be aligned with policies reflecting the reduced role and appliance of natural gas and an increased importance of electricity grids.**

6. Conclusion

When planning for a low-carbon future, it is evident, that the entire energy system must be taken into account to ensure that a decarbonisation focus in one place does not simply increase emissions somewhere else. The same level of consistency should be applied across EU policies, which should be considered jointly so as to ensure that the targets are in line with the Paris Agreement.

It is critical that various efforts are made simultaneously to remove the barriers hindering the energy transition in order to ensure that stakeholders successfully overcoming one barrier are not immediately blocked by further ones. Periodical reviews and – if necessary – changes accordingly should be formalised. Carbon taxation in all countries and other direct or indirect incentives should be ensured to encourage the realisation of energy savings, the implementation of renewables and the use of efficient energy system infrastructure applications.

Investments in infrastructure to decrease fuel demand such as district H&C networks, heat pumps and energy savings should be promoted in terms of the following combined and complementary efforts:

- 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 profitalbe for our local economies.
- Setting up frameworks to improve qualifications and the number of skilled professionals supporting decarbonisation solutions.
- Ensuring certainty (predictability) for investors, avoiding "stop-and-go" measures.
- Removing administrative barriers for stakeholders to establish district heating and cooling and use an increased share of renewables in H&C as well as recover excess heat[19].
- Requiring integrated energy planning and regular evaluation of status across all energy sectors and at all governmental levels.
- 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.

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[19] The administrative process of selling low-grade excess heat in some cases require that the industry is approved to be considered an energy production company similar to a company owning a power plant.

- 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 into the long-term.

If the HRE 2050 scenario would be implemented, it would result in the following short- to long-term benefits covering all levels of society:

- Lowered uncertainty of future fuel prices, thereby ensuring a more stable framework for energy-producing companies, consumers on different levels (households, services and industry) and (public) investors.
- Opening of the market for locally-based heat sources, thereby increasing the security of supply and local economic growth, while also making the countries more resilient to geopolitical changes.
- Creation of local jobs – both on a (sub-)country level and in terms of strengthening the competitiveness of European industries nationally and internationally.
- Reduction of the overall energy system cost compared to alternative decarbonisation scenarios.
- Improvement of living standards by ensuring better air quality (locally), while also reducing emissions (globally).

16	**HRE4 shows how an energy system transition can facilitate the integration of at least 87% renewables in total. The HRE 2050 scenario does not hinder but rather enables the possibility of further RE implementation. Contributions from all energy sectors have to support the implementation of such a cost-effective and socially acceptable pathway. The targets should be reflected in directives such as the EED, RED, EPBD and EU ETS.**

The ambitious long-term climate and energy targets of the EU must be translated into adequately ambitious short-term actions through policies that facilitate the energy transition in the electricity, thermal and transport sector. Cross-sectorial, complementary efficiency and renewable targets applied at all governmental levels will be essential for realising a sustainable low-carbon society. Integrated management, knowledge transfer, holistic energy planning tools, open business models with broader forms of collaborations and incentives are some of the most important aspects that need to be carefully addressed, since in most cases the barriers faced are political, regulatory and organisational rather than technical.

By decarbonising the energy sector as a whole, Europe can prepare to embrace the demand caused by improved living standards and ensure a sustainable future for all its inhabitants. However, this requires a strong commitment and bold actions in terms of ambitious energy and emission targets adequate to keep global warming significantly below 2 °C compared to the pre-industrial area.

A common understanding of a joint European roadmap to show the determination, providing effective incentives and ensuring stable framework conditions, would enable investments into the sustainable energy infrastructure needed to speed up the energy transition process, which will itself be beneficial for the public and private sector as well as the citizens of Europe.

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8. Abbreviations

CAPEX:	Capital expendidures
CHP	Combined heat and power
CO_2	Carbon dioxide
COP:	Coefficient of performance
DC:	District cooling
DG ENER	Directorate-General on Energy
DG CLIMA	Directorate-General on Climate Action
DG REGIO	Directorate-General on Regional and Urban Policy
DH:	District heating
DSO:	Distribution system operator
EE:	Energy efficiency
EED:	Energy Efficiency Directive
EPBD:	Energy Performance of Buildings Directive
EU ETS:	European Union Emissions Trading System
GWP:	Global warming potential (factor)
H&C:	Heating and cooling
HP:	Heat pump(s)
HRE:	Heat Roadmap Europe project series starting in 2012
HRE 2050:	Heat Roadmap Scenario for 2050
HRE4	Heat Roadmap Europe 4 (H2020-EE-2015-3-MarketUptake)
ICT:	Information and communications technology
MEP:	Member of the European Parliament
MSR:	Market Stability Reserve (of the EU ETS)
OPEX:	Operational expendidures
Peta:	Pan-European Thermal Atlas
PEF:	Primary energy factor
PV:	Photovoltaics
RE:	Renewable energy
RES:	Renewable energy sources
RED:	Renewable Energy Directive
VRE:	Variable renewable energy