Guidelines for the Energy System Transition

Recommendations for Local and Regional Policymakers - Heat Roadmap Europe 4

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Heat Roadmap Europe

A low-carbon heating and cooling strategy

Guidelines for the Energy System Transition

Recommendations for Local and Regional Policymakers

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Preface

The findings of Heat Roadmap Europe 4 (HRE4) proves that a common and coordinated effort of all citizens 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 nations 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 most European countries 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 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 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 guide their countries to an economically feasible, socially accepted and environmentally needed low-carbon future, in particular from sub-national authorities, urban planners and regional developers, to accept their responsibility and take on their necessary role as leaders towards a fossil fuel free energy system. Cities and regions can prove once more their committment and ability to be key drivers in the low-carbon transition. But more authorities need to engage to accelerate this process and scale up the impact. This is therefore the chance for local to regional decisionmakers to make their voices heard and guide their own municipalities and provinces 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].

This report includes guidelines for local and regional policymakers on the steps of strategic energy planning, as well as key messages for them and other stakeholders to keep in mind during such processes. Together with the corresponding reports for national policymakers [3], this document provides an overview of recommendations on how to multi-laterally facilitate an energy system transition towards decarbonisation by 2050.

Key messages and requested actions from local and regional policymakers

1	**HRE4 shows how using already existing and mature technologies in the heating and cooling sector the total CO_2 emissions can be reduced by 86% compared to 1990. This verifies that decarbonisation in line with the commitments under the Paris Agreement is indeed possible and that the coupling of sectors is essential for the most cost-efficient, economically and socially feasible low-carbon energy system.**

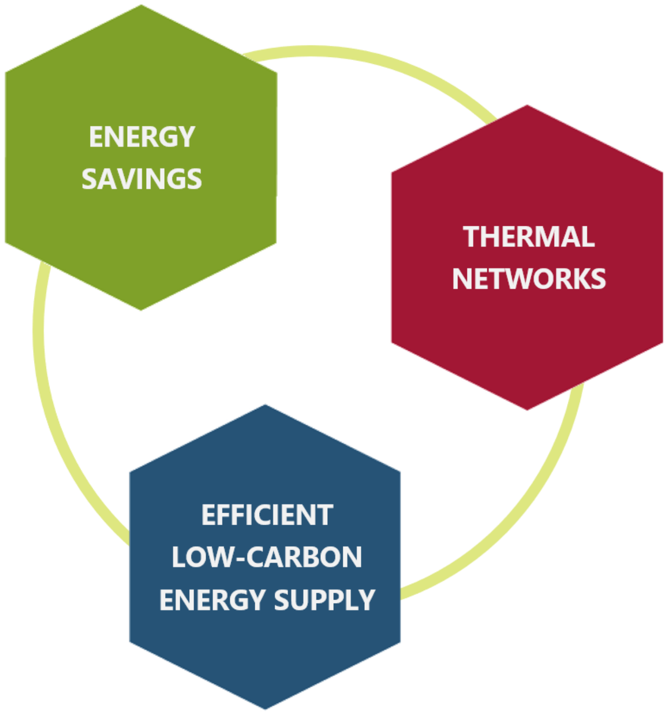
- By redesigning the heating and cooling sector the total costs of decarbonisation can be reduced by 6% annually compared to conventional methods of decarbonisation. In all future scenarios less financial resources are spent on fossil fuels and more on the infrastructure that delivers sustainable energy. This requires clear sectorial targets and policies that facilitate and

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

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 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 decarbonisation goals. Substantial amounts of cost-effective energy savings are ready to be exploited at local and regional scales, and these are key for the successful decarbonisation of the whole energy system.**

- Substantial amounts of cost-effective energy savings are ready to be exploited and these are key for the decarbonisation of the energy system. Related national policies need to reflect the higher, but feasible energy saving targets – typically at least 30% for space heating in buildings. Consequently, also 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.

- HRE has identified an excess heat potential corresponding to more than the heat demand in all of Europe's buildings. Small to large-scale excess heat sources could cover significant shares of the district heat production. 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.

EFFICIENT LOW-CARBON ENERGY SUPPLY

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 to enable integration into the energy system.**

- 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.

- 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.

THERMAL NETWORKS

- Increasing the share of district H&C, in combination with cheap thermal storages, heat pumps and CHP, can stabilise the electricity grid, thus facilitating the integration of renewables when introducing more fluctuating sources such as wind and solar. Therefore, the proposed solutions *enable* significant electrification of the H&C sector rather than excluding it.

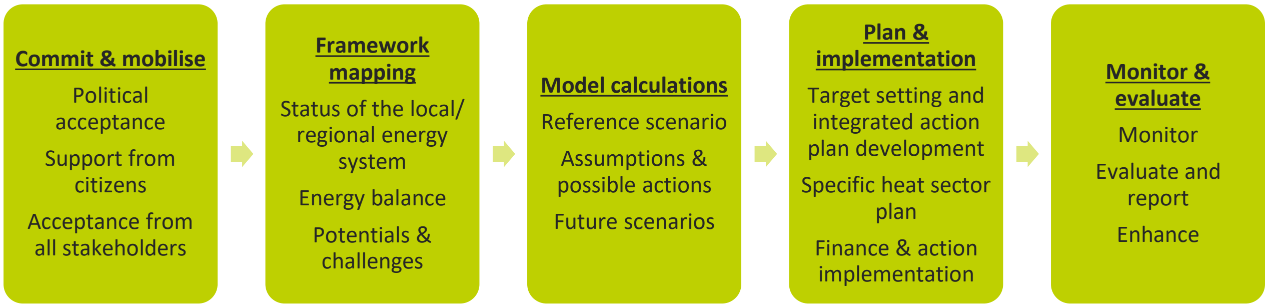
- By means of detailed spatial analyses, HRE shows that on average approximately half of each country's total building heat demand in the residential and service sectors is located in high density areas – though of course there are some countries with higher or lower shares, depending largely on their level of urbanisation. Combining cost calculations with the overall system modelling reveals the scientific evidence supporting the conclusion that more than half of European heat demand in countries can cost-effectively be supplied with district heating in 2050. Furthermore, the spatial components of HRE, in particular its Pan-European Thermal Atlas (*Peta*), which is a valuable online tool freely available to local and regional planners can even pinpoint *where* these new or expanded networks can be located.

5	**HRE4 proves that an integrated approach of all energy sectors delivers the most cost-effective decarbonisation. Consequently, stakeholders of all sectors should cooperate much more intensively, develop business models jointly and implement integrated solutions. Furthermore, local and regional authorities should establish an ambitious framework through their climate and energy targets, provide the platform and facilitate the stakeholder engagement.**

Local and regional authorities may not be directly responsible for most of the emissions in their territory or have the resources or the mandate to directly control them. However, they have the decisive coordination power and access to all actors within a defined area. Engaging the most relevant stakeholder groups in the planning process is particularly crucial at a local to regional level for the successful implementation of any decarbonisation target. The (early) involvement in planning exercises of all those actors who know best the municipal to regional conditions will reveal the beneficial opportunities for their engagement and increase their commitment and acceptance towards supporting its implementation. Key stakeholder groups could cover the following:

- Representatives (technical staff and policymakers) from the local/regional authority, its related departments and pertinent agencies of the municipality/region.
- Local stakeholder organisations (e.g. industry associations, housing companies, consumer/prosumer groups, trade unions, NGOs, etc.)
- Energy suppliers (e.g. electricity, district energy and gas companies) and transport companies.
- Technical partners (e.g. relevant technology manufacturers/installers, craftmenetc.).
- Scientific partners (e.g. universities, applied research institutions etc.).
- Financial sector (e.g. local and national banks, investors, foundations, cooperations etc.).

A general process of strategic energy planning with an emphasis on stakeholder engagement is summarised below. It includes an early stakeholder involvement ("Commit & mobilise"), preparation of stakeholder-specific information ("Framework mapping"), engagement (also) to verify assumptions for the scenario development – ("Model calculations") and writing, approving, mobilising finance and implementing a common strategic plan ("Plan & implementation"), such as a SECAP (Sustainable Energy and Climate Action Plan), integrated Climate Protection Concepts (iCPC) or REAP (Regional Energy Action Plan), followed by a monitoring and participatory evaluation process together with involved parties ("Monitor & Evaluate"). The steps within the integrated energy management cycle are indicated below:



In turn, the benefits will cover all levels of (also) the local/regional community. The arguments for supporting the energy transition include the following:

- Lowering the uncertainty of future fuel prices thereby ensuring a more stable framework for both energy producing companies, consumers on different levels (households, services and industry) as well as public investors.
- Opening the market for locally based heat sources can increase the security of supply and make the countries more resilient to geopolitical changes.
- Creation of local jobs – both directly in the energy system and in terms of strengthening the competitiveness of industries nationally as well as internationally.
- Reducing the overall energy system cost compared to alternative decarbonisation scenarios.
- Improving living standards by ensuring better air quality (locally) while also reducing emissions (globally).

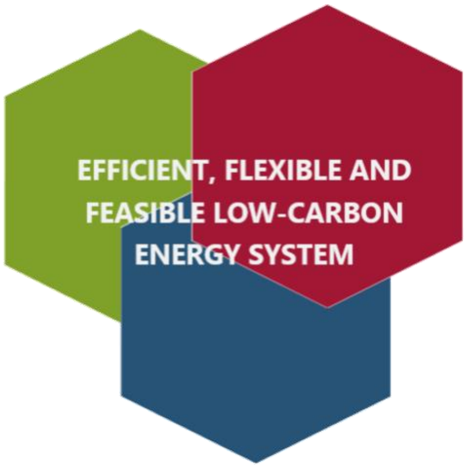
Long-term targets and aligned policies must all facilitate the energy transision towards a sustainable low-carbon society. Integrated knowledge, planning tools, business tools, innovative collaborations and incentives are needed since in most cases the barriers faced are political and regulatory rather than technical.

- A horizontal integration of these 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.

7	**All local and regional sectors should be included in a combined decarbonisation strategy. Long-term targets for combined efforts of all these sectors must include an ambition level corresponding to the local/regional plans, as well as the necessary decarbonisation rate according to the Paris Agreement.**

- More support is also needed to ensure implementation 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.

- National policies 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.



- Regional/local analyses of exisiting options for various consumer types and locations can help identify where there are needs for financial support and necessary interventions to overcome other types of barriers experienced in the local/regional context as well.

8	**Mandatory local and regional integrated energy plans should be aligned with national energy planning, implementation and reporting. Consequently, to maximise their combined impact over time and between energy sectors, sub-national authorities should demand resources in case there are none or these are insufficient to improve the quality and interlinkages of all governmental levels' efforts.**

- The recommended solutions should be promoted in terms of the following (combined) efforts to remove barriers:
  - Establishing continuous energy planning at local and regional levels, including regular evaluation of their status vs. targets to improve the foundation for local/regional authorities and other key stakeholders to make decisions and

implement policies, by analysing various opportunities pathways towards decarbonisation.
- Ensuring a transparent process of any energy transition activities which enables effective dialogue with affected citizens, consumers and other relevant civil society active within the community.
- Gathering additional relevant stakeholders, such as local industries and services (e.g. in the financial sector) to include their business interests in the development of a common decarbonisation strategy.
- Raising general awareness of targets and plans while formulating a common narrative for all citizens that the decarbonisation of our society is something we can and must realise together, something we and the environment around us can prosper from, and – with sufficiently ambitious targets – something we can be proud of.
- Setting up frameworks to improve qualifications and number of skilled professionals.
- Supplying easy to access and low-cost financing schemes for decarbonisation investments.
- Removing administrative barriers for stakeholders.
- Ensuring certainty (predictability) for investors, avoiding "stop-and-go" measures.
- Improving feasibility directly or indirectly (e.g. support/taxation).
- Aligning local and regional policies with each other (also to be in line with national and EU targets) to work together towards the same end-goal.

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[2], 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 *European* 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 at the HRE website. Two outcomes stand out in

[2] 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.

particular as major results building upon the knowledge gathered from the other HRE analyses: the Pan-European Thermal Atlas (version 4) and the energy system scenarios of the 14 HRE countries.

- The Pan-European Thermal Atlas (*Peta*) represents a publicly available online interactive 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:
    - Heating and cooling demand respectively on a hectare level.
    - Renewable heat resource potentials such as geothermal, solar district heating and biomass.
    - Pinpointed potential excess heat sources from conventional sources (e.g. waste incineration, power plants and industrial processes), as well as lower-grade temperatures (e.g. from wastewater treatment or metro stations.
    - Existing and prospective district heating areas incl. cost of establishing networks and indication 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 excess heat and heat demand within a given region.

- The development and findings of the modelled HRE 2050 decarbonisation scenarios, includes methodologies used, different energy demands, different energy supply technologies, their role within the wider energy system and how these compare with alternatives [1]. Though these reports portray data at a national level, they nonetheless provide valuable insights with certain trends being similar, and ramifications affecting the regional and local levels, too. These 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 (EU), 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, economically viable, and can be achieved with proven technologies already used today. The "Heat Roadmaps" representing decarbonisation pathways for 14 EU countries[3] 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* to facilitate the process towards a cost-effective decarbonisation of the heating and cooling sector targeting policymakers at municipal, city and regional levels – oftentimes the first two are jointly referred to as the "local level".

> This report, mainly focusing on local/regional level recommendation, is complemented by similar guidelines addressing the national level, including recommendations from a broader energy system perspective, which may be of interest to the reader.
> *Guidelines for the Energy System Transition – The National Aspects of the HRE 2050 Scenario and Associated Policy Recommendations* [3]
>
> 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]

[3] The HRE4 project especially focuses on those fourteen EU countries with the highest H&C demands: Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Italy, the Netherlands, Poland, Romania, Spain, Sweden and the United Kingdom.

By profiling the energy demands it becomes evident how important the H&C sector is when aiming for a decarbonised energy system. H&C accounts for around 50% of the European final energy demand.

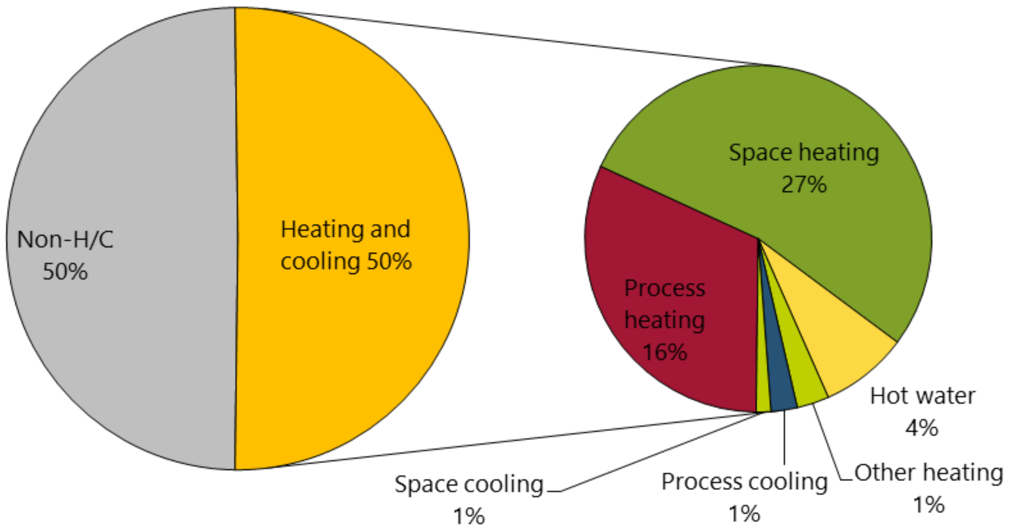

Figure 1. Heating and cooling demand in 2015 in the EU28 by end-use compared to total final energy demand [4].

2. Strategic energy planning

2.1. Overcoming barriers

To some degree, the feasibility of converting from the present fossil-based thermal energy system to a low-carbon alternative does not always seem to have enough incentives (if even positive at all) to realise the transition in practice. Nonetheless, when looking below the surface, the benefits to decarbonisation, including its economic advantages, become more apparent and make it clearer why both natural gas boilers used for space heating and inefficient direct-electric heating are strongly recommended to be phased out.

At a local/regional level, a potential starting point for the above-mentioned example could be to ban the installation of fossil-based H&C supplies in new buildings, and at the same time phase them out in existing buildings. This measure could go hand in hand with support for the shift to alternatives (e.g. financial support for the installation of a HP). In order to minimise the impact of those who have grown dependent on fossil fuels and their associated technologies, economic incentives to shift to alternatives could be implemented simultaneously in order to avoid any increased expenditures for the consumers.

A combination of regional and local strategic energy planning, all aligned to national strategies, is needed to analyse which options make the most sense for various consumer types and locations in cities and provinces. In such a way, identification of specific needs for financial support and where there are needs for help to overcome other barriers.

1	**Mandatory local and regional integrated energy plans should be aligned with national energy planning, implementation and reporting. Consequently, to maximise their combined impact over time and between energy sectors, sub-national authorities should demand resources in case there are none or these are insufficient to improve the quality and interlinkages of all governmental levels' efforts.**

In general, (inter)national fuel prices (including carbon taxation) applied as pure market mechanisms cannot be entrusted with the task of ensuring the energy transition alone, but rather function more effectively when combined with other mechanisms. Other than improving the feasibility of low-carbon solutions (in)directly (e.g. support/taxation) – possibly by applying a local/regional component to emission taxation – and supplying access to affordable financing schemes, many other, non-financial barriers must also be overcome at a local/regional level, for example by means of the following solutions:

- Developing strategic energy planning with the target of local/regional decarbonisation. This should include regular (re-)evaluation of its status, to improve the foundation for decisions and policies, while also analysing the development and identify various opportunities and alternative pathways.
- Aligning local with regional policies to work together towards the same decarbonisation end-goal as national and EU ones should have.
- Removing unnecessary administrative burdens.
- Setting up frameworks to improve the qualifications and quantity of skilled professionals working in related fields within the city/province.
- Formulating a common decarbonisation narrative to help raise awareness among local/regional citizens that the energy transition is something to be realised together, that all (and even the environment) can prosper from, and – with sufficiently ambitious targets – is a goal to be proud of and to which their community can meaningfully contribute.
- Providing certainty and predictability for investors in these sectors, avoiding "stop-and-go" measures, so that they can feel secure in providing funds to cost-effective local/regional initiatives.

2.2. Engaging stakeholders

Strategic energy and climate action planning (SECAP)[4] is a stakeholder-centred approach promoted internationally (e.g. by the Covenant of Mayors). Such an approach is generally recommended for creating long-term and sustainable transitions towards efficient/renewable energy systems, both locally and regionally (as well as taking into account their linkages to other types of climate mitigation and adaptation).

Stakeholder involvement in the planning process is crucial for the successful implementation of actions at a local/regional scale. The involvement of key actors into planning will create a sense of ownership to the actions, thereby increasing their initial acceptance and further commitment towards supporting its implementation.

The stakeholder groups could cover the following:

- Representatives (technical staff and policymakers) from the local/regional authority, its related departments and pertinent agencies of the municipality/region.
- Local stakeholder organisations (e.g. industry associations, housing companies, consumer/prosumer groups, trade unions, NGOs, etc.)

[4] Formerly, SEAPs (Sustainable Energy Action Plan) were internationally often used for municipalities. Meanwhile, the REAP (Regional Energy Action Plan) methodology is still a commonly applied standard.

- Energy suppliers (e.g. electricity, district energy and gas companies) and transport companies.
- Technical partners (e.g. relevant technology manufacturers/installers, craftmenetc.).
- Scientific partners (e.g. universities, applied research institutions etc.).
- Financial sector (e.g. local and national banks, investors, foundations, cooperations etc.).

In some cases, a more formal consortium could be established as a separate entity/project to handle the processes, keep track of the development, organise relevant meetings, possibly even raise funding, update details of the strategy along the way, etc. Expenses for such organisations could be financed (partially) by the municipality/province, through certain grants/projects and/or maybe even sponsored by relevant local/regional companies. Examples of such formal entities include the following in Denmark:

- *ProjectZero* in Sønderborg[5]. In this case the energy plan made towards a 2029 horizon includes representatives from the municipality, DH company, DSO, TSO, consulting engineers and energy-related industries.
- *EnergiPåTværs*[6] / *Gate21* in the Capital Region of Denmark + Region Zealand have developed a joint energy strategy based on partners from municipalities and energy-supply companies. The project is financed by the Capital Region of Denmark and the energy-supply companies, though municipalities supply their own staff time.
- *Energirådet*[7] (The Energy Council) in the Ringkøbing Skjern Municipality, Denmark. The municipality argues that: "An area that imports energy and sends large sums of money out of the area is worse off than an area like ours, producing its own RE and thereby increasing local cash flows benefiting citizens and businesses."

2.3. The process of planning for an integrated energy system

There are three major phases – analyse, act and accelerate - in which stakeholder involvement is not only beneficial, but often a prerequisite for a successful decarbonisation process of the energy infrastructure[8]. The first phase is to analyse the framework conditions, develop a common long-term energy vision for the municipality/region, and identify priorities. This involves the perspectives and contributions from numerous interest groups and stakeholders. Local and regional authorities are in

[5] More information also available in English at www.projectzero.dk.
[6] Danish website: www.energipåtværs.dk. Energi På Tværs can be translated as "Energy Across", which presumably refers to the collaboration across municipal borders, stakeholder groups, etc.
[7] Danish website: www.energi2020.dk.
[8] Based on ICLEI's GreenClimateCities methodology used by local and regional governments around the world for climate mitigation and adaptation.

a suitable position to provide the platform and steer a stakeholder dialogue on a local-specific, integrated energy strategy. Energy strategies co-created in such a way often lead to concrete stipulations even in broader urban or rural development plans, which (ideally) take into account all the key interests and needs of local and regional, public, private, scientific and civic actors.

This phases into the second major step of the cyclic management process, the formulation of a SECAP, iCPC or REAP, the mobilisation of finance and the implementation of the short-term measures, which contribute to achieving the long-term vision. This involves a thorough and continuous collaboration and decision-making from key stakeholders in order to achieve a comprehensive impact within and across sectors.

The last major phase is finalising the process cycle and prepares the initiation of a new one. A participatory as well as technical in-depth evaluation, based on the monitored Key Performance Indicators, often reveals that a repetition of the whole process would be beneficial and needed to achieve the long-term vision and targets. By entering a new cycle, new developments can be reflected in the vision, plans and prioritised measures. The whole integrated assess-plan-implement-evaluate cycle may be updated and repeated as often or frequently as deemed necessary by the city or region to achieve their targets.

Elements in such a planning process could include the following points of stakeholder involvement:

- Kick-off workshop: where local/regional policymakers and other staff have an important role in convincing other stakeholder groups about the ambitions and necessity of a SECAP/iCPC/REAP development.

- Scenario workshop: The most important stakeholders discuss possible future framework scenarios for a transition to a decarbonized municipality/region. The idea is to define the most important assumptions and identify challenges and opportunities under different socio-economic development scenarios.

- Establishment of a stakeholder platform/alliance with thematic action groups
    - The creation of thematic working groups is an approach that has been proven to beneficial for many planning processes, by allowing stakeholders to contribute to covering those areas where they have the most expertise/interest (e.g. energy efficiency in buildings/industries, district energy systems, decentralised H&C, electricity/biogas production, etc.).
    - It may prove useful to generate materials (e.g. handouts) which allow other stakeholders to understand better the specific topics, their (historical) development in the local/regional context, current status, scenarios depicting different decarbonisation pathways and their expected consequences.

- Generally, each working group first provides inputs about long- and short-term objectives within their implementation area, which can be compared to the overall decarbonisation goal of the city/region through scenario calculations.
- Later, each group revises its own objectives, if necessary, and clarifies key responsibilities which will greatly facilitate a successful implementation of actions.
- Often SMART[9] indicators are used, meaning in a practical sense that it is very clear for each proposed measure: who is responsible, when it will be done/due, precisely where, who should benefit/be engaged, how it is funded, how implementation takes place, which monitoring will be in place as well as who is evaluating and reporting towards whom.

These are some recommended elements that support an integrated energy management processes leading to the creation of a common plan, broader political discussions and public acceptance.

One of the main goals of the co-creation of a common vision and plan is that, by its very nature as a collective process, a common platform for a transformative dialogue is established for all relevant interest and stakeholder groups. This contributes to build up a strong communal awareness and strengthens public acceptance of climate and energy decisions that may also be controversially discussed.

Such integrated plans can also serve as a starting point for more detailed sub-plans and actions, which can specify additional thematic objectives and provide a practical basis for decision-making. This may include very relevant topics such as a specific heat plan or an analysis of surplus industrial heat. An integrated energy plan should also analyse and highlight the synergies with other public objectives and strategies in the fields like social welfare, economic growth or smart specialisations.

Below is an example of the major elements laid out as a cyclical process with five steps: Kick-off, mapping, model calculations and plan and implementation.

[9] There are many mnemonic variations of SMART, but quite commonly it stands for: Specific, Measurable, Achievable/Assignable, Relevant/Realistic and Time-bound.

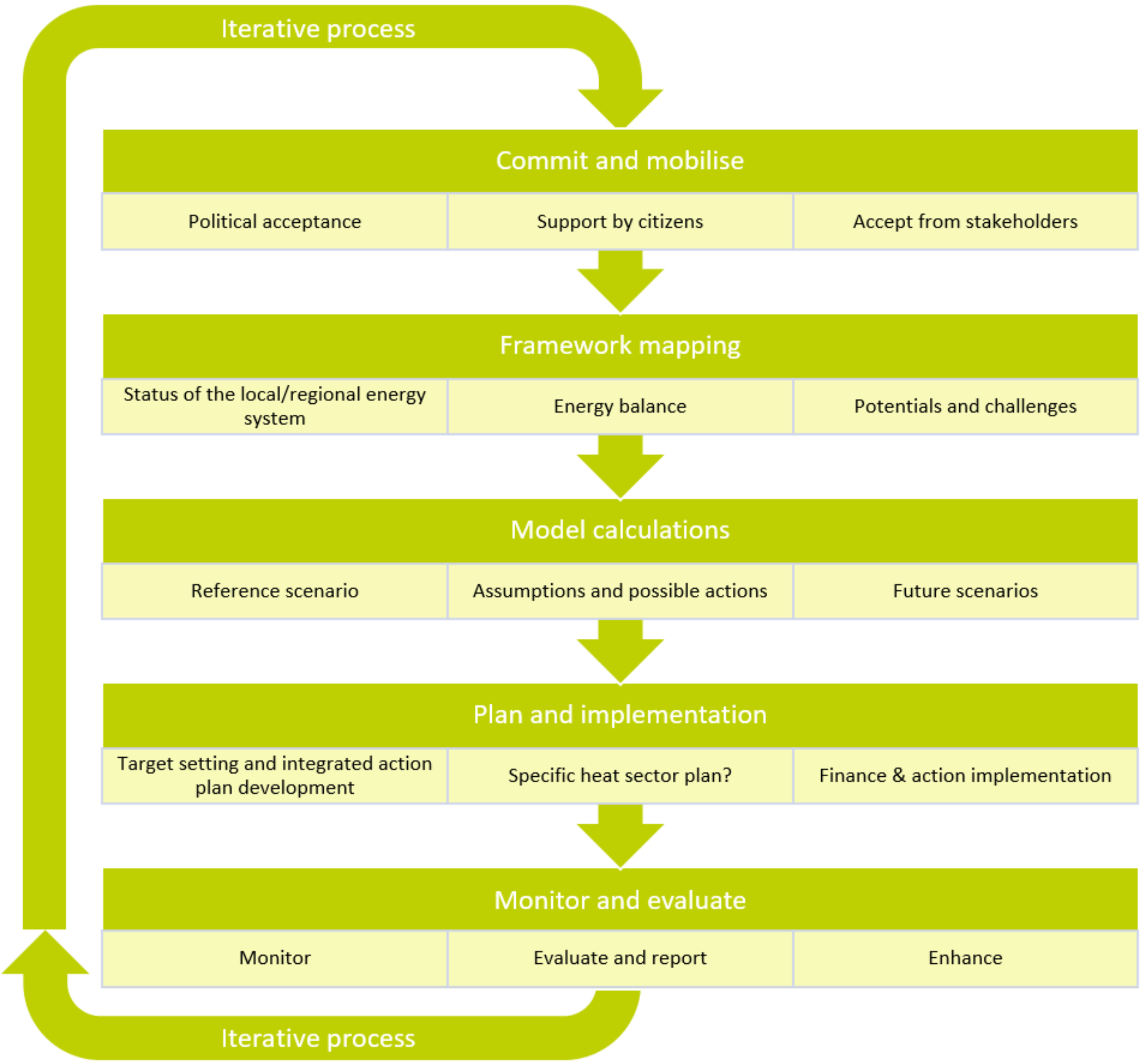

Figure 2. Process of integrated energy planning from early stakeholder involvement ("Commit & mobilise"), preparation of baseline and informative materials ("Framework mapping"), scenario development ("Model calculations"), creation of a common, integrated plan ("Plan and implementation") followed by a monitoring and participatory evaluation process ("Monitor & Evaluate").

2.4. 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 3 below sketches the pillars as well as interconnections between them. One example for each of these pillars (hexagons in Figure 3) is district heating (DH) 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.

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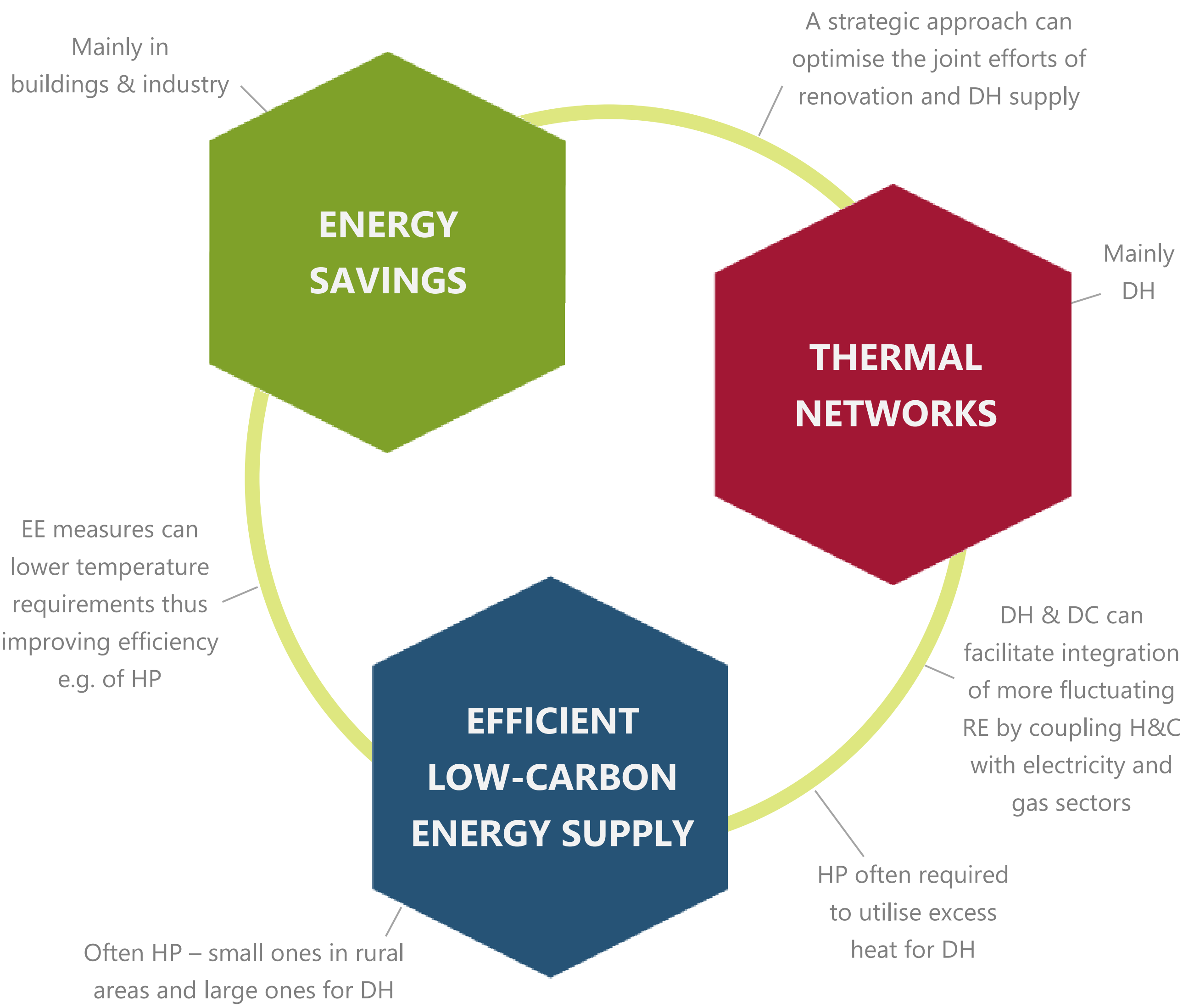

Figure 3. The three HRE "pillars" including examples of linkages between them.

The "Heat Roadmaps" of each of the 14 countries are commonly referred to as the HRE 2050 scenario. These do not aim to reject other optional pathways but rather to show possibilities incl. synergy effects when moving to sustainable future where intelligent choices today will reduce future costs and speed up "the energy transition". One aim is to democratise the debate on how future energy systems can and should be structured.

Detailed energy system modelling has made it possible to consider the connections between demands and supplies for heating, cooling, electricity and transport to optimise the overall system. HRE 2050 shows a 86% decrease in CO_2 levels compared to 1990 while introducing a RE share of 87% of the primary energy supply[10]. In this context it should be mentioned that HRE 2050 does not hinder but rather *enables* the possibility of even further implementation of renewables.

2	**The holistic HRE approach considering jointly electricity, heating, cooling and transport reveals synergies between (and within) these different sectors and shows that decarbonisation is indeed possible with existing mature and market-ready 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 [5,6], decarbonisation can be achieved at lower costs than "conventional decarbonisation"[11] 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

[10] Since HRE4 focus on H&C though the entire energy system is considered, there is a small share of remaining fossil fuels – primarily in transport, industry and flexible CHP.

[11] 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].

reach the same conclusion regardless of priorities: that remains no reason to delay pushing this development forward.

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.

3. Energy savings

3.1. Feasibility of energy savings

Substantial amounts of cost-effective energy savings have been identified and are ready to be exploited at a local and regional scale, being key for the decarbonisation of energy systems in towns and provinces. When targeting energy savings objectives, it should be remembered that the end-goal should not be simply maximising the savings on their own, but rather ultimately the emission reductions. Therefore, the extent of savings targeted should be balanced with other low-carbon alternatives, such as a RE-based supply, as illustrated in Figure 4.

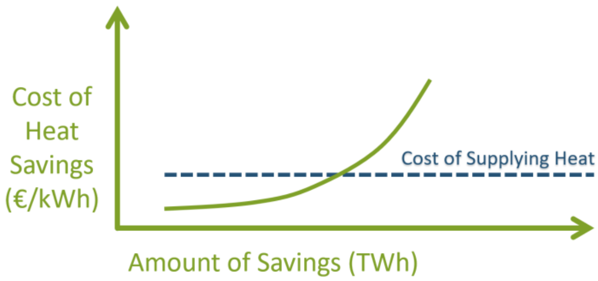

Figure 4. Illustration of the principle that savings should be realised to an extent until it becomes more relevant to apply a decarbonised heat supply.

3	**Energy efficiency is required on both the demand and supply side to achieve cost-effective decarbonisation. Local governments need to address the combination of energy efficiency measures with the decarbonisation of the energy supply.**

To engage consumers, it is recommended as a first step to get a full overview of existing support schemes at all levels, which could be applied for energy retrofitting at the scale of city districts, whole towns, wider regions, etc. If any subsidies have a strong potential for such activities, this information should be clearly presented in a way that can be effectively directed towards the target groups (e.g. private homeowners or local businesses).

Homeowners' potential benefits from energy savings should be highlighted (i.e. addressing the question "what's in it for me?") to help ensure acceptance. This could include the following:

- Increasing the property value (use and refer to local/regional examples if possible).
- Lowering costs for H&C.

- Increasing comfort options.
- Improving reputation (as a role model) within the community reducing CO_2 emissions.

Furthermore, favourable financing and installation options for homeowners and local/regional businesses could be created by facilitating wider-scale initiatives. For example, by initiating dialogues with local/regional stakeholders:

- Banks and other investors to develop other financing options which can be applied in that context.
- Relevant craftsmen, electricians or other installation contractors/companies based in your area to promote their services.

For publicly-owned buildings, a key approach to allocate public budgets towards energy savings could be to highlight the longer-term cost-savings expected, as well as the additional socially-beneficial outcomes from deep energy renovations and an improved indoor climate, such as: a better learning environment in schools, healthier elder homes, a more comfortable working environment in public office buildings, etc.

Regular follow-up evaluations on the progress and impact on local to national legislation and support schemes should be implemented to ensure that the expected targets of the municipality or province are still effectively met.

Considering the fact that once investments have already been made for the so-called "low-hanging fruit" of energy efficiency renovations, the remaining savings potentials in a city/region will usually require higher investment costs, and therefore need to be made even more attractive for end-users to ensure their realisation. Supporting the even deeper thermal renovation of buildings that will anyway undergo a more shallow level of renovation could be an important means of avoiding such missed opportunities.

Stronger price signals (e.g. energy obligation schemes) can prove to be crucial drivers to ensure the realisation of those savings needed to reach local/regional decarbonisation targets. Additional factors which cities and provinces ought to suitably address, and support, include better information-availability (e.g. smart meters), communication approaches (e.g. "nudging" consumers) and the proper education of both the craftsmen providing concrete energy efficiency services and the homeowners/businesses where it is applied.

3.2. Including industries in the decarbonisation process

The extent of attainable H&C savings within a town's/region's industry tends to be more limited than in residential or service buildings. On the one hand, the temperature levels of many industrial processes cannot be altered much. On the other hand, many of these companies often have already implemented those savings measures deemed most profitable to them (at least the "low-hanging fruit").

Nonetheless, remaining energy efficiency measures with relatively small investment costs compared to the reference technology have still been identified. Therefore, local/regional efficiency requirements and financial incentives should reflect the highly cost-effective potential for energy savings still to be found in industrial and service sectors from a socio-economic perspective.

Working towards a circular economy approach could result in an even larger share of overall savings within the whole city/province by recycling resources, both in terms of materials and energy flows. Therefore, building on the process of strategic energy planning described in 2.1 dialogues should be initiated with local/regional industries in order to understand specific industries' energy consumption needs, barriers and limitations. All of this could be the key to unlock new opportunities for them achieve (further) savings, which of course in turn should translate into clear benefits (economic, health, environmental etc.) for the wider community.

In fact, the increasing societal focus towards environmentally-aware industries can offer local/regional authorities another entry-point as an opportunity to promote those industries due to their interest in energy savings by creating a local system [7] for highlighting and communicating the energy savings achieved in these industries. This could be through for example, badges or annual awards for businesses and industries committed to supporting/implementing their own energy-saving achievements.

Figure 5. Badge for shops in the Sonderborg area committed to reduce energy consumption. [7]

Figure 6. Diplomas for different energy savings levels from companies in the Sonderborg area. [7]

Furthermore, it may be worth noting that stricter efficiency requirements related to buildings and industrial processes can prove to be advantageous, since sustainability requirements across *all* sectors tend to stimulate additional improved technologies and products in other sectors as well, thereby increasing their competitiveness (locally, regionally, nationally and globally) in the long run.

Indeed, more and more frequently, customers are demanding more sustainable technologies and production chains for the goods and services they purchase. From the perspective of a local/regional authority, general support of these transitions can be useful, but it tends to be even more effective if the authority itself adopts more sustainable procurement procedures (e.g. purchasing only RE-based energy or using only low-carbon mobility options) to drive the market.

3.3. Energy savings efforts combined with district energy/individual supply

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).

4	**Energy efficiency measures in buildings and district energy can be 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.

Similar to these synergy effects, the example of replacing a boiler with a heat pump shows that a new heat supply system can benefit from energy efficiency measures. Heat pumps run very efficiently in new buildings and in those that have undergone deep renovation (which in some cases can even be a requisite to make the building "heat pump ready"). 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.

[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. Efficient, low-carbon energy supply

4.1. Decarbonising individual heat supplies

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.

5	**Where decentralised heating/cooling systems are more feasible than centralised thermal networks, individual heat pumps should be promoted since they can contribute to decarbonisation and to the flexible integration of renewables.**

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.

The Pan-European Thermal Atlas (*Peta*) is a public online interactive portal to support planners, investors and not least policymakers by presenting and quantifying the possibilities (geo)graphically for all 14 HRE countries in terms of (among other features) a) H&C demand on a hectare level and b) various heat sources to decarbonise the H&C sector such as geothermal sources, solar district heating potentials, 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 Leas-Users [8]

The details regarding the underlying methodology which the maps are based on is described in *Methodology and assumptions used in the mapping* [9]

Similar to section 3.1, it is recommended as a first step to get an overview of any existing national support schemes for scrapping individual boilers and/or installing heat pumps. If any direct or indirect subsidies seem to show some potential for such activities, this information should be clearly presented towards the target group (e.g. private homeowners or businesses with individual boilers). Indirect subsidies could include a tax discount on the share of the bill associated with the labour share of costs for building renovations or installation of RE-systems. Though this could be an incentive for homeowners/businesses to engage professionals within the community, it is relevant to consider if it indeed increases the number (and quality) of energy efficiency/RE measures realised, or if it simply would represent a tax discount for those who would have realised such measures anyway (e.g. tax discounts for those already wealthy enough to afford such investments). Obviously, the aim should be to generate true added-value, meaning to enable those in the community who would not (be able to) install such technologies/measures without support.

Similar to the potential benefits associated with energy savings measures seen in section 3.1, the homeowners' potential benefits from converting to a low-carbon alternative should be clarified i.e. value of property (including an example), lowered costs for heating/cooling (comparison with alternatives), increased comfort and reduced emissions (comparisons with alternatives). Likewise, the more favourable financing and installation options for homeowners can be created by facilitating large-scale operations e.g. in terms of engaging financing options and installers.

To strengthen outreach towards target groups across the city/province, the abovementioned initiatives could be communicated in a variety of ways (e.g. in informational meetings, via social media or through printed materials). It also has proven useful to offer citizens a chance to do site visits to see for themselves how technologies and measures (e.g. a heat pump installation) could appear *in situ* at their own home/business.

How to use HRE's free-to-use *Peta* platform to identify specific geographical target areas for individual heat pumps, or other decentralised RE systems, in the town/region:

1. Open the *Peta* online map as a starting point for this.
2. Use the *Peta* to explore its layers on existing district heating areas, prospective supply districts and heat demand densities.
3. In principle, decentralised heat pumps are most appropriate for areas of low to moderate heat demand density, but especially any which are located outside marked areas of the existing/prospective district heating layers.
4. Mapping all the areas with the largest volume can help create a list of "target areas".
5. Prioritisation of the list of target areas (e.g. by assessing the type of heat supply installations in each area) typically requires on-the-ground knowledge (e.g. from the local/regional authority) to formulate a valid overview of potential HP/RE installations.

4.2. 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.

6	**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.**

4.3. Flexibility from large and small consumers/prosumers must be valued

Introducing many more consumers/prosumers[13] 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.

7	**Policies and price signals should incentivise flexible interactions for prosumers to help balance electricity grids and not just maximise the owners' self-consumption (e.g. via household batteries). Failing to ensure that such systems respond to network balancing demands will end up being counterproductive for the overall energy system.**

It is important to ensure that the recommended (large share of) heat pumps should not purely operate as baseload. Thermal storages can cost-effectively be applied to facilitate the flexibility services requested from the heat pumps – especially when applied in large scale for district heating plants. Individual heat pumps can shift electricity from surplus to times of low demand by storing

[13] 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.

the electricity in hot water tank or in some cases in the building envelope itself. Giving this service a value, would accelerate the technology deployment.

4.4. Excess heat 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.

Two key district energy technologies can increase the potential for using excess heat in a locally or regionally scaled system:

- 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 low-temperature excess heat sources in district heating networks where it is not possible to apply it directly.

When planning for the utilisation of excess heat in local/regional district energy systems, the first step is to establish an understanding of national regulative frameworks regarding such activities, which may include complicated tax considerations related to both the supplier (e.g. an industrial facility) and recipient (DH/DC company). Important components within national frameworks could be, for example, specific excess heat taxes or subsidies for integrated excess heat. Below is seen an approach for screening of excess heat sources in a local area (grey box), followed by a decision flow tree when using the screening results in an actual excess heat-to-district heating process.

Screen for excess heat sources* in your local area:

1. Use the *Peta* as starting point.
    - The *Peta* map can be supplemented with local community knowledge from e.g. local authorities or business associations to strengthen quality of screening.
2. Identify potential excess heat sources.
    - Sort by distance – longer distances require larger investment in transmission pipes.
3. For each potential heat source identified:
    - Contact owner to learn about type of excess heat (e.g. clean hot water, hot waste water, flue gas, etc.), their interest in delivering excess heat and required price level. If price level is above existing heat production price, the excess heat source is not relevant.
    - Gather data about excess heat potential. Screening results should include excess heat energy potential, excess heat temperature levels and availability profile of the excess heat.

* The *Peta* includes geographically pinpointed and categorised excess heat sources such as power production, industrial processes, waste incineration, metro stations, urban waste water treatment plants, data centres and service sector buildings. 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 to investigate the utilisation of this further.

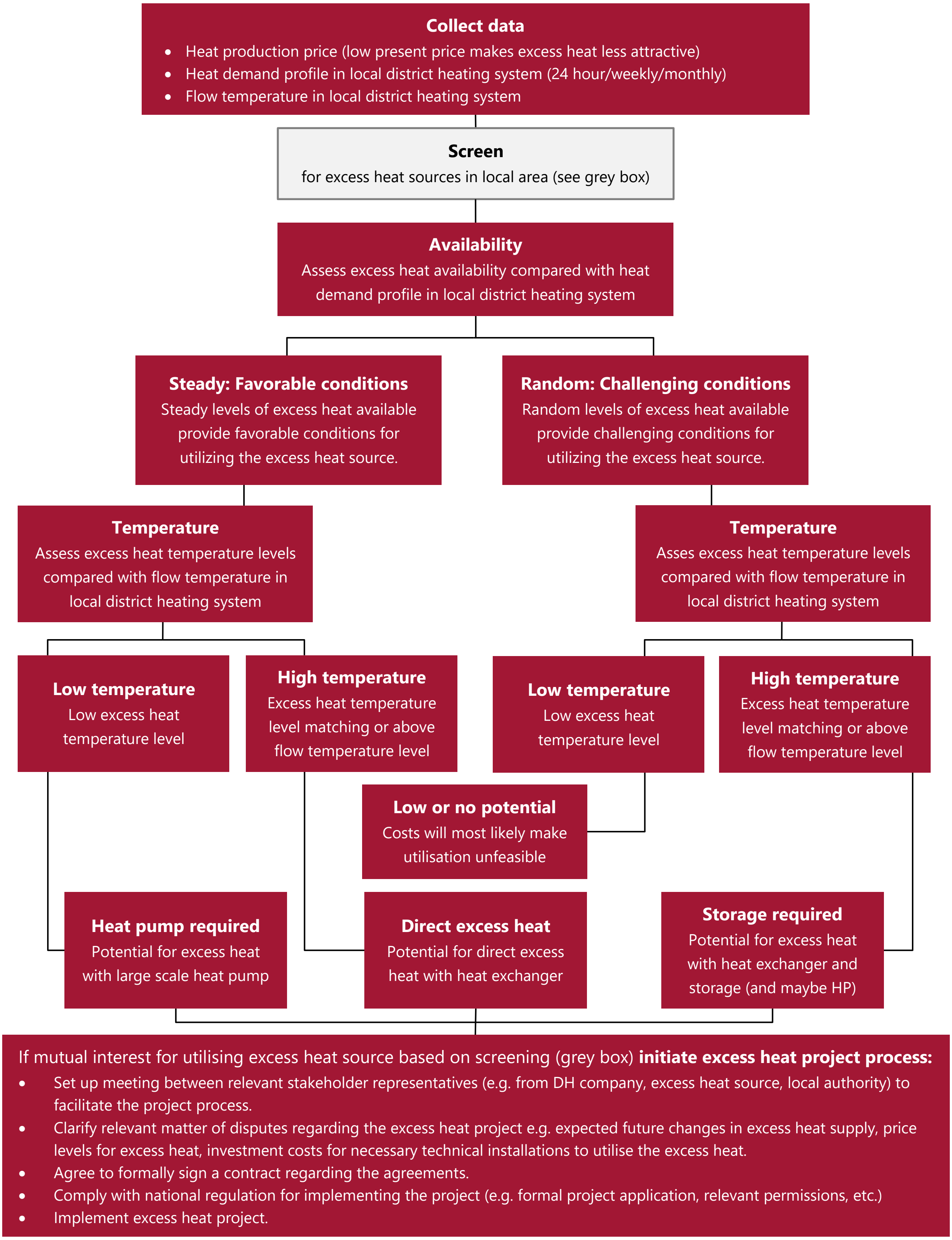

Figure 7. Decision flow tree as an approach for using the screening results in an actual process of utilising excess heat for district heating.

4.5. CHP plays a key role but is not a "one-size-fits-all solution"

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.

In the future, there will likely be an increased demand for biomass as it tries to cover non-energetic gaps of several fossil-based demands of today, such as bioplastics and biofuels for transport. Therefore, the use of biomass in boilers and CHP plants should not be considered as an "easy-fix" solution to cover all of a city's or region's decarbonisation goals. Besides expected scarcity for the non-energy uses of biomass, strict sustainability requirements will certainly be crucial to ensure that it is sourced in a sustainable and effective manner, meaning that it does not contribute to deforestation or other harmful effects. Other combinations than CHP using the heat output from a process should also be considered in integrated energy systems.

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 [10] 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.

4.6. Increasing cooling demand

There is a demand for cooling throughout Europe, not just in the south, but even including (perhaps unexpected) places like Scandinavia. In fact, cooling demand is expected to increase significantly towards 2050 all across European towns and provinces. However, the advantage to this trend comes from the fact that cooling demands often offer a direct opportunity to use the extracted heat from other applications (e.g. district heating), thus representing yet another synergy opportunity, which has already been today applied in several places across Europe.

Renewable cooling should be considered in long-term planning to take into account the obvious synergy options between H&C applications (e.g. feeding excess heat from a cooling process into local/regional DH). A close collaboration with key stakeholders (e.g. cooling equipment providers) could be useful to tap into low-temperature excess heat options.

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.

4.7. Acceptance from citizens

Some degree of local ownership can increase public acceptance of RE installations such as wind turbines. 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 coming neighbours. By owning a share (e.g. of a wind farm) the locals may see it less "intruding". An additional option is to somehow compensate the affected local environment (e.g. by financing non-related local activities thus improving the local area).

An initial dialogue between the project developer and affected future neighbours of the installation can eliminate several prejudices and concerns based on "the unknown". Good experiences have been made by inviting affected neighbours on a viewing trip, where one could see/hear a similar facility.

In the example of onshore wind turbines, a large part of the planning process timeline can be allocated to an initial debate period among key local/regional actors, followed by a later period of public hearings where even individual citizens have the opportunity to contribute with ideas and proposals, as well as have the opportunity to comment through public consultations before the final political decision. For example, citizens may attend political meetingsto meet local/regional politicians, managers, technical staff and project developers to voice concerns/questions. An open and transparent process, and the ability to be heard, will in many cases define if a project is approved or not, since any "loud" uncertainty from citizens will often influence politicians' own concerns and how they vote for or against approving a project.

A few points are worth mentioning in this context:

- It is important to enhance fact-based and proactive communication, since social media (possibly including fake news) represents a growing challenge for municipal/regional planning processes.
- A transparent and inclusive framework for public participation in decision-making processes (public consultation procedures and consultation meetings) should/must be provided.
- Enthusiastic community members, once identified, often function well if engaged as local/regional "ambassadors" from the beginning.
- Initiatives for local/regional communities to increase and sustain acceptance should be developed (i.e. creating relatable "win-win" solutions).

4.8. 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. In this context it should be noted that establishing new natural gas-grids holds considerable lock-in risks.

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, 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.

8	**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.**

4.9. Optimisation and changeover from a fossil-based DH supply

In many (old and new) DH networks, the heat is supplied by fossil fuels, which often gives DH a bad reputation in general among many citizens (at least in certain countries, regions and cities, this is often a challenge). In terms of (big) older inefficient DH networks, a strategy can be to divide the network in zones from a planning perspective. Between these zones the network temperatures can be differentiated. In some zones it may be sufficient with a lower supply temperature. Hence, the return flow in the main DH network can act as supply line for this zone. This means that this specific zone uses lower temperatures in their area while reducing the return temperature in the rest of the DH network thus improving its overall efficiency. The various reasons for the high temperature requirements can be addressed in a stepwise approach until the entire network temperature can be lowered (see section 3.3).

Local and regional, and even national, governments can support evaluation schemes where experienced consultants with knowledge of that context can investigate the possibilities for a changeover from fossil fuels to renewables and excess heat, together with energy savings measures (e.g. renovation of networks). Such screenings could form the basis of informed local/regional decision-making for the DH board members, thereby highlighting their most suitable and feasible decarbonisation options. However, before final investment decisions are made, more thorough calculations would be needed. With such measures, local to national governments could effectively support an energy transition of existing district heating networks without needing to (yet) financially support investments in equipment or infrastructure.

Different options for strengthening the local/regional economy in existing district energy systems may be available, depending on the local to national context. However, based on experiences from a state-financed project in Denmark (where district heating plants screened to be at risk of high heat-price increases are being serviced with free consultation about cost savings from the Danish Energy Agency), four key categories with cost-saving potentials for district heating plants have been identified. Based on a particular plant's current costs in each of the four categories, it may be possible to calculate an actual cost-saving potential (as € per customer per year) to be used as a basis for choosing those actions with the highest impact. The four key categories are:

1. Production and transmission
   An analysis of current costs for heat production (a quick comparison with national levels). If the result is a high cost level, an analysis is carried out to lower costs by either establishing a transmission pipe to a neighbouring DH area or installing new heat production technologies, such as large-scale heat pumps or solar thermal.

2. Customer base potential
   An assessment of potential new customers and marginal cost-savings per new customer connected within a certain DH network area (meaning 0 km of new transmission pipe is needed) and potential new customers and marginal cost-savings per new customer connected in nearby areas (X km of transmission pipe needed).

3. Distribution
   An analysis of the potential for optimising flow temperatures in the DH grid (by a flow temperature controlling system), improving cooling/return temperatures (by identifying DH customers with poor cooling and service visits) and reduced water consumption (by a specific thermography of the DH grid and use of remote meters).

4. Economic and operational cooperation
   An assessment of regular expenditures for the DH plant (e.g. if any regular administrative expense items can be shared with other DH plants) or whether restructuring loans and the depreciation rate could be used to optimise the financial situation.

5. Thermal networks create synergies

5.1. District energy to enable decarbonisation

9	**District energy can play a leading role in the energy transition since it can connect the electricity and H&C sectors, which – with the flexibility provided by thermal storages in particular – enables the integration of more fluctuating renewables such as wind and solar energy.**

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

- District energy in cities, and even across whole regions, is one of the least-cost & most efficient solutions for reducing emissions and primary energy use. Almost all of HRE's country-level heat roadmaps show a strong potential to economically increase the current share.
- 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.
- Beyond its ability to use economies of scale to take advantage of renewables, district energy 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[14]).
- Because district energy is typically not strictly conditional on the availability of just excess heat or any single type of renewable source where circumstances (e.g. fuel prices) may change over time, the feasibility of establishing district energy systems is generally a solid venture and a safe investment.
- 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.
- In case energy-savings targets are not met, district energy can 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[15]).
- District energy 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

[14] For instance, according to studies [11] 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.
[15] 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.

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. Similarly, DC can utilise cooling sources such as lake water or seawater thereby increasing the overall efficiency and reducing the stress on electricity grids, which is a common challenge where individual air conditioners frequently create extreme peak loads during hot periods of the year.

The *Peta* 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 cost per unit of annual sold heat/cold.

In any new district heating system, remote sensors may prove to be a very feasible investment. The additional investment costs are relatively small compared to the potential energetic and financial gains which can be obtained by using real-time data from the sensors to identify errors, to evaluate opportunities for lowering network temperatures, and to analyse the needs for upgrading pipes in case of expansions in a given direction (e.g. from new built environments). Furthermore, long-term data collection enables the improvement and optimisation of the overall system in preparation for a future which will include new technologies and/or opportunities to be integrated based on data-driven decisions.

5.2. Extending DH networks

As a starting point when looking to extend a DH network, it should first be clarified how much heat demand can be connected to the DH network with the existing heat production capacity, before any additional heat production capacity is to be introduced.

If extending the district heating network requires the installation of additional heat production capacities, multiple options and their associated costs should be thoroughly investigated. Any extension is typically only considered where installation of new heat production capacities can be implemented without subsequently increasing the heat price for existing consumers.

Potential areas for extending DH networks can be identified by using the steps below.

1. Screen for potential expansion areas (see guidance in the box below)
2. Preliminarily calculate the connection shares required to ensure an economic balance in each potential (new) area.

3. Create a strategic extension plan for DH, based on knowledge from the above steps, which should address the specific extension areas and potentially an order of prioritisation.
4. Based on the areas prioritised, target groups in potential areas (typically private homeowners or businesses) should be contacted to explain the possibility, and reasoning, for DH to assess local/regional interest in connecting to DH.
    a. This can be done in various ways (e.g. informational meetings, letter campaigns, door-to-door interventions, etc.)
    b. Information should be prepared ahead of time (perhaps as printed materials) to address potential questions from target groups. For example, answering common questions about: investment costs to connect, expected heat prices, time plan, foreseen inconvenience, any required installation within the house/business, etc.
    c. It may be worth considering the possibility to increase incentives for converting to DH by making attractive deals for new customers to connect to DH networks. Reduced revenues from such discounts can be mitigated by an increased number of customers.
5. Choose which areas to extend DH and start the specific project technical (and financial) processes, including detailed technical calculations, dimensioning and plans, project application, permits, etc.

How to use HRE's free-to-use *Peta* maps to assist in the screening of potential areas to extend district heating networks:

1. The *Peta* online map acts as a starting point for this task.
2. The most useful map layers are those showing existing district heating areas, prospective supply districts and heat demand densities.
3. Identify the existing DH network(s) to be considered in the screening.
4. Identify prospective supply districts (i.e. those areas which show strong potential for DH – visually depicted with the colourful heat demand density layer[16]) located outside the selected DH area(s) within a potential distance for establishing a transmission pipe to the existing DH network. This can be measured within *Peta* using the ruler-like measurement tool on the upper-left corner of the map). A general rule of thumb is that longer distances often require higher heat demand densities to be economically viable, but there is, technically-speaking, little reason that long-distance DH systems should always be avoided. In fact, a case in point is found in southern Sweden, where Helsingborg is connected (through Landskrona) to Lund 50 km to its south to form a regional DH grid.
5. Check for additional areas with decent heat demand densities[17] located only a short distance (e.g. 2 km or less) away from the selected existing DH area(s), but outside prospective supply areas.

[16] In many cases they overlap with already existing DH.
[17] When considering new DH 120 TJ/km^2 or more is typically very cost-effective, but much lower densities may prove feasible when considering the connection to a nearby larger network.

6. Map all the identified areas, their distance to existing DH connection points and the volume of heat demand density to create a list of potential extension areas.
    a. It may be worth first prioritizing either the closest areas to the existing DH area or those areas with the largest volume (i.e. highest heat demand density and suitable size).
    b. The list of target areas could be further qualified by assessing the type(s) of heat supply installations found/feasible in each area – this knowledge would best come from local/regional experts.

5.3. Establishing new district energy networks

In areas with high H&C demand densities located too far away[18] from existing district energy networks, it may be more relevant to investigate the possibility of establishing a new district energy plant and network instead of trying to connect it to an existing one. This requires in-depth knowledge regarding the specific national regulations, and any relevant local and/or regional norms as well, about establishing new H&C production plants supplying public grids. It may prove useful to contact other (possibly newly-established) district energy plants in (nearby parts of) the country to learn about current processes. A general plan for how to analyse and set up a district energy network can be seen below in Figure 8.

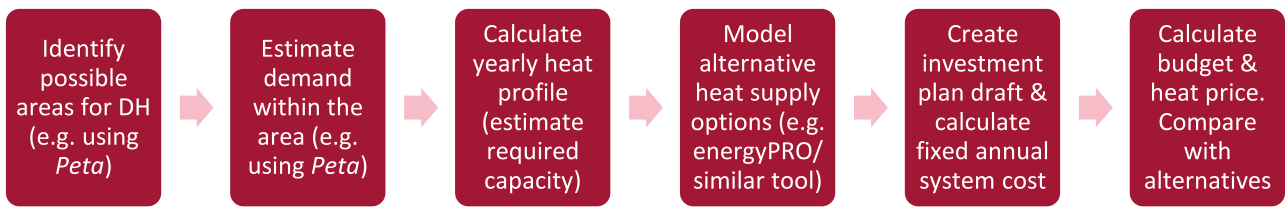

Figure 8. Illustration of a potential screening procedure for (new) district energy [12].

In general, the two most important economic parameters when establishing a new district energy plant and network are to secure low H&C production costs and a high connection share. H&C production costs are dependent on the type of technology to be installed. This decision should be based on an analysis of the relevant production solutions available in the area such as (industrial)

[18] This must be analysed for the specific area, as it varies considerably due to the local/regional context (especially heat production prices and capacities within a given DH network). A conservative rule of thumb is that 20 km away from existing DH networks rarely will be economic viable, though there are still exceptions to this rule (e.g. the 50 km Swedish example mentioned before of Helsingborg-Landskrona-Lund).

excess heat, large-scale heat pumps using various H&C sources (waste water, sea/lake water, groundwater, geothermal or air), solar thermal, etc.

It is recommended to ensure that those buildings with large heat/cold demands will indeed connect to the new district energy network so as to ensure that a base income from thermal energy sales and basic resilience of the plant being feasible from the very first day of operation. Some national regulations include a possibility to make connection to district energy network mandatory. Such regulations can be used to secure high connection share in the selected area even before construction begins. Nonetheless, even when such regulations are in place, forcing customers to connect should still be applied cautiously (and best only after public consultations and acceptance) when there is a high certainty that a low(er) heat price will result for the new district energy customers.

When mandatory connections are not regulated, or this approach is not chosen to be enforced, voluntary connection should be proactively promoted through preliminary contact with homeowners, businesses, real estate developers, etc., and perhaps even gathering signatures from potential customers expressing their interest/commitment to connect to district energy. This can be achieved in different ways, such as informational meetings, letter-campaigns, door-to-door interviews, etc. It is recommended to prepare relevant printed materials in advance to address potential concerns from target groups (e.g. about investment costs to connect, estimated heat prices, time plans, foreseen inconveniences, required installation within houses/businesses, etc.), as well as highlighting the benefits which connected consumers might expect, such as the following (see also Figure 9):

- A building's substation can be very compact (meaning saving space possibly otherwise occupied now by a boiler) and is easy to regulate (so no need to fear a loss of control).
- There are no smoke, emissions or noise from the installation (as opposed to many alternative options, such as oil boilers).
- The heat production can be effectively decarbonised (leading to an energy footprint which consumers can be proud of).
- District energy systems create multiple jobs directly benefitting the community/region (e.g. construction, installation experts, operation and maintenance of the plant, network and substations).
- There is almost no need of maintenance from the side of the consumer. Service of the substation and surveillance/repairs of any leakages is already included in the annual fee.
- District energy, largely due to economies of scale, are typically able to off lower costs of H&C compared to decentralised alternatives.

What is most important to engage consumers differs depending on country/region, but in the end often the last bullet point above is the most critical to emphasise. Therefore, in some cases it may even be advisable to consider the possibility of introducing further financial incentives for connecting to the district energy grid, by making attractive deals for new customers to achieve/ensure a high connection rate. This might mean some kind of a subsidy or tax break to join, but it does not have to be the case. For example, another option could be to simply spread the cost to consumers over a longer period of time – e.g. by (transparently) inserting part of the installation costs already into their heating bills – thereby avoiding a single, large up-front connection fees for consumers[19]. Regardless of the approach, it tends to be quite important that consumer tariffs clearly and accurately reflect the fixed part of their annual system costs. Doing this not only helps to ensure that there is no mismatch between expenses and revenues for the company, but also sensitizes customers to understand that proper H&C services have a distinct value.

In terms of consumer contracts, it may prove useful if they are defined in such a way that they only come into force if a certain share of the area (e.g. number of households/businesses or volume of H&C demand) officially agrees to connect. Therefore, the district energy company can actually withhold the right to cancel the plans for establishing a network until a certain threshold is ensured. This approach helps to avoid risks for investors while consumers will not be stuck with higher prices, in case insufficient numbers decide to connect after the network has been built[20].

Figure 9. Example of printed material from Danish DH company highlighting the benefits of DH and offering customers the chance to connect via a subscription with a fixed annual cost, instead of paying for installation costs, thereby avoiding high investment costs upfront for customers (English explanations have been added onto it for clarity.)

[19] Further info on up-front investment cost barriers and this kind of solution is found in the HRE4 report "Business Cases and Business Strategies to Encourage Market Uptake" [13].

[20] An example of documents used for this approach can be found in annex 3, 4 and 5 of [12].

5.4. Ownership structure and stakeholder engagement

A core point is the ownership structure of the district energy plant, where it is often recommendable to have a local/regional governing authority involved directly or indirectly (e.g. as full or partial owner), since it will often require significant efforts of community engagement to successfully establish a district energy company and its related infrastructure. In any case, it is important to have continuous communication between various stakeholders (e.g. informing affected citizens about plans, expected timeline and reasons for road work related to H&C services).

Regarding some level of public/community ownership of these companies, when it comes to ensuring that a district energy supply is decarbonised (e.g. to fulfil a municipality's SECAP or a province's REAP), having an agreement in place other than a traditional contract-based approach may be advantageous. In many cases, the way to realistically ensure a "green transition" is by gathering relevant government authorities, the district energy company and other key stakeholders to work together to develop a strategy towards (a certain) RE/CO_2 target, even if not as formal a document as mentioned in section 2.2. The benefit for municipalities/regions is that having the companies and others "on board" means that all are working towards the same goal, and, for example, not only the energy demands of *public* buildings are decarbonised. The benefit for the district energy companies is that their role is also somewhat ensured in the city's/province's future energy mix (e.g. a continued/extended need for district energy is ensured, as long as it lives up to the agreed RE/CO_2 targets), thereby providing long-term certainty of investments.

Often a municipality, or sometimes even a regional authority, owns all or part of the district energy company itself (i.e. production plant and network). In many countries privatisation of formerly-public-owned district energy companies has been carried out, but also in many of these, this approach has not proven to lower consumer costs. Public or community-owned district energy companies tend to focus less on a fast return of investment, but rather on maintaining a solid foundation for continued operation and low prices for customers. Therefore, some communities and/or municipal/regional authorities try to buy back previously privatised district energy companies in order to regain control (e.g. in terms of the choice of investments and targets, such as RE shares of the supply). In any case, the most suitable ownership model for a given town or province will also depend greatly on national framework conditions, the history of district energy in the city, region and/or country, public acceptance or lack thereof, the experience of public/community/private companies to provide services successfully, etc.

6. Conclusion

When planning for a low-carbon future, it is evident that the entire energy system must be taken into account so as to ensure that a decarbonisation focus in one place does not simply lead to increased emissions somewhere else. The same level of consistency should be applied across all local and regional policies, which should then be considered jointly to ensure that they are aligned with national targets, e.g. to make sure they are in line with a country's commitments to the Paris Agreement. Local and regional authorities can act as the catalyst of the energy transition by bringing various stakeholders together to combine their efforts on a common decarbonisation strategy.

It is critical that barriers hindering the energy transition is removed at all levels in order to ensure that local to national stakeholders successfully overcoming one barrier are not immediately thereafter blocked by others. Periodical reviews and – if necessary – changes should be formalised accordingly in those policies, administrative processes, etc. which either now cause a particular barrier or could facilitate overcoming it. Carbon taxation and other (in)direct incentives at local/regional levels should complement those properly ensured at national levels to encourage the full achievement of energy savings, the smart integration of renewables and the implementation of efficient energy system infrastructure where most suitable.

Investments in such infrastructure to decrease fossil fuel demand via district energy networks, heat pumps and energy savings will result in the following benefits covering all levels of society:

- Lowered uncertainty of future fuel prices, thereby ensuring a more stable framework for both energy-producing companies and individual consumers/prosumers on different levels (households, services and industry), as well as for (public) investors.
- Opening of the market for locally-/regionally-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 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).

10	**All sectors should be included in a combined decarbonisation strategy. Long-term targets for combined efforts of all sectors must include an ambition level corresponding to this end-goal.**

Though the responsibility of creating the framework which will facilitate the decarbonisation of the energy sector as a whole lies first and foremost with the decision- and policymakers at a national level, it is also the duty of local and regional authorities to make sure that national actors properly establish/maintain this framework, and that they themselves enact mechanisms which complement it. By achieving this, the country as a whole can better ready itself to embrace also increased demands caused by improved living standards and ensure a sustainable future for all inhabitants. However, this requires at all levels a stronger commitment and bolder actions in terms of truly ambitious energy and emission targets, and an intelligent choice of pathways accounting for all the demands of tomorrow. For this reason, HRE's national scenarios and Heat Roadmaps are key tools to facilitate more viable predictions and suitable solutions to address them, and still are quite useful as guidance even for sub-national levels' decision-making processes.

A common understanding of national roadmaps, and their local/regional implications, to show the determination, providing effective incentives and ensuring stable framework conditions will no doubt boost energy infrastructure investments and speed up the energy transition process, thereby benefitting both businesses and private citizens. Municipal, city and regional policymakers are therefore strongly urged to fully consider all the proven opportunities, tools and recommendations offered by HRE4 and act accordingly to make sure that each town and province contribute positively to national and international initiatives.

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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
DH:	District heating
DSO:	Distribution system operator
EE:	Energy efficiency
EU:	European Union
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
iCPC:	integrated Climate Protection Concepts
OPEX:	Operational expendidures
Peta:	Pan-European Thermal Atlas
PV:	Photovoltaics
RE:	Renewable energy
REAP:	Regional energy action plan
SEAP:	Strategic energy action plan
SECAP:	Sustainable energy and climate action plan
VRE:	Variable renewable energy