Common Implementation Roadmap for Renewable Heating and Cooling Technologies

European Technology Platform on Renewable Heating and Cooling

RHC Renewable Heating & Cooling

European Technology Platform

Co-funded by the European Union

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Renewable Heating & Cooling
European Technology Platform

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TABLE OF CONTENTS

EDITORIAL

It is widely known that Heating and Cooling is responsible for almost 50% of the final energy demand in Europe. The extensive use of Renewable Heating and Cooling technologies is therefore, in combination with a strong increase in efficiency, crucial to secure Europe's energy supply in a sustainable way. Following the publication of the Strategic Research and Innovation Agenda for Renewable Heating and Cooling Technologies (SRIA) in 2013, the RHC-Platform developed this Implementation Roadmap based on the more detailed Roadmaps of its Solar Thermal, Biomass, Geothermal, and Cross-Cutting panels.

The Roadmap describes the top priority research themes and value chains with the highest impact on the societal challenges in Europe until 2020. It is obvious that having seen the potential of Renewable Heating and Cooling technologies neglected for decades, there is a strong need to significantly increase the research budgets for the sector. The panel Roadmaps and this Common Implementation Roadmap provide a good overview of the topics and the budgets needed.

Future energy systems will be far more integrated than they are today. The Heating and Cooling and the electricity sectors will be interconnected through combined heat and power plants, heat pumps, and power to heat technologies. Thermal energy supplied by solar thermal, biomass and geothermal will remain dominant in the Heating and Cooling sector due to high efficiency and cost competitiveness, especially by covering the heating demand in winter time. The research and development actions described in this Roadmap will enable the RHC-technologies to assume its important role in the energy sector.

Gerhard Stryi-Hipp
President of the European Technology Platform on Renewable Heating and Cooling

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Lead author of the Roadmap

EXECUTIVE SUMMARY

Research is one of the cornerstones for the further development of RHC technologies and their widespread use. New solutions, the adaptation of existing ones for new applications and markets, or just critical measures to demonstrate, standardise, combine or popularise technologies which already exist, will contribute to an accelerated deployment of RHC in the EU in the context of the 2020 milestones. However, there is an inherent complexity in developing Renewable Heating and Cooling Technology Roadmaps due to the variety of ways heat can be produced, transported, stored, and delivered, and the many different profiles of end users, as well as the difficulty to draw exact boundaries between them.

This need of clarification and identification has been one of the paramount goals of the RHC-Platform during the past years of activity and is summarised in Chapter 2 and Chapter 3. Three main aspects are considered: the identification of technologies which ought to be developed as a priority based on the work of the four panels, the relationship between the different Research & Innovation (R&I) priorities with these cross-cutting technologies and, finally, how RHC research is addressing the needs of the different users and demand profiles that exist in the EU.

As noted in the European Commission's Energy Roadmap 2050, there is no doubt that RHC is vital to the decarbonisation of our energy sector. Decarbonisation should not be regarded as a burden, but rather as an opportunity for Europe's sustainable growth and industrial renaissance alike.

The significant role that RHC can play in the achievement of this goal is based on three main pillars which are comprehensively analysed in Chapter 4. These pillars are the RHC contribution to the security of our energy supply (reducing our fossil fuel imports in doing so), to a more cost competitive and less price-volatile energy market, and, last but not least, to a reduction in the emission of pollutants by decreasing our consumption of fossil fuels, leading to a better urban environment.

Finally, Chapter 5 addresses how private investment - critical in decarbonising the Heating and Cooling sector - could be stimulated. A key message here is that not only it is necessary to strengthen R&I investments and increase the budget for R&I projects, but also to strengthen the market deployment policy for RHC technology.

1.

INTRODUCTION:

From Vision to Implementation

❶ INTRODUCTION: FROM VISION TO IMPLEMENTATION

1.1 THE RENEWABLE HEATING AND COOLING PLATFORM (RHC-PLATFORM)

The Common Implementation Roadmap is the latest in a series of publications from the European Technology Platform on Renewable Heating and Cooling (RHC-Platform), which have led RHC technologies from a vision towards an implementation plan over the last few years.

Endorsed by the European Commission and boasting a strong membership of over 800 RHC sector stakeholders from industry, research, and the public sector, the RHC-Platform represents all renewable energy technologies for Heating and Cooling from all over Europe.

The RHC-Platform's mission is to provide a framework for stakeholders to define and implement an innovation strategy to increase the use of Renewable Energy Sources (RES) for Heating and Cooling, and to foster growth and market uptake.

The RHC-Platform consists of four Technology Panels which include all Renewable Heating and Cooling sources and technologies. Acting under the guidance of the respective Steering Committees, each Panel is responsible for collecting and developing stakeholders' inputs from the respective sectors.

The scope and operational structure of the RHC-Platform ensure the balanced and active participation of the EU stakeholders at the appropriate levels, including all interested industries, scientific research organisations, public authorities and civil society.

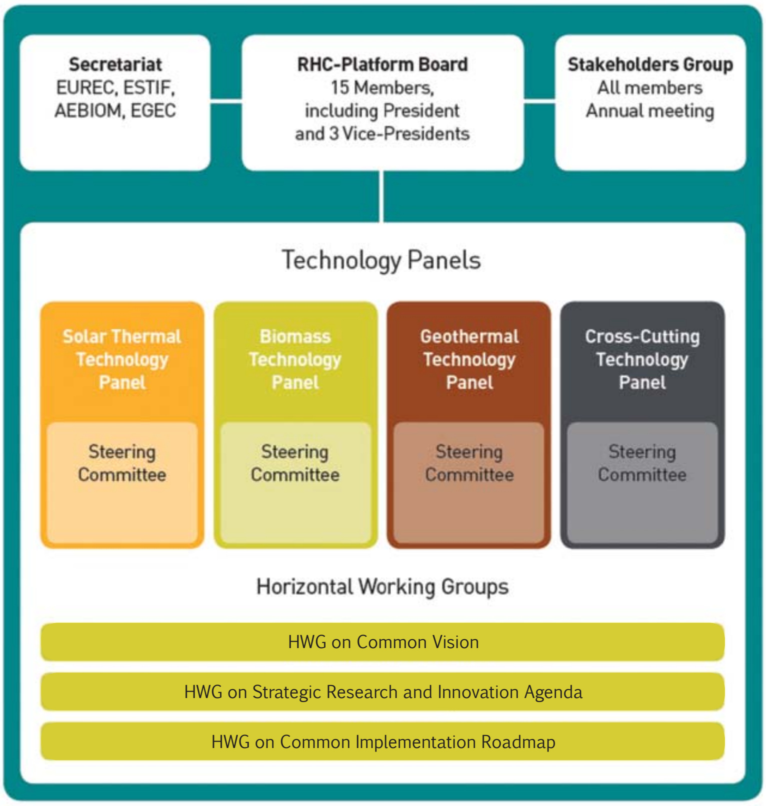

Figure 1: Current structure of the RHC-Platform

1.2 THE FOUR RHC TECHNOLOGY ROADMAPS: THE PILLARS OF THE RHC COMMON IMPLEMENTATION ROADMAP

In 2014, the four RHC panels (Solar Thermal, Biomass, Geothermal, and Cross-Cutting) finalised their own Technology Roadmaps, investigating the Strategic Research Priorities for each technology. Building on the efforts of each panel, the 'Common Implementation Roadmap' aims to present an integrated vision of the research implementation priorities.

The Common Implementation Roadmap pinpoints the specific measures for Renewable Heating and Cooling as a whole and considers how each technology's needs fit together. It analyses the benefits of RHC for Europe, for example in terms of energy import reduction and job creation, and it looks at how investments in the RHC sector could be encouraged.

1.3 THE PREVIOUS ACHIEVEMENTS

Launched in May 2011, the **'Common Vision for the Renewable Heating and Cooling Sector in Europe'**[1] was the first publication of the RHC-Platform. The study identified the huge potential of the Renewable Heating and Cooling technologies, which could satisfy up to 100% of the Europe's Heating and Cooling demand by 2050.

In 2012, the four Technology Panels of the RHC-Platform developed their **Strategic Research Priorities** (RHC-Platform, 2012).[2] These studies provided stakeholders with a structured view of the technological potential of all RHC technologies. A comprehensive set of research, development and demonstration priorities were defined to support the decarbonisation of the Heating and Cooling sector.

In 2013 the RHC-Platform launched the **Strategic Research and Innovation Agenda for Renewable Heating and Cooling (RHC-SRIA)**[3], a milestone publication which summarised the research priorities of the individual panels and, for the first time, provided a comprehensive overview of the short, medium and longer term R&D needs of RHC technology.

The RHC-SRIA identified the state-of-the-art, the research objectives and the critical targets (e.g. in terms of performance increase / cost reduction) required to realise the potential of RHC technology. It also offers recommendations for research, development and demonstration funding in the timeframe of 'Horizon 2020' and in line with the wider EU 2030 Energy and Climate Framework.

The implementation of the SRIA technological and non-technological priorities will be crucial in formulating a strong push for a renewable energy paradigm, providing European citizens with affordable and sustainable Heating and Cooling.

In 2014 the four panels published their **Technology Roadmaps**[4]. These documents provide detailed implementation plans for research actions until 2020, which are prioritised to generate the highest impact and societal benefit. The roadmaps also estimate the public and private financial resources necessary for the achievement of their goals.

The Common Implementation Roadmap takes over from the work done by the four individual Technology Roadmaps and explores the interconnectivity of the different RHC technologies.

1 RHC-Platform (2011), Common Vision for the Renewable Heating and Cooling sector in Europe: 2020-2030–2050. Available at http://www.rhc-platform.org/publications/

2 Available at http://www.rhc-platform.org/publications/

3 RHC-Platform (2013), Strategic Research and Innovation Agenda for Renewable Heating and Cooling. Available at http://www.rhc-platform.org/publications/

4 Available at http://www.rhc-platform.org/publications/

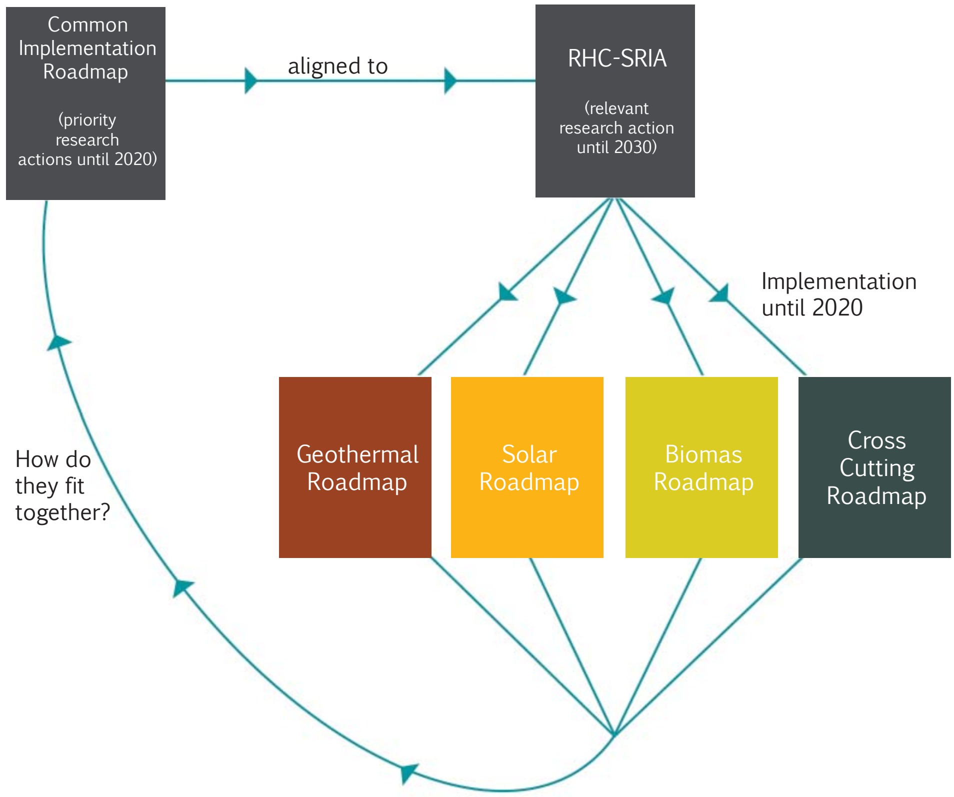

Figure 2: Relationhip between SRIA, the four Technology Roadmaps and the Common Implementation Roadmap

2.

A COMMON TECHNOLOGICAL ROADMAP TO 2020:

Clustering of the 4 Technology Roadmaps

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2 A COMMON TECHNOLOGICAL ROADMAP TO 2020: CLUSTERING OF THE 4 TECHNOLOGY ROADMAPS

This Chapter intends to highlight the main aspects of the Technology Roadmaps produced by the four panels of the RHC-Platform, individually representing solar thermal, biomass, geothermal and cross-cutting technologies. Our approach is to provide a general view of those technologies which, according to the ideas developed by the different panels, deserve prioritised attention in the 2014-2020 timeframe. For more details about the many proposed Research and Innovation actions summarised here, the interested reader is strongly on istead of about advised to consult the individual Roadmaps.

2.1 SOLAR THERMAL TECHNOLOGIES

Solar thermal energy has a high potential for Renewable Heating and Cooling in Europe, but today only generates about 20 TWh of heat, which corresponds to less than 1% of the heat demand in Europe. To unlock its potential, research and development is needed to reduce costs, improve user-friendliness, and extend the type of applications. With these actions the sector aims to provide solutions to critical societal challenges. A focus on the three following 'pathways' is suggested for the technological development of solar thermal energy until 2020.

2.1.1 Solar Compact Hybrid System (SCOHYS)

Solar Compact Hybrid Systems (SCOHYS) are compact heat supply systems including both a solar heating source and a backup heating source (based on bioenergy, heat pumps or fossil fuels), with a solar fraction of at least 50% in the case of domestic hot water (DHW) SCOHYS systems, and with a solar fraction of at least 25% in typical Central European applications in the case of combi SCOHYS systems (delivering both domestic hot water and space heating). The main objective of the SCOHYS roadmap pathway is the reduction of solar heat costs by 50% with reduced space requirements and installation time. In addition, improvements in reliability and performance are expected. Research and Innovation (R&I) actions should focus on three areas: SCOHYS in single family homes (DHW and combi systems), SCOHYS for DHW in multi family homes, and SCOHYS as combi systems in multi family homes.

The R&I actions involve research on individual components and address how these can be combined. Additionally, the roadmap identifies actions in the field of enabling technologies, standards and quality, socio-economic framework, and legal and administrative aspects. The SCOHYS roadmap pathway and its sub-tasks are shown in Table 1.

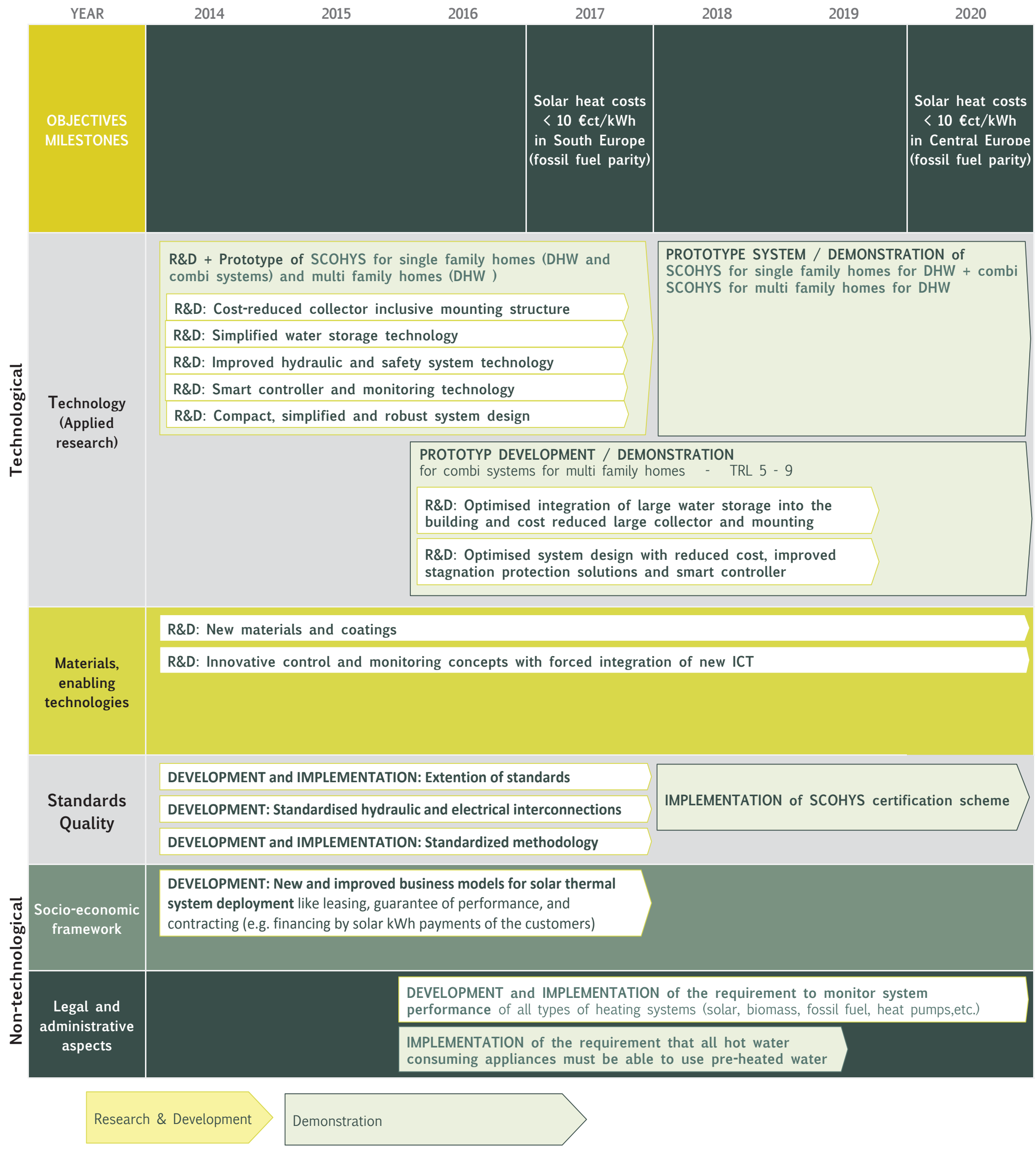

Table 1: Roadmap pathway for Solar Compact Hybrid Systems (SCOHYS)

2.1.2 Solar-Active-House (SAH)

The Solar-Active-House (SAH) provides a solution towards achieving the goal of the 'nearly zero-energy building'. With a good, but not high-end insulation, the energy required to meet the residual heating demand can be provided by solar thermal energy. The SAH roadmap pathway focuses on cost reduction as well as the optimisation and standardisation of the technology for Solar-Active-Houses with about 60% solar fraction; the aim is to develop Solar-Active-Houses as a competitive solution for nearly zero-energy buildings, as required by the European Union by 2020. 'Solar fraction' is the share of solar thermal energy in the overall heat demand for DHW and space heating.

The objectives of the SAH roadmap pathway are to develop the concept so that it can be used by the whole construction sector to achieve a nearly zero-energy building. Therefore, in a SAH with a solar fraction of around 60%, the heating costs should be on a par with those of today's combi systems with a solar fraction of approximately 25%.

The Solar-Active-House (SAH) roadmap pathway includes actions for newly built single family homes, newly built multi family homes, and refurbishment of existing buildings. This is shown in Table 2.

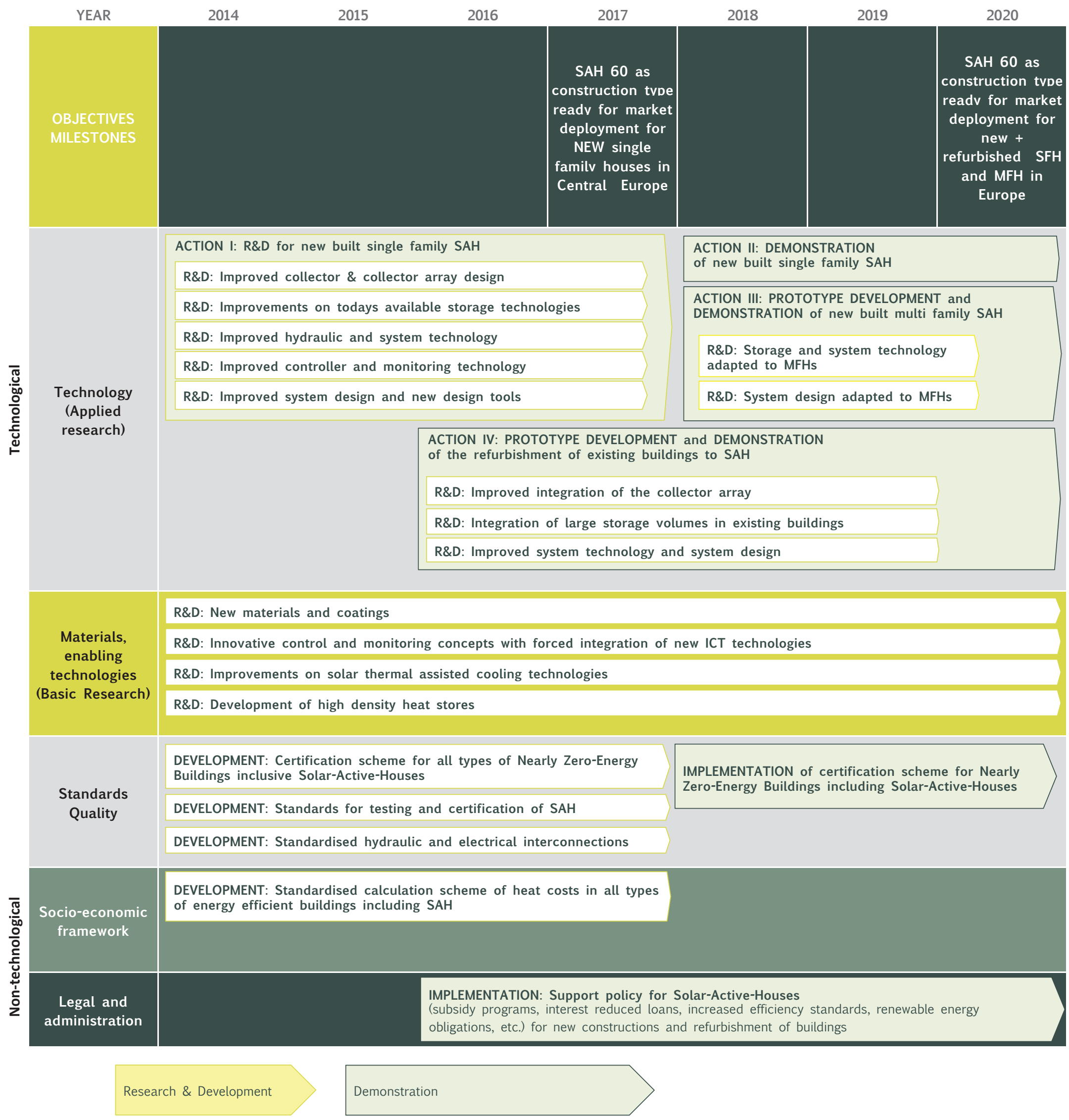

Table 2: Roadmap pathway for Solar-Active-House (SAH)

2.1.3 Solar Heat for Industrial Processes (SHIP)

The huge potential for solar thermal energy in the field of industrial processes is almost untapped. The SHIP roadmap pathway enables the sector to enter this market and includes all industrial applications with process temperatures up to 250˚C i.e. both low and medium temperature applications and is shown in Table 3.

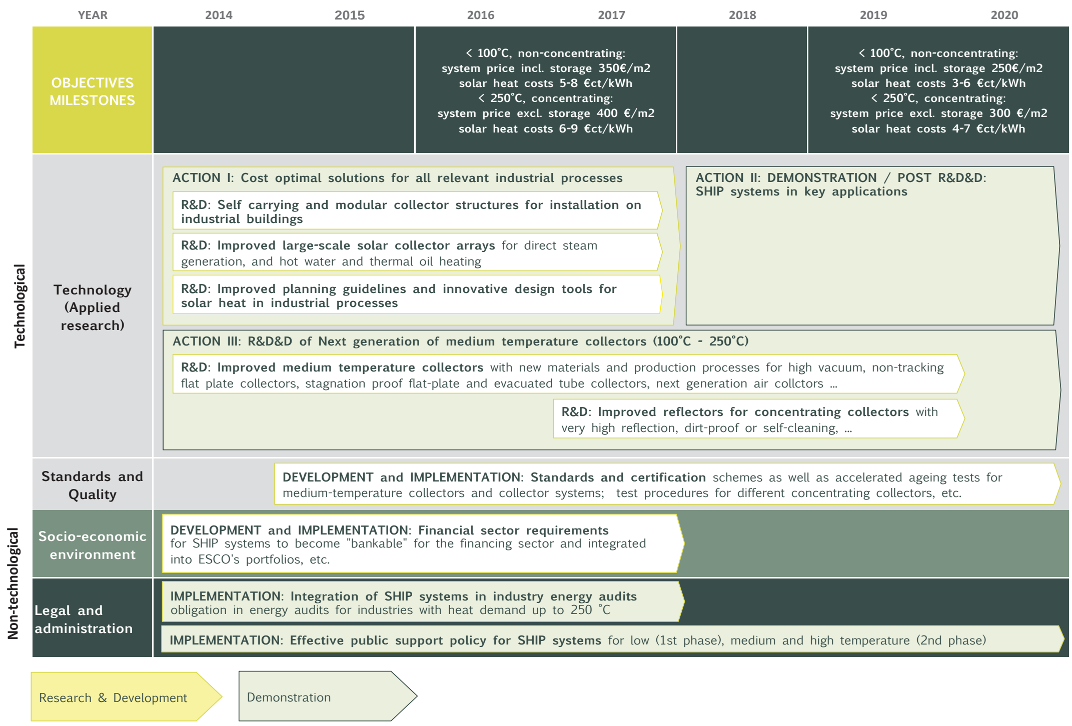

Table 3: Roadmap pathway of SHIP systems

2.2 BIOMASS TECHNOLOGIES

Providing 92% of all renewable heat, bioenergy is a key pillar of the Heating and Cooling sector today. The Biomass Technology Roadmap published in 2014 identified the importance of, and placed special emphasis on ensuring the commercial availability of reliable, cost-competitive, supply-secure, and environmentally friendly bioenergy Heating and Cooling solutions for the different consumer types in Europe.

The Biomass Panel adopted a value-chain approach in the drafting of the Roadmap to encourage successful implementation. This approach integrates the different research priorities throughout the entire supply chain from the sourcing of the biomass, the logistical aspects needed to transport it or the energy carriers, as well as its conversion into Heating and Cooling (and electricity). The Roadmap also emphasizes the need for efficient and sustainable solutions, which are vital in gaining public acceptance of bioenergy as a sustainable and reliable option in the heating sector. The Biomass Panel recommends the strengthening of current efforts to deliver a clear legislative framework regarding sustainability requirements for biomass used for Heating and Cooling. This will require a tangible progress towards regulatory consensus as we approach 2020.

The Biomass Technology Roadmap addresses four selected value chains: 1) Advanced biomass fuels replacing coal, fossil oil and natural gas in heat and CHP production (Advanced fuels), 2) cost and energy efficient, environmentally friendly micro and small-scale CHP (Micro and small-scale CHP), 3) High efficient large-scale or industrial steam CHP with enhanced availability and increased high temperature heat potential (up to 600 ºC) (High efficient large-scale or industrial CHP), and 4) High efficient biomass conversion systems for polygeneration.

2.2.1 Advanced fuels

Through the development of standardised and sector-oriented, sustainable advanced biomass fuels (new biocommodities, thermally treated biomass fuels, fast pyrolysis bio-oil and upgraded biomethane), the biomass fuel supply should double by 2020 when compared to its current use (~110 Mtoe in 2012). This includes the supply of adequate feedstock at competitive production costs. The feedstock range of bioenergy supply chains should be broadened through the mobilisation of alternative biomass feedstock resources, such as forest and agricultural residues and wastes.

Sustainable, innovative and cost-efficient advanced feedstock production and pre-treatment technologies for different biomass sources need to be developed to meet the quality requirements for thermally treated biomass, bio-oil and biomethane production. New and advanced fuels, as well as generally broadened biomass feedstock require appropriate conversion technologies ensuring the efficient and environmentally friendly use of the supplied fuels.

Action[5]	KEY PERFORMANCE INDICATORS (ALL BY 2020)
Feedstock	30% reduction of biomass supply costs for forest biomass and 20-30% reduction for agrobiomass residues through the use of intelligent machinery, and supply chain and logistical optimisation.
	30% reduction of CO_2 emissions in the biomass supply chain (forest biomass)
Bio Oil	Commercial bio-oil production for heating applications, 20% reduced bio-oil costs through process integration and logistical optimisation
	Full scale bio-oil production with plant availability > 6,500 hrs per annum
	Bio-oil upgrading to higher value products demonstrated at industrial scale.
	Use of flexible feedstock such as forest and agricultural residues and their blends
	Bio-oil fulfilling the specifications of new EN standard (for boilers and engines) under development by CEN (mandate accepted 10/2013). New bio-oil grades having improved quality – higher LHV, no solids, good stability, pH > 4.
	Physically upgraded bio-oil usage in small scale CHP and stationary engines demonstrated;
	Chemically upgraded bio-oil usage in micro-CHP and engines demonstrated (including small scale heating sector)
Thermally Treated Biomass Fuels	Increased co-firing potential of >50% commercial operation of biomass co-firing in coal CHP plants
	Reduction of production costs by 5 - 10 €/MWh (1.4 – 2.8 €/GJ)
	Operational hours at full load of 8 000 hours/year
	Overall biomass-to-thermal treatment-pellets/briquettes energy efficiencies (based on net calorific value as received) >90%
	Minimum share of agrobiomass 10%
	Development of risk avoiding guidelines and MSDS as a standardised procedure
	10 to 15% of annual production to have a verified in large scale a quality that can be stored outdoors
	Proven availability of standardised thermally treated biomass in the EU with the trading volume of thermally treated biomass about 1 – 2 million tons.

5 All base values for these KPIs are detailed in the Biomass Technology Roadmap

Upgrading of Biogas to Biome-thane	Diversification of raw material for biogas production with an increase of biogas yield of alternative energy crops by 20-30%
	Increase in the efficiency of biogas up-grading to a power consumption of Ø 0.15 kWh/Nm^3
	Cost reduction of biogas upgrading by 10-20%
	Improvement of load flexibility of biogas CHP systems with part load operability of biogas CHP units > 40%
	Increase of efficiency of biogas CHP systems by 10-20%
	80% of all European biogas plants have implemented the use of "waste heat" from their CHP units with GHG savings of almost 14 million tons.

Table 4: Key Performance Indicators for Advanced Fuels

2.2.2 Micro and small scale CHP

Small and micro-scale CHP constitutes a highly energy efficient solution (total sum of thermal and electrical efficiency > 85 %) for flexible bio-electricity and thermal energy supply. Small and micro-CHP technology has been developed for various applications. Micro-scale CHP uses serial products developed for residential scale heating with electricity production (possibly grid independent, typical P < 5 kW_e) or as cogeneration systems for small industries, the service sector, or in micro grids (base heat for more than 2,000 hours/year, typical P < 50 kW_e). Small scale CHP systems are plants rather than products for cogeneration in industries, the service sector, or DHC (base heat for more than 5,000 hours/year, typical P < 250 kW_e).

Action[6]	KEY PERFORMANCE INDICATORS (ALL BY 2020)
Micro & Small-Scale CHP	50% reduction in electricity production costs
	Minimum lifetime of suitable components for bio-oil engines and turbines of 2,000 operational hours
	Proven lifetime of 20.000 h (<5 kW_{el}) / 35,000 h / 50,000 h (>50 kWel)
	Electric system efficiencies based on solid state technologies of 2%
	Electric system efficiencies based on thermodynamic cycles of 7% (<5 kWel) <10% -12% (5 - 50 kWel)12-15 (<250 kW_{el})
	Decrease in investment costs of solid state technologies to 10 EUR/W
	Decrease in investment costs of thermodynamic cycle technologies to 3.5 EUR/W
	Reduce emissions to 1/10 of the specifications in EN303-5 (except for NO_x)

Table 5: Key Performance Indicators for Micro and Small Scale CHP

2.2.3 High efficient large scale or industrial CHP

In 2010, about 54% of the gross inland consumption of biomass was fed into electricity and/or heating plants, or used in industrial processes. Biomass use in industrial power plants and District Heating and Cooling (DHC) is expected to roughly double in 2020 through the retro-fitting of previously fossil-fuelled as well as new biomass plants. Biomass units are base load units that should be flexible in terms of operation and availability in order to continuously cover the needs for heating/cooling and electricity demand. Additionally, taking into account the increasing strictness of air quality requirements, (i.e. IED for large combustion plants and air quality package for medium-sized plants (1 – 50 MW)), and the limited availability of high quality wood resources in Europe, significant R&D efforts are required for the development of highly-efficient and multi-fuel biomass systems.

6 All base values are detailed in the Biomass Technology Roadmap

The nearly 143,000 medium-sized combustion plants (MCPs) that are now in operation in the EU emitted a combined total of some 554 thousand tons (kt) of nitrogen oxides (NOx), 301 kt of sulphur dioxide (SO_2) and 53 kt of particulate matter (PM) in 2010. Even without additional measures, these emissions are expected to come down by 2025, but the potential to further reduce these emissions is significant. In particular, biomass CHP units should exhibit increased fuel flexibility, allowing the use of more complex and low cost biomass fuels (e.g. agrobiomass and waste recovered fuels/sludges), while increasing steam parameters and/or heat medium temperature as well as effectively addressing environmental issues (e.g. emission control and ash utilisation).

High Efficient Large Scale / Industrial Steam CHP[7]	KEY PERFORMANCE INDICATORS (ALL BY 2020)
New installations	Net nominal electric efficiency of 34% for clean wood boilers and 32% for wide fuel mix boilers
	Steam characteristics of 600°C / 175 bar (clean wood boilers) and 563°C / 160 bar (wide fuel mix boilers)
	Total increase in CAPEX of no more than 10% over current state of the art for new technologies
	Electricity production costs reduced by at least 5% in clean wood boilers and at least 9% in wide fuel mix boilers
	For emissions, increase catalyst operating times and reach conformity with IED
	Increase ash utilisation to 30%
Existing / Retrofit	> 50% agrobiomass fuels thermal share in fuel mixture in wood fired units
	Max. 10% reduction from nominal operational electric efficiency
	For emissions, increase catalyst operating times and reach conformity with IED
	Increase ash utilisation to 30%

Table 6: Key Performance Indicators for High Efficient Large Scale / Industrial Steam CHP

2.2.4 Polygeneration

Bioenergy as a storable energy source presents a real advantage when considering its integration in the overall renewable energy system. Besides the production of Heating and Cooling, CHP (combined heat and power) and CHP-C (combined heat, power and cooling or polygeneration) technologies are able to provide intermittent electricity, balancing both daily and seasonal changes in solar and wind electricity production and loads of boilers, increasing plant availability, peak load duration and economy. Depending upon the season, climatic condition, and time of day, the primary function of such biomass-fuelled units may change from electricity, Heating and Cooling to even bio-oil production (polygeneration, for example with integrated bio-oil production).

Action[8]	KEY PERFORMANCE INDICATORS (ALL BY 2020)
Polygeneration	>90% overall average annual efficiency
	Emissions reduced (CO, NO_x and SO_x) by half compared to condensing power production
	Efficiency in electricity production of > 30% (<10MW_e) and > 40% (<200 MW_e)

Table 7: Key Performance Indicators for Polygeneration

7 All base values are detailed in the Biomass Technology Roadmap

8 All base values are detailed in the Biomass Technology Roadmap

REQUIRED RD&D ACTIVITIES UP TO 2020		
Topic	2014-2016	2017-2020
Advanced fuels (non-residential, industrial and CHP)		
Commercial plants for thermally treated biomass	BR	Demo
	AR	
Sustainable and cost efficient feedstock	AR	Demo
Full use of the energy content of biogas	AR	M
	Demo	M
Commercial plant for bio-oil	BR	Demo
	AR	
Micro and small-scale CHP (residential and non-residential)		
Thermoelectrics	BR	AR
Stirling engine	AR	Demo M
Steam cycle	AR	Demo
ORC	Demo	Demo M
Micro gas turbine	AR	Demo
Gasification +IC	AR	Demo
High efficient large-scale or industrial steam CHP with enhanced availability and increased high temperature heat potential		
New materials (e.g. for superheat tubes, catalysts, etc)	AR	Demo
Optimisation of boiler design / placement of heat exchange surfaces / leaning techniques	AR	Demo
Development and testing of suitable co-firing matrices for problematic biofuels	AR	Demo
Corrosion control (additives), ash utilisation	AR	Demo
Demonstrate fuel flexibility and optimal efficiency under variable load at 3-4 CHP units		Demo
Polygeneration (Industrial and CHP)		
Energy storage	BR	Demo
	AR	
Concept developments	AR	M
3 Demonstrations in different scales	AR	Demo

Table 8: Required RD&D activities up to 2020

BR ... basic research
AR ... applied research & experimental development
Demo ... demonstration
M ... market-ready

2.3 GEOTHERMAL TECHNOLOGIES

Geothermal energy has the potential to play a crucial role in our future energy mix, providing decarbonised, affordable energy for society and facilitating the competitiveness of European industry.

Geothermal Heating and Cooling can supply energy at different temperatures (low or high temperature), at different loads (it can be base load and flexible), and for different demands (heat and cold: less than 10 kW_{th} to tenth of MW_{th}). Geothermal will be a key energy source both in smart cities and in smart rural communities, based on local resources, supplying Heating and Cooling and electricity, as well as solutions for smart thermal and electricity grids via underground thermal storage.

Currently, geothermal energy sources provide more than 4 million tonnes of oil equivalent (Mtoe) per year for Heating and Cooling in the European Union, corresponding to more than 15 GW_{th} installed capacity, where geothermal heat pump systems contribute the largest part. But still the potential is huge for residential and tertiary sectors, as well as for industry.

Following current trends, in the European Union (EU-28), the geothermal contribution in 2020 may amount to around 40 GW_{th} installed, corresponding to about 10 Mtoe. Additionally, the development of Enhanced Geothermal Systems (EGS) will provide further opportunities for CHP systems by substantially enlarging the geological areas in which geothermal energy may be profitability extracted. Furthermore, deep Geothermal energy applications can benefit from hybridisation with other renewable heat energy sources, such as solar thermal or biomass, in order to increase the overall efficiency of the thermodynamic conversion cycle.

The technological challenges for an accelerated deployment of geothermal Heating and Cooling across Europe are to develop innovative solutions especially for refurbishing existing buildings, but also for zero and plus energy buildings, as the systems are easier to install and more efficient at low temperatures for both Heating and Cooling. Secondly, there is a challenge to develop geothermal District Heating (DH) systems in dense urban areas at low temperatures with emphasis on the deployment of EGS. Finally, the third goal is to contribute to the decarbonisation of industry by providing competitive solutions for Heating and Cooling.

2.3.1 Shallow Geothermal Technologies

The quantitative development of the European geothermal Heating and Cooling market in the next decade is expected to be fuelled mainly through the introduction and consolidation of shallow geothermal systems, with a quite mature market in both Sweden and Switzerland, and well-developed markets in Austria, Norway, Germany and France. In other emerging European markets, high growth is possible and is expected over the next years (Italy, Spain, United Kingdom, Hungary, Romania, Poland and the Baltic states). The aforementioned mature market countries will see a steady increase, mainly stimulated by sales in the renovation segment, while in all other countries, a significant growth is to be expected. The fast development for geothermal heat pumps illustrates how shallow geothermal energy resources, previously often neglected, have become very significant, and should be taken into account in any energy development scenario.

The main Key Performance Indicators and Objectives for Ground Source Heat Pumps are:

- SG1. A Seasonal Performance Factor in the order of 5 for 2020.
- SG2. A Hellström-efficiency (a measure of the impact of borehole thermal resistance) of about 80% in 2020.
- SG3. A further decrease in energy input and reduced costs for operating the geothermal heat pump system.

The interlink between the different proposed actions in the Geothermal Roadmap and the above listed KPI's is highlighted in the following Table 9.

RESEARCH AND INNOVATION PRIORITIES	KPI's	TRL
Ground coupling technologies		
Improved vertical borehole drilling technologies to enhance safety and reduce cost of BHE installations - Improved installation technologies and geometries for ground Heat Exchange technology.	SG3	5->6
European-wide Geoactive Structures Alliance. Development of a network of laboratories to create 4 testing sites.	SG1, SG2, SG3	5->6
Improved pipe materials for borehole heat exchangers (BHE) and horizontal ground loops. New pipes for higher temperatures. Better thermal transfer fluid.	SG1, SG2	3->4
Systems, integration and environment		
Creation of a new European wide database to map conductivities and potential (to 100 m depth) and feasibility of vertical BHE systems.	SG3	7->9
Development of a geophysical tools for Shallow reservoir potential estimation – enhanced TRT methods for non-conventional systems.	SG3	4->6
Integration of design of the shallow geothermal system and building energy system with regard to optimum thermal use and operational strategy.	SG1, SG3	7->8
System concepts and applications for geothermal large scale and medium scale cooling in warm climates – hybrid systems, new high temp pipe materials and new short term storage materials and concepts. Campaign to support 50 demonstration plants.	SG1, SG2, SG3	3->7
Development of ground coupling technologies and installation techniques for high capacities through hybrid systems and integration with other RES sources. Campaign to support 50 demonstration plants.	SG1, SG3	7->8
Non-technical provisions: measures to increase awareness, harmonisation of shallow geo- standards, shallow geothermal installer EU wide training certificate, shallow geothermal Smart City deployment policy along the line of previous projects.		8->9

Table 9: KPI's and TRL for Research and Innovation Priorities for Shallow Geothermal

2.3.2 Deep Geothermal Technologies

Promising areas are the development of smart thermal grids (1st generation) with the building of new district H&C networks (Geothermal District Heating & Cooling, with ca. 5 €-cent/kWh, is one of the most competitive energy technologies), optimisation of existing networks, and the increase of new and innovative geothermal applications in transport, industry, and agriculture.

During the next 10 years, new geothermal combined heat and power (CHP) plants with low temperature installations and Enhanced Geothermal Systems will be developed. The sector is forecast to reach an installed capacity for geothermal electricity of 3-4 GWe in the EU-28.

A typical EGS plant today has a capacity of 3-10 MWe, but future commercial plants will have a capacity of 25-50 MWe and 50-100 MWth (producing from a cluster of 5 to 10 wells, as currently found in the oil & gas industry). CHP installations could provide heating representing 2 Mtoe by 2020 at high temperatures, suitable for energy intensive industry. The main KPI's and 2020 Objectives for Deep Geothermal Technologies are:

DG1. Improved exploration of geothermal resources and creation of a European geothermal resource database. In the future, not a single project should need to be abandoned after the decision to go ahead with drilling.

DG2. Reduce cost for drilling and underground installations by at least 25% compared to the situation today.

DG3. Novel, improved production technologies to improve efficiency and reduce operation and maintenance cost by at least 25%, improve system reliability and energy efficiency of operation, in particular by decreasing energy consumption of production pumps by at least 50%.

DG4. Innovative solutions and components for improved surface systems for heat uses in DHC (including CHP) and industrial processes, developed with the target of providing optimum heat transfer from the ground system to the distribution system, can increase heat exchange efficiency by 25% and component longevity in the thermal water circuit by 40 %.

DG5. Enhanced Geothermal System (EGS) design with reliable performance parameters, such as flow rate, temperature and thermal and electrical power, will, ultimately, establish EGS as a technology applicable almost everywhere for both heat and power production.

Related to these KPI the geothermal roadmap has been structured with a number of R&I priorities, which are listed below in tabular form. Shallow and deep geothermal technologies are considered separately.

RESEARCH AND INNOVATION PRIORITIES	KPI's	TRL
Deep Geothermal Resources		
Create a European Geothermal resource database.	DG1	5->7
Exploration technologies (geochemical and geophysical exploration campaigns), characterisation and assessment of geothermal reservoirs.	DG1	3->5
European campaign for slimholes: new technologies & drilling campaign.	DG1	6->7
Deep Geothermal Drilling		
Improve current drilling technologies.	DG2	4->5
Develop novel drilling technologies by 2020: in laboratories (by 2015), on site (by 2017), on a demonstration plant (by 2020).	DG2	3->7
New drilling concept: horizontal, multi-well, closed loop systems.	DG2	3->5
Deep Geothermal Production		
Reservoir engineering: Well design & completion, reservoir stimulation and management.	DG3	3->7
New Materials: corrosion, scaling.	DG3	2->3
HT/HP tools, high temperature production pump.	DG3	5->6
Surface systems equipment: low temperature systems, heat pumps, turbines, cooling generation (via heat absorption).	DG4	6->7

EGS Flagship Program		
Establish network of complementary 5-10 European EGS test laboratories.	DG3, DG5	5->6
Demonstration sites in different geological settings (3 plants of 5 MW_e-10MWth), and upscale (1 plant=10 MWe-20MWth & 1 plant=20 MWe-40MWth).	DG1, DG3, DG5	3/4->6
Training and education of new geothermal professionals specialised in EGS.	DG5	
Public acceptance: microseismicity, stimulation, environmental impact, emissions.	DG5	
Grid flexibility: Flexible and base load electricity production from EGS plants, test on dispatchability, design regional flexible electricity system.	DG5	3->6

Table 10: KPI's and TRL for Research and Innovation Priorities for Deep Geothermal

2.4 CROSS-CUTTING TECHNOLOGIES

In order to realise the potential of RHC technology, it is necessary to exploit synergies among renewable energy production, distribution, and consumption, by developing 'cross-cutting technology'. Cross-cutting technology enhances the thermal energy output of RES systems, improves the system output, or allows RES, such as aerothermal energy, to be used in building-specific applications. Cross-cutting technology is an essential enabler of the transition towards a renewable landscape.

Four key energy technologies or applications have been identified that fit the definition above.

- District Heating and Cooling
- Thermal Energy Storage
- Heat Pumps
- Hybrid Renewable Energy Systems and priorities with generic impact on RHC applications in the residential sector

2.4.1 District Heating and Cooling

District heating and cooling (DHC) provides a broad platform for the integration of RES into the heat market. It increases the overall efficiency of the energy system by enabling the use of combined heat and power plants as well as the recycling of heat losses from a variety of energy conversion processes. DHC further enables the use of renewable energy in areas with a high building density and a high energy demand since biomass and geothermal energy can be used in heating stations in a very efficient way. By aggregating a large number of small and variable heating and cooling demands, DHC allows energy flows from multiple RES to be combined while reducing primary energy demand and carbon emissions in the community served.

RESEARCH AND INNOVATION PRIORITIES	PREDOMINANT TYPE OF ACTIVITY	PRIORITY TIMELINE	TRL	KPI
Large scale demonstration of Smart Thermal Grids	Demonstration	2014-2016	4➔7	Cost of heat with 50% renewables decreases from 200 €/MWh in 2012 to 50€/MWh in 2020.

Booster Heat Pump for DHC	Demonstration	2014-2016	3➔6	The reference sCOP value compression HP increases from 3.5 in 2012 to 5 in 2020 while the heat generation costs is reduced by more than 30%.
Develop and roll-out DHC driven white goods and low temperature solutions for domestic hot water preparation	Development/ Demonstration	2018-2020	4➔6	The average electricity consumption of white goods is reduced from 850 kWh/yr in 2012 to 153 kWh/yr in 2020.
Improved, highly efficient substations for both present and future lower temperature networks	Demonstration	2016-2018	3➔6	Substations' manufacturing costs are reduced from 5,000 to 10,000 € in 2012 to 4,000 to 6,000 € in 2020. Average electricity consumption of substations for residential buildings reduced from 4,380 kWh/year in 2012 to 2,600 kWh/year in 2020, while the number of 'smart substations' has a market share of 80%.
Optimised integration of renewable energy sources in DHC systems and enhancement of thermal energy storage at system level	Demonstration	2018-2020	3➔6	The reference heat cost is reduced from 50-200 €/MWh in 2012 to 40-90€/MWh in 2020, while the energy efficiency of DHC systems is increased by 10%.

Table 11: District Heating and Cooling Research and Innovation Priorities

2.4.2 Thermal Energy Storage

Thermal energy storage is the solution to the key bottleneck problem preventing the widespread and integrated use of RES, since the renewable supply does not always coincide with the demand for Heating and Cooling. Numerous technologies in sensible, latent or thermochemical form, both in on-site and large scale applications can time-shift renewable energy supply to periods of greatest demand. Each technology is characterised by different specifications and specific advantages.

RESEARCH AND INNOVATION PRIORITIES	PREDOMINANT TYPE OF ACTIVITY	PRIORITY TIMELINE	TRL	KPI
Next generation of Sensible Thermal Energy Storage	Development	2014-2016	3➔8	1,000 litre tank cost (excluding insulation and VAT) is reduced from 400 - 900 € in 2012 to 300 - 700 € in 2020, while the heat loss is reduced from 150W – 200W to 56W.

Improving the efficiency of combined thermal energy transfer and storage	Research / Development	2018- 2020	1➔6	New fluids for thermal energy transfer and storage allow a reduction of annual electricity consumption for pumping from 75 kWh in 2012 to 50 kWh in 2030, while the energy density is increased by 30%.
Increased storage density using phase change materials (PCM) and thermochemical materials (TCM)	Research	2016-2018	2➔8	Stable, micro encapsulated salt hydrate PCM cost reduced from 8 €/kg in 2012 to less than 2 €/kg in 2030. Energy seasonal solar TCM storage increased from 60 kWh/m^3system in 2012 to 250 kWh/m^3 system.
Improvements in Underground Thermal Energy Storage (UTES)	Demonstration	2016-2018	4➔6	Energy efficiency increased from 60% in 2012 to 75% in 2020. Lifetime of the UTES at elevated T increases from 10 years in 2012 to 20 – 30 years in 2020.
Optimised integration of renewable energy sources in DHC systems and enhancement of thermal energy storage at system level	Demonstration	2018-2020	3➔6	The reference heat cost is reduced from 50-200 €/MWh in 2012 to 40-90€/MWh in 2020, while the energy efficiency of DHC systems is increased by 10%.

Table 12: Thermal Energy Storage Research and Innovation Priorities

2.4.3 Electric compression and thermally driven Heat Pumps

Heat pumps transform renewable thermal energy available at low temperatures from natural surroundings to heat at higher temperatures. The heat pump cycle can be also used to provide cooling. Heat pumps use aerothermal, hydrothermal and geothermal energy as stand-alone installations or in combination with other renewable energy sources.

Although the technology has matured over the past years, research and development can contribute to the improvement of the efficiency, cost effectiveness, and suitability of the technology in the built environment.

While the majority of heat pumps today use electric compression units, thermally driven heat pumps using the sorption cycle are a promising technology for heating, and can also provide cooling.

These so called ‘sorption cooling systems’ are regarded as one of the most efficient technologies to convert RES and excess heat into cooling.

RESEARCH AND INNOVATION PRIORITIES	PREDOMINANT TYPE OF ACTIVITY	PRIORITY TIMELINE	TRL	KPI
Cost competitive heat pump kit for houses with existing boiler	Development	2014-2016	4➔7	PER of the heat pump and gas boiler system referred to primary energy increased from 0.8 (gas boiler only) to 1.7 in 2020. Reference average cost of 4-8 kW HP in the range 4-8 kW, including installation, reduced from 6,000 – 8,000 € in 2012 to 4,000 – 5,500 € in 2020.
Optimisation of thermally driven heat pumps and their integration in the boundary system	Development	2014-2016	4➔7	Reference thermal system sCOP (e.g. for air source) increased from 1.15 in 2012 to 1.4 in 2020. Reference specific unit cost reduced from 450 €/kWth in 2012 to 350 €/kWth in 2020.
Development of a heat pump for near-zero energy buildings (single family house)	Development	2018- 2020	4➔6	sCOP (for heating and cooling) increased from 3.5 in 2012 to 6 in 2025. Contribution to the production of DHW higher than 40% in 2025.
High capacity heat pump for simultaneous production of cold and hot water for heating/cooling the building	Development	2016-2018	4➔6	sCOP of air-to-air HP increased from 7 in 2012 to 10 in 2020. Refrigerant charge lower than 0.1 kg/kW.
Sorption cooling systems driven by hot water at moderate temperature	Development	2016-2018	3➔6	Driving temp for absorption today 95°C -> 60°C. Reference sCOP (water cooled) increased from 0.5 in 2012 to 0.8 in 2020.
Enhanced industrial compression heat pumps	Development	2018-2020	3➔6	Carnot efficiency increased from 0.3 in 2012 to 0.4 in 2025. Production cost of the heat pump unit reduced from 300 €/kW in 2012 to less than 200 €/kW in 2025.
Process integration, optimisation and control of industrial heat pumps	Demonstration	2014-2016	4➔7	Reference sCOP compression HP (at ΔT = 35 K , Tevap = 40 °C) increased from 3.5 in 2012 to 5 in 2020. Reference sCOP absorption HP increased from 1.1 in 2012 to 1.5 in 2020. Average system cost reduced from 500-600 €/kW in 2012 to less than 400 €/kW in 2012.

Improvement of sorption cooling from renewable energy sources and excess heat	Development / Demonstration	2018-2020	4➔7	Cost for absorption chiller reduced from 160 €/kWc in 2012 to 100 €/kWc in 2025. Specific weight reduced from 7 kg/kWc in 2012 to 5 in 2025.
New concepts for industrial heat pumps	Research	2016-2018	2➔4	Temperature of the delivered heat increased from 100°C in 2012 to more than 200°C in 2020 with a temperature lift higher than 70K. Payback time reduced from 5 years in 2012 to less than 3 in 2020.

Table 13: Heat Pumps Research and Innovation Priorities

2.4.4 Hybrid systems and Priorities with generic impact on RHC applications in the residential sector

Hybrid systems are defined as those systems which provide heating, cooling and/or domestic hot water through the combination of two or more energy sources into a single system, therefore overcoming the limitations of individual technologies. Hybrid systems are used in small-scale applications like Heating and Cooling systems for single family houses as well as in large-scale applications suitable for District Heating and Cooling or industrial processes.

Systems using one renewable and one non-renewable source are considered as a merely short term (i.e. until 2020) technological option. In the long term, hybrid systems will combine two or more renewable energy sources.

RESEARCH AND INNOVATION PRIORITIES	PREDOMINANT TYPE OF ACTIVITY	PRIORITY TIMELINE	TRL	KPI
Automation, control and long term reliability assessment	Development	2014- 2016	3➔7	Reference system customer price (for Central Europe) reduced from 800 – 1,500 €/kW in 2012 to 640 – 1,200 €/kW in 2020. Primary Energy Ratio of a reference system reduced from 0.8 in 2012 to 0.65 in 2020. Increase in the system efficiency as a result of the integration of smart controllers higher than 20% in 2020.

Next generation of highly integrated, compact hybrid systems	Development	2018-2020	3➔6	Renewable share of the reference hybrid system increased to more than 75% in 2030. Reference system customer price (for Central Europe) reduced from 800 – 1,500 €/kW in 2012 to 500 – 1000 €/kW in 2025.
Integration, automation and control of large scale hybrid systems for non-residential buildings	Development	2016-2018	4➔6	Primary Energy Ratio of a reference system reduced from 0.8 in 2012 to 0.5 in 2020. Average increase to the payback time, compared with conventional alternatives reduced to 5 years in 2020 and to 1 in 2025.

Table 14: Hybrid Systems Research and Innovation Priorities

Table 15 shows some items of relevance to all types of residential Heating and Cooling from RES that will help to improve system efficiency and ease of installation. These issues are related to the system level rather than to the single component level. While components often are tested and certified with specific procedures (e.g. the Solar Keymark for solar thermal collectors), such certification practices and schemes do not exist for overall Heating and Cooling systems.

RESEARCH AND INNOVATION PRIORITIES	PREDOMINANT TYPE OF ACTIVITY	PRIORITY TIMELINE	TRL	KPI
Developing standards for the overall system design and for hydraulic and electrical interconnections of different building components	Development	2016-2018	Applicable to all TRLs	Installation time is reduced by 30%. Material cost reduction for the end-user of 20% (cfr CCT.3). 20% reduction of human interventions for maintenance / reparation.
Elaborating standards, tests, and benchmarks for system efficiency	Development	2014-2016	Applicable to all TRLs	Establishment of harmonised test procedure(s), recognised among industry, research and standardisation bodies in EU, in order to test different RHC systems. The harmonised test procedure(s) should be tested in at least 5 EU countries by relevant research and/or standardisation bodies.

Table 15: Research and Innovation Priorities with generic impact on RHC applications in the residential sector

3.

INTERCONNECTION BETWEEN THE DIFFERENT RHC TECHNOLOGIES

and links to different demand profiles

RHC Renewable Heating & Cooling
European Technology Platform

❸ INTERCONNECTION BETWEEN THE DIFFERENT RHC TECHNOLOGIES AND LINKS TO DIFFERENT DEMAND PROFILES

One reason for the complexity of the Heating and Cooling sector is the fact that heat and cold can be generated, transported, stored and delivered in many ways to satisfy the demand of end users with many different profiles. This leads to a variety of solutions and often to different technology combinations in order to provide optimal alternatives. The Cross-Cutting Technologies (CCT), as enablers for all RES, play a special role and so this Chapter presents the connections between the RES for Heating and Cooling and CCT from the point of view of R&I actions - as described in the previous Chapter - and technical progress.

3.1 INTERCONNECTION BETWEEN CROSS-CUTTING TECHNOLOGIES AND SOURCE ORIENTED TECHNOLOGIES

3.1.1 How Solar Thermal is linked to Cross-Cutting Technologies

Home owners don't want to buy heating components separately, such as solar collectors, water storage units, backup-heaters and other equipment, but rather a solution for domestic hot water and/or space heating. R&I is necessary to further develop solar thermal and cross-cutting components, however it is highly important to also focus on R&I actions for optimised system technology. Cross-cutting technologies contribute to this process with components like thermal storage and system technologies like hybrid systems and control technology.

Strong R&I work is required for thermal energy storage (TES). Solar thermal system solutions require (in almost all cases) a heat store. This is due to the mismatch between solar radiation and heat demand profile; usually a thermal energy storage system is needed to make solar thermal energy useable. Depending on the scale of the mismatch and the desired solar fraction, TES is designed to bridge the gap from just a few hours or days, up to weeks and months. However, to store solar thermal energy means additional investment costs and additional thermal losses, which increase with storage size and duration. In order to increase system efficiency and solar fraction, the solar thermal sector requires TES with reduced thermal losses, improved charging/discharging characteristics, and higher heat density (reduced volume for the same heat capacity).

Furthermore, concepts and technologies for hybrid systems of solar thermal energy with heat pumps, as well as with biomass systems such as pellet and wood chip boilers, with improved control concepts and a reduced number of subcomponents, are necessary. The improved integration of large collector arrays into buildings (multi family and tertiary ones especially) as well as decentralised solar collector areas in district heating systems with and without large seasonal heating storage is another field in which R&I is needed.

3.1.2 How Biomass is linked to Cross-Cutting Technologies

Biomass units are able to produce both electricity and heating/cooling on a continuous basis. Therefore, as it can be considered as a type of stored energy, biomass can cover the energy needs when other renewable sources are not available. For this reason, biomass can be considered to be an essential element for the stability of integrated renewable energy systems. The complementarity of bioenergy technologies and cross-cutting technologies is also proven when high temperature heat (up to 600°C) is required.

DHC networks throughout Europe often use the heat produced from biomass heating and/ or Combined Heat and Power (CHP) units as a primary supply. Technologies that improve the management of small and variable Heating and Cooling demands from customers or minimise thermal losses also have a direct impact on the supply side, e.g. by allowing more customers to be connected to an existing grid, or by allowing a better dimensioning of the supply side during the design phase. Moreover, the large-scale demonstration activities outlined in the Biomass Technology Roadmap, such as those of the 'High efficient large-scale or industrial steam CHP system with enhanced availability and increased high temperature heat potential (up to 600°C)' priority can be coupled with the demonstration activities of the CCT Roadmap, e.g. 'CCT.17 Large scale demonstration of Smart Thermal Grids'. This way, the efficiency and environmental performance of new or retrofitted large-scale CHP units can be tested in the actual operating conditions of a smart thermal grid for DH.

Thermal Energy Storage (TES) technologies are a common supporting feature of several bioenergy heating systems in the residential or District Heating (DH) sector, mostly for short-term storage. Improvements in TES technologies will allow bioenergy heating units to manage their heat production more efficiently, e.g. by avoiding shut-downs or abrupt load changes. Also, using standardised and sector-oriented biomass fuels will secure the energy supply and the efficient operation of biomass plants. For CHP units, the use of advanced solid and liquid biofuels means an increase in their heat output, and thus an increase in their total efficiency. At domestic scale, TES are widely diffused components in space heating and DHW supply systems based on biomass combustion and on biomass / solar thermal hybrid systems. Next generation (cost effective and efficient) sensible TES (CCT.6), in addition to phase change materials (PCM) and thermochemical materials (TCM) (CCT.8), will also be a relevant component for small and micro scale CHPs and are highly relevant for consideration in the automation and control system of hybrid energy systems at all scales.

Heat pumps are a versatile technology, utilising low temperature waste heat from various sources. Such low temperature streams are produced by bioenergy heating systems of all scales. Improvements in heat pump technologies will allow for the utilisation of such streams and will contribute to the increase of the overall total efficiency. Biomass combustion or upgraded biogas systems may substitute natural gas in the field of thermally driven heat pumps (CCT.2).

Hybrid renewable energy systems include a number of technologies that will allow for the combination of two or more energy sources in a single stream. Since bioenergy is the most common technology for RHC, it can be expected that most hybrid systems will include some type of bioenergy system. For example, 'CCT.3 Automation, control and long term reliability assessment' allows for improved load control; this leads to better dimensioning of the capacity of CHP units in the design phase, allowing them to operate as closely as possible to full load, thus bringing higher efficiencies and lower emissions. A major role of the successful deployment of CCT.3 will be for packaging purposes of integrated hybrid renewable energy systems. Pellet burners / biomass micro CHPs may also be an element (first attempts are already on-going) of the next generation of highly integrated, compact hybrid systems (CCT.5) in order to ensure independence from electricity.

From the Strategic Research and Innovation Agenda of the RHC-Platform, Priorities 'RHC.1 Developing standards for the overall system design and for hydraulic and electrical interconnections of different building components' and 'RHC.2 Elaborating standards, tests, and benchmarks for system efficiency' are absolutely necessary for all RHC technologies at residential scale. There is a strong need to develop new industry standards and testing procedures in order to improve the efficiency and longevity of installed systems in which the observed performance is often below the expected and theoretical levels of performance.

3.1.3 How Geothermal is linked to Cross-Cutting Technologies

There is a fundamental link between shallow geothermal technologies and heat pumps, since the heat pump is a structural element in any shallow geothermal application, enabling the system to exchange heat between the underground and the building HVAC (Heating, Ventilation & Air-Conditioning) system. Any progress in HVAC components (better efficiency, lower cost, adaptation to temperatures delivered by geothermal systems), and in particular HP components, will be of benefit to the overall geothermal system. Additionally, shallow geothermal applications are often found in combination with other sources of renewable heat. These forms of hybridisation (solar – geothermal, air source – geothermal, etc.) play a key role in adjusting the demand profile of many applications to the characteristics of the different heat sources, optimising the balance between cost competitiveness and efficiency. This is particularly true in high capacity non-residential applications with unbalanced heating/cooling demand in which the thermal equilibrium in the soil can only be re-established by means of supplementary heat sources and sinks. Here, the development of optimised hybrid schemes and control appliances are key factors.

Sensible Underground Thermal Energy Storage (UTES) for low temperature applications (at less than 40 °C) using either groundwater-bearing layers (ATES) or wells into the ground water, or using borehole heat exchanges (Borehole Thermal Energy Storage (BTES)), uses the same type of installation procedures and technologies that make up the core of the shallow geothermal systems. These areas are thus closely interlinked. In the 40-90 °C heat storage temperature range for ATES and BTES systems, a breakthrough would be needed that would open up shallow geothermal systems to a wider range of applications in non-residential and industrial areas.

In the DHC sector, there are two relevant technologies that are closely interlinked with the Geothermal Roadmap topics. As mentioned before, the first are technologies using the ground as a vast heat store or sink through UTES, with shallow geothermal technology principles; the second relates to deep geothermal energy production by means of direct heat supply by thermal water production and reinjection, or additionally by using other technologies like deep borehole heat exchangers (BHE) or heat from geothermal CHP plants. The capacity of such installations can start from about 0.5 MW_{th} (in particular deep BHE) and may achieve values in excess of 10 MW_{th}. The heat could be fed directly into a district heating system (if production temperature matches the required supply temperature), or be used as a heat source for large heat pumps (including absorption heat pumps, engine-driven compression heat pumps, etc.). Additionally, cold production is possible with absorption chillers driven by geothermal heat. Further development in DHC technologies (including cascading and storage) will make it possible to use geothermal heat more efficiently.

3.2 CONTRIBUTION TO APPLICATION-ORIENTED SOLUTIONS

The Research and Innovation actions described in the Strategic Research and Innovation Agenda were structured according to the final users since Heating and Cooling demand profiles, supply temperatures, costs, and relevant technologies vary a lot and therefore markets with completely different characteristics and needs exist. Four main demand profiles were identified to cover substantially the most important user groups, which lead to the proposed classification into residential, non-residential, industrial and district wide (or Smart City) users.

In this subchapter, the different R&I actions will be linked and related to these four application domains to highlight the fact that, from the point of view of technology and research, different solutions and paths have to be found depending on the market and demand profiles to be addressed.

3.2.1 RHC Research and Innovation in the Residential Sector

The needs of the residential market can be divided into two main segments: retrofitting and newly built. Although in new buildings holistic solutions in line with the nearly zero-energy building concept are under development, the majority of the market needs solutions that can be easily integrated into existing buildings and that significantly reduce their fossil fuel demand. Today in Central and Northern Europe, as well as in in the Southern European Countries with different climates, space heating is responsible for more than 80% of the heat demand in residential buildings; less than 20% is needed for DHW. Though the space heating demand can decrease by up to 75% (due to improved thermal insulation and improved façade air tightness by refurbishment), it will still be comparable with the demand for DHW.

Contribution from Solar Thermal Technologies

Today, manufacturers are selling solar thermal systems as units comprising the different components of the system. These components must be installed and connected on-site by the installer in the building and combined with an external backup-heater. Manufacturers offer solar systems that can be combined with a huge variety of heating system designs. However, this diversity increases complexity, costs and installation failures, as well as the risk of suboptimal operation due to conflicts between the controller of the solar system and the backup-heater.

This challenge can be solved by the Solar Compact Hybrid System (SCOHYS), which includes the pre-assembled solar system and the backup-heater in one compact unit. SCOHYS will be a compact solution at reduced costs and with high reliability due to simplified design, the presence of only one control unit (including both control and monitoring functions), the high level of prefabrication, and the reduced installation effort. Due to an optimised combination of components and prefabrication in an intelligent way, the energy performance and the reliability in the long term will improve.

The Solar-Active-House (SAH) concept as solution for the nearly zero-energy building requirement has been becoming increasingly relevant in the residential sector. The contribution of solar energy to space heating in this context requires an increase of the solar fraction per building. Today, in Central Europe, combi-systems for DHW and space heating typically have a collector area of 10 to 15 m^2 and can provide a solar fraction of about 25%, depending on the size and the efficiency of the building and the climatic conditions on site. This solar fraction is significantly increased in the SAH to at least 50%. Since in Central and North Europe the level of solar radiation is in winter time much lower than in summer time, a solar fraction close to 100% requires the storing, of a significant amount of solar heat that is generated during the summer for heating purposes through the installation of a very large seasonal thermal storage tank. However, based on improved insulation standards for buildings and improved solar thermal technology, the SAH with a solar fraction of about 60% was developed as a good compromise of a high solar fraction at an acceptable storage volume. In Central Europe, a typical single family SAH needs a collector area of 30 to 40 m^2 and a water storage tank of only 5 to 10 m^3. More than 1300 such Solar-Active-Houses have already been built.

The final goal of the solar sector is to increase the solar fraction with the SAH concept at low solar heat costs, which can be achieved in two steps. Figure 3 shows the SCOHYS roadmap pathway (SCOHYS roadmap (rm)) and its result (cost reduction by 50% for the same solar fraction), and SAH roadmap pathway (SAH rm) and its result (increased solar fraction at the same solar heat costs), for the year 2020 in the solar fraction to solar heat cost diagram. In a second step (SAH 2030), the final goal of high solar fraction at low heat costs will be achieved by 2030.

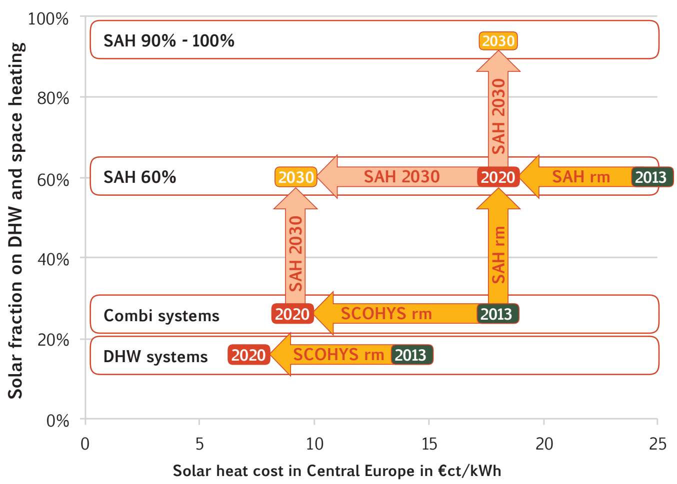

Figure 3: Development of solar heat costs (x-axis) for different applications/solar fraction (y-axis) at specific years (fields with "2013", "2020" and "2030"). The arrows stand for the different roadmap pathways (SCOHYS and SAH rm until 2020 and SAH 2030 beyond 2020) (costs for typical systems in a specific area, Central Europe)

Contribution from Biomass Technologies

Biomass based technologies can serve almost any residential application either as an individual Biomass-only solution, or as part of hybrid packages providing heat, hot water, and ventilation and air conditioning / cooling to residential buildings. As for solar thermal (and probably all other RHC technologies) the development of package solutions reducing the diversity of system solutions and reducing the potential for mistakes in the practical installation of the systems is a key requirement for technical solutions for the residential RHC sector. While firewood will remain the most relevant fuel for the individual room heating systems, upgraded and advanced biofuels will gain importance in automatically fired boilers and stoves.

In 2013, biomass based solutions for the residential sector included approximately 442,000 pellet boilers installed at residential scale (<50kW) in eight member states[9] and more than 2 million pellet stoves in six member states[10] according to a study published by the European Pellet Council (EPC). Due to their commercial viability in several European member states, significant growth of such applications is foreseen up to 2020.

Biomass technologies will serve the new building market mostly with back up technologies (individual room heaters, possibly with water heat exchangers, and in any case with advanced TES opportunities) or with base load supply technologies (in the case of multi-family homes or a number of flats connected with a micro-grid). The latter is offered by boilers or micro-CHP technologies. As far as pre-fab buildings are concerned, biomass burners are a component of hybrid HVAC packages developed around TES as a central and enabling technology component.

Contribution from Geothermal Technologies

In the residential sector, the main geothermal technology to cover Heating and Cooling demand is the shallow geothermal heat pump system. This technology is suitable for small, individual houses as well as larger multi-family houses or groups of houses. Capacities range from under 10 kW_{th} to over 500 kW_{th}. The depths of geothermal heat exchange ranges from a few meters to more than 200 m, depending on technology used, geological situation, demand profile, and other design considerations. Geothermal heat pumps can deliver all the thermal energy required for living; space Heating and Cooling as well as domestic hot water (DHW).

For space cooling, in certain regions with a moderate climate, direct cooling from the ground via cooling ceilings etc. is possible, allowing for space cooling with minimum energy input. In warmer regions with higher cooling demand, the heat pump can be used in cooling mode. For well-insulated houses with a forced ventilation system, geothermal energy can contribute to pre-heating or pre-cooling ventilation air while it passes through intake pipes buried in the ground.

The R&I actions addressing the European residential geothermal sector more directly are based on the objectives and KPIs related to shallow geothermal technologies, mainly in increasing the efficiency of systems (new materials, better integration and design), allowing a better characterisation of suitable areas and applications, and decreasing installation costs through different techniques (improved drilling or other types of heat exchangers, such as geo-active building structure elements). As in many other areas, a special mention must be given to the development of measures to increase awareness, harmonisation of shallow geo-standards, for an EU-wide shallow geothermal installer training certificate, and for a shallow geothermal smart city deployment policy, consistent with the findings of other projects.

Contribution from Cross-Cutting Technologies

All priority I (2014-2016) actions in residential housing sector are seen as developmental activities. Advancements in heat pump technology should focus on developing cost-competitive heat pump kits for houses with existing non-electrical boilers. This is an essential tool for the refurbishment of the existing European housing stock, and for the optimisation of thermally driven heat pumps. Additionally, this is essential to the integration of these technologies into the boundary system to support the market penetration of such equipment, enhancing the efficiency and the long-term stability, and reducing their size, weight and cost.

9 AEBIOM (2013), European Bioenergy Outlook, European Biomass Association, available online: http://www.aebiom.org/blog/category/publications/statistics/

10 Selected countries were AT, DE, FI, HU, IT, SK

As regards the development of new generation hybrid systems, special attention should be paid to the automation and control of systems; the scope of this research should be to develop an integrated control platform with the necessary technical developments on control monitoring and automation to improve the quality of the systems. Finally, development in sensible thermal energy stores should focus on significantly reducing heat losses, increasing exergy efficiency, efficient charging and discharging characteristics, and high flexibility to adapt and integrate it in existing buildings with limited space for storage. The need for standards in design and implementation is greatest. End users here do not have sufficient knowledge to judge design and implementation quality. Standards and standardised test procedures need to be developed to ensure that Renewable Heating and Cooling systems are satisfactory in all aspects.

For priority II actions (2016-2018) research is needed to increase storage density using phase change materials (PCM) and thermochemical materials (TCM) in order to enable the implementation of TES in applications with less available volumes and to enable the cost-effective long-term storage of renewable heat.

In the long term, with priority III (2018-2020), the development of a heat pump for near-zero energy buildings (single family houses) is expected. That is a small capacity-reversible heat pump (around 3-4 kW_{th}), with low cost, and easy installation, operation and maintenance for the new low-energy consumption houses of the EU. This should entail optimal integration with ventilation heat recovery, cooling, dehumidification, and domestic hot water production. Development and demonstration efforts should be put into developing compact/prefabricated hybrid systems with improved efficiency, which are inexpensive and with simplified installation to reduce damage, and which are adapted to the various configuration of heating systems and climates. Finally, the further development and improvement of fluids that combine the heat transfer function with thermal energy storage is outlined; these will lead to smaller required storage volumes, an increase in heat transfer efficiency and a reduction in auxiliary energy for pumping.

3.2.2 RHC Research and Innovation in the Non-Residential Sector

Non-residential or service buildings require in general a different approach when compared to residential buildings due to two main differentiating aspects: firstly the demand profile is substantially different and includes, under certain circumstances, large cooling loads (even in Northern or Central European buildings), and secondly systems tend to be much larger and highly integrated whereby hybridisation of different technologies, as well as cross-cutting technologies concepts are usually widely applied. The complexity in the design and installation of such systems is higher and safety requirements are more demanding (e.g. by dealing with steam in the system in the case of Solar Thermal applications).

Contribution from Solar Thermal Technologies

Developments in solar Heating and Cooling solutions for residential buildings are also relevant for the non-residential sector. The service sector requires larger solar thermal systems which allow economies of scale but also imply customised planning. The efficiency of the solar thermal system depends a lot on the demand curve and the temperature requirements, e.g. solar thermal systems are well suited to supply the high volume of hot water consumed throughout the whole year by hotels, hospitals, homes for elderly people, prisons or swimming pools.

Solar cooling solutions are an option for the non-residential sector due to a high cooling demand, especially if there is a high demand on domestic hot water and Heating and Cooling, like in hotels. Most of the cooling demand in the service sector is currently supplied by electrical systems, causing problematic consumption peaks. Therefore, thermally driven cooling technologies constitute promising alternatives and are set to play a key role in the efficient conversion of energy in the field of building air-conditioning and refrigeration, especially in southern Europe. Today, these technologies are used largely in combination with waste heat, district heat, or co-generation units. Thermally driven cooling cycles can be efficiently run with solar thermal energy too. In climates where cooling is not required during the whole year, as is the case in Europe, these systems benefit from the possibility to provide cold in summer and heat in winter time.

R&D priorities for solar Heating and Cooling systems in non-residential buildings look at simplifying installation and maintenance, improving integration, and increasing stability, reliability and long-term performance, leading to cost competitive solutions. The identification of the accurate applications and cases suited for solar cooling and heating in the non-residential sector will be decisive. The improvement of thermally-driven cooling components deserves special attention.

Contribution of Biomass Technologies

Small scale CHPs and fuel flexible boilers shall be developed for the reliable provision of the base heat loads for non-residential buildings, services and grids for a relevant time span of the year under competitive conditions. In the field of non-residential buildings, these may be integrated into smart package solutions with other RHC technologies. Advanced or upgraded biomass fuels, such as biomethane and syngas can be effectively used in existing gas fired boilers, either directly or following the injection into the natural gas grid. Specific high temperature applications shall be identified to allow for tailor-made biomass technology developments and a proper segmentation of the heat market amongst the RHC technologies. Thermal (biomass based) cooling technologies shall be developed for applications where this is deemed to be economically competitive. The bigger the application, the more relevant will be the supply chain management of either locally available fuels or of retailed upgraded fuels.

Contribution from Geothermal Technologies

In the services sector, shallow geothermal energy systems (ground source heat pumps or underground thermal energy storage) are the most relevant technologies, ranging in capacity from some 10 kW_{th} for small businesses or offices, to 1 MW_{th} or more for larger projects. The ability to provide both Heating and Cooling is the major asset of shallow geothermal technologies in this sector. Systems will generally be more complex than those for the residential sector. In the case of shallow geothermal systems, the economy of plants is usually better, as a significant demand for cooling extends the running time of the system, and also scale effects reduce specific first cost to less than 70% of the specific cost of smaller, residential systems. Generally less than 50% of the cost is related to the underground works on these shallow geothermal installations.

There are a number of Research and Innovation priorities in the Geothermal Roadmap which specifically addres non-residential applications, such as areas dealing with larger systems (development of solutions for cooling and high capacities) and priorities that emphasise design, integration and also the use of shallow geothermal Aquifer systems (ATES technologies) which are mostly suitable in larger applications.

Additionally, deep geothermal energy (i.e. from boreholes deeper than 400 m, or from high enthalpy geothermal resources) might be applicable in cases with higher heat demand (thermal spas, large offices, hospitals, etc.).

Contribution of Cross-Cutting Technologies

Priority II (2016-2018) development is needed in the non-residential sector. Firstly, there is a need for the development of a high efficiency, high capacity heat pump solution for the Heating and Cooling of buildings with simultaneous production of hot water for space-heating and chilled water by automatically changing the refrigerant circuit in order to reject/take the necessary heat to/from the air or water from a geothermal loop (air and water versions of the heat pump). Additionally, the heat pump should preferably employ a low GWP refrigerant and offer a competitive cost, high reliability, optimised control, and easy integration with other systems. Secondly, integration, automation and control of large scale hybrid systems for non-residential buildings are needed. Finally, development of sorption cooling systems driven by hot water at moderate temperature; for instance, with solar heat or low temperature excess heat. In this case the expected outcome includes the development of optimised solutions for the heat rejection, fully reliable and automated operation, and easy integration with other systems.

3.2.3 RHC Research and Innovation for Industrial applications

The heat demand for industrial applications in the EU was estimated by the IEA to be 165 Mtoe in 2010. Most of this demand is covered by well-established fossil-fuel based systems, resulting in significant impact on the greenhouse gas emissions from the industrial sector. From the point of view of research, RHC technologies for industrial applications have very specific characteristics since the delivery temperatures vary completely from case to case, being much higher than in the building related sectors in many of the most relevant applications.

Contribution of the Solar Thermal Technologies

Solar Heat for Industrial Processes (SHIP) is currently at a very early stage of development. Less than 120 operating SHIP systems are reported worldwide, with a total capacity of over 40 MW_{th} (>90,000 m²). Most of these systems are pilot plants with a relatively small size. However, there is great potential for market and technological developments as 28% of the overall energy demand in the EU28 countries originates in the industrial sector, with the majority of this is heat being below 250°C.

Solar industrial process heat costs depend to a great extent on the type of application, and especially on the temperature level needed. Up to now, several solar thermal process heat systems exist in Europe with heat costs between €38 and €120 per MWh.

According to a study (Ecoheatcool 2006), around 57% of the total industrial heat demand is required at temperatures below 400°C and 30% at temperatures below 100°C. A high share of the heat demand below 100°C could be met with SHIP systems using improved and adopted current technologies, if suitable integration of the solar heating system can be identified. With R&I and technological development, more and more medium temperature applications, up to 250°C, will also become market-feasible. The objectives of the SHIP roadmap pathway are the achievement of cost optimal SHIP systems and its integration in relevant industrial applications, as well as the development of next generation SHIP systems with increased solar fraction and its adaptation to industry machinery standards (including new ways to feed in solar heat into the industrial processes).

In several specific industry sectors, such as food, wine and beverages, transport equipment, machinery, textiles, pulp and paper, the share of heat demand at low and medium temperatures (below 250°C) is around 60% (POSHIP 2001). Tapping into this potential would provide a significant solar contribution to industrial energy requirements.

Contribution of the Biomass Technologies

Currently covering almost 12% of the industrial heat demand, biomass represents the most important renewable energy source in this sector. Its main advantage lies in it being a well-established technology, capable of providing heat or process steam continuously and at all temperature levels. Additionally, certain types of biomass heat are cost competitive with fossil fuel alternatives, even without the need for subsidies.

Large-scale biomass heat units for industrial applications are already capable of reaching high thermal efficiencies; therefore, the RHC-Platform highlights the importance of promoting large-scale biomass CHP units for industrial applications, since they can produce bio-electricity, an important value-added product, with a lower subsidy level compared to biomass-fuelled electricity-only plants. The advantage of the industrial CHP units is the presence of an existing heat market which in many cases is not subject to seasonal demand variations, as is the case with DH networks. In addition, large-scale industrial units have a higher degree of fuel flexibility, which will allow for the mobilisation and effective utilisation of biomass resources that remain mostly unexplored, such as many types of agricultural residues, or waste derived fuels. Load flexibility, a key issue in large scale fossil fuel-fired units, can also be increased from biomass utilization, e.g. by direct or indirect co-firing.

R&D needs for industrial biomass applications are targeted towards increasing the fuel flexibility, use of new energy carriers like thermally treated biomass fuels as well as increasing the electrical efficiency component of the total CHP plant efficiency, leading to higher availability rates.

Furthermore, large-scale applications will require new technological solutions for reducing the environmental impact of biomass-to-energy schemes, e.g. through the reduction of gaseous pollutants, as well as the identification of new utilisation routes for process residues, such as biomass fly ash. There is substantial improvement potential of old and inefficient biomass units which already operate and if properly retrofitted, can be operated much more efficiently.

In addition to the production of Heating and Cooling, polygeneration technologies are also able to provide intermittent electricity, balancing both daily and seasonal changes of solar and wind electricity production and loads of boilers, increasing plant availability, peak load duration and economy. In the polygeneration process, several cross-cutting issues are taken into account in order to achieve the maximum utilisation of Biomass and to achieve high operational flexibility in renewable energy infrastructure.

Contribution of the Geothermal Technologies

Geothermal energy can provide heat in the low temperature range (less than 95 ºC including cooling) and because geothermal energy has definite base-load characteristics and is always available when required, it matches perfectly with stable demand patterns of most industrial processes. The annual full-load hours can be rather high, and thus the return on investment for the geothermal installation is favourable. In this form, geothermal heat is already used in agriculture/aquaculture (e.g. greenhouses), drying processes in the food industry, etc.

Another geothermal technology useful for industrial applications is underground thermal energy storage (UTES). In particular UTES at 40-90 °C can directly supply heat for low temperature industrial needs such as batch processes or seasonal industries (e.g. sugar refineries), where periods of heat (and/or cold) demand are followed by phases of inactivity.

Geothermal heat can also be used as operating energy for absorption chillers, to supply cooling to industrial processes. R&D priorities for UTES and absorption cooling are included among the cross-cutting technologies presented in this Chapter.

In the medium temperature range (95-250 °C), geothermal energy can provide heat above 95 °C from deep geothermal resources and from high-enthalpy geothermal resources. High enthalpy resources, some of which show temperatures over 250 °C, are used almost exclusively for the purpose of electric power production, but often with the cogeneration of heat in a combined heat and power system. Use of the heat for industrial purposes is also feasible. R&D will be required to provide for the right matching and adaptation of the geothermal heat source to the specific characteristics of the industrial process concerned.

For the heat source as such, most R&D needs are the same as for deep geothermal in DHC, as long as temperatures below about 120 °C are considered. As the temperature of the geothermal fluid increases, other problems need to be solved, like degassing of the fluid (pressure control), corrosion, and insufficient pump technology. It is also important to mention here the possibility of using Enhanced Geothermal Systems (EGS) to feed the heat requirements of many industrial processes or DHC, possibly in combination with electricity production (cogeneration or poly-generation).

All these developments require the support for a range of R&I actions and programs to enlarge our understanding of deep geothermal resources (mitigating the financial risks inherent in these types of projects), improve and decrease the cost of deep drilling, and also improve the surface systems. The launch of EGS flagship program to demonstrate the possibilities of this technology on a wide scale is also needed.

Contribution of the Cross-Cutting Technologies

Priority I (2014-2016) demonstration activities are needed for process integration, optimisation and control of industrial heat pumps. The work should focus on the development and demonstration of electrically and thermally driven heat pumps in individual industrial applications as well as in combination with district Heating and Cooling networks including thermal energy storage.

For priority II (2016-2018), demonstration activities to improve Underground Thermal Energy Storage (UTES) are encouraged (in the same context as mentioned in the Geothermal program). Improvement should address system concepts and operational characteristics of UTES systems, investigation of optimum integration of UTES into industrial processes and DHC systems. Research on new concepts for industrial heat pumps should look at exploring alternative thermodynamic cycles for heat-pumping and heat-transforming for different industrial applications with the goal of increasing the operating window of industrial heat pumps so that they can deliver heat at medium pressure steam levels (around 200˚C).

Priority III (2018-2020) activities are the development of advanced compression refrigeration cycles based on novel working fluids for use in medium temperature industrial applications (condensation temperatures up to 150 ˚C and evaporation temperatures up to 100 ˚C), and the improvement of sorption cooling from renewable energy sources. In this last topic, development is required for conversion technology for heat into cold, adapted to the characteristics of the renewable resource, e.g. to improve efficiency of low-temperature absorption chillers and decrease the necessary source temperature to activate the chiller.

3.2.4 RHC Research and Innovation for DHC/Smart Cities

Cities and districts account for most of the European demand for Heating and Cooling for residential and non-residential uses and it is clear that the extension and deployment of District Heating Systems will play a key role in reaching the objectives of an increased use of RHC resources instead of fossil fuels. In DHC applications the issues of cost, integration, and flexibility as well as storage are primary and RHC technologies must still evolve substantially to become a suitable choice in many cases.

Contribution of Solar Thermal Technologies

In Europe there are around 195 large-scale solar thermal plants for Heating and Cooling (≥ 500 m²; 350 kW_{th}) in operation with a total installed capacity of approximately 320 MW_{th}. The largest plants are located in Denmark with more than 25 plants exceeding 7 MW_{th} (10,000 m²) capacity, while the largest plant worldwide has an installed capacity of 23.3 MW_{th} (33,300 m²). These large-scale systems are mainly used for solar district heating which, in most countries, is a small and undeveloped niche market.

Solar heat costs for district heating systems vary a lot from about € 40 to € 190 per MWh, depending on the existing district heating infrastructure, e.g. due to the high share of district heating in Denmark the costs to connect solar thermal systems is low. The solar fraction has an impact on the resulting solar heat cost. This cost will be relatively lower if no additional hot water storage is needed for the solar thermal system at small solar fractions, and higher in solar thermal district heating systems with a significant solar fraction and very large central hot water storage of several thousand cubic meters.

Only 1% of the solar collector surface is currently connected to district heating systems, but a couple of central pilot solar heating plants with seasonal storage - mainly built in Scandinavia and Germany - have proved that these type of systems can reach high solar fractions (50% up to 100%). With the expected growth of district heating systems in densely populated urban areas, solar thermal systems will be able to contribute to the heat supply to these areas, though the roof area for collector installation is often not given in this areas.

Contribution of Biomass Technologies

In District Heating (DH) Systems, the retrofitting of old and inefficient boilers to become more effective at high availability rates, while increasing their fuel flexibility is a key challenge and priority in linking biomass and DH. The successful conversion of DH systems to operate on low carbon fuel sources can be seen in Scandinavia, where many DHC networks are already operating on biomass. In Sweden, around 65% of the final heat consumption came from solid biomass in 2010, 30% of which was DH[11]. This contributed greatly to a reduction in fossil fuel use in DH, with production of heat from oil dropping from 30.9 TWh in 1980 to 2.2 TWh in 2012, and coal from 12.9 TWh in 1986 to 2.7 TWh in 2012[12]. Biomass can be seen as the ideal transmission fuel to make existing fossil fuelled District Heating and Cooling (DHC) networks more sustainable. The work that

11 AEBIOM (2013), European Bioenergy Outlook, European Biomass Association, available online: http://www.aebiom.org/blog/category/publications/statistics/

12 Swedish Energy Agency (2014), Energy in Sweden – Facts and Figures 2014, available online: https://energimyndigheten.a-w2m.se/Home.mvc

has been done in Scandinavia to convert fossil fuel boilers to biomass units could be replicated especially in Eastern European countries, where comparable DH systems exist. On top of this, the integration of advanced control techniques to reduce energy consumption and losses in existing biomass CHP and DH plants can greatly increase the efficiency of these units. When looking to the planning of future biomass DHC networks, to further increase efficiencies and greatly reduce energy losses, efforts should be made to incorporate multiple enabling technologies, such as heat pumps, and storage at small and large scale.

There is significant potential for green communities to utilise currently unexploited local biomass sources. For example in agricultural communities where agricultural residues can be used. Additionally, synergies can be formed with other networks such as in the upgrading of biogas for use in the transport sector, the injecting of upgraded biogas into the natural gas grid, or in electricity generation from CHP units.

Contribution of Geothermal Technologies

Deep geothermal energy production is the relevant technology in this sector, mainly with direct heat supply through thermal water production and reinjection, but also using other technologies like deep borehole heat exchangers (BHE) or heat from geothermal CHP plants. The capacity of such installations can start from about 0.5 MW_{th} (in particular deep BHE) and may achieve values in excess of 10 MW_{th}. The heat could be fed directly into a district heating system if the production temperature matches the required supply temperature, or be used as a heat source for large heat pumps (including absorption heat pumps, engine-driven compression heat pumps, etc.). Cold production is also possible with absorption chillers driven by geothermal heat.

Taking advantage of further development in DHC technologies (including cascading and storage) will make it possible to use geothermal heat more efficiently. These technologies are not only suitable in combination with DHC networks, but can also be used for large individual buildings in the services sector or for industrial purposes. From the point of view of R&I actions needed, progress in geothermal DHC systems will benefit from all the measures mentioned in the context of industrial applications.

Contribution of Cross-Cutting Technologies

All applications, including DHC and smart-cities, will benefit from priority I (2014-2016) actions such as the large scale demonstration of smart thermal grids. Advanced DHC systems must be developed which are able to deal with both centralised and decentralised, hybrid sources (e.g. solar thermal, biomass, geothermal, heat pumps, waste heat, waste-to-energy, excess renewable electricity, storage). Additionally, smart metering and load management systems are needed for the integration of thermal and electrical grids into a liberalised energy market.

Such smart thermal grids have an important potential to meet the load balancing needs of combined heat and power production in a liberalised market for electricity. Also demonstration of electrically driven industrial heat pumps in district Heating and Cooling networks has been highlighted. Heat pumps are used to upgrade heat from low temperature sources to temperatures high enough for direct use in a DH network.

For priority II (2016-2018), the development of improved, highly efficient substations for both present and future lower temperature (below 70 ºC) networks, looking at harmonising substations standards, reducing materials cost, investing in the automation of manufacturing methods, and achieving good performances are identified. DHC networks need new harmonised EU standards for the overall system design and for hydraulic and electrical interconnections of different building components.

A topic with priority III (2018-2020) is the demonstration projects to show the feasibility of using in-house appliances which directly use thermal energy from the thermal district energy system, including an evaluation of different possibilities of DHW preparation (e.g. additional heating or direct heating without storage) considering the local energy systems framework needs to be made. Finally, further research activities at demonstration level are needed to allow DHC networks to efficiently integrate all types of RES without jeopardising the quality of the service provided to the consumers.

4.

SOCIETAL BENEFITS FROM RENEWABLE HEATING AND COOLING

RHC Renewable Heating & Cooling
European Technology Platform

4 SOCIETAL BENEFITS FROM RENEWABLE HEATING AND COOLING

Today's fossil fuel dominated energy supply for Heating and Cooling is unsustainable from an economic, environmental, and social point of view. To highlight the dominance of fossil fuels, the Figure below shows the distribution of fuels that contributed to the gross heat generation in the EU-27 in 2011. According to these figures, 42.8% of this heat was generated by gases, 28.5% by solid fuels, 16.5% by renewables, 6.1% by petroleum and products, 0.2% by nuclear, and 5.9% by other sources[13].

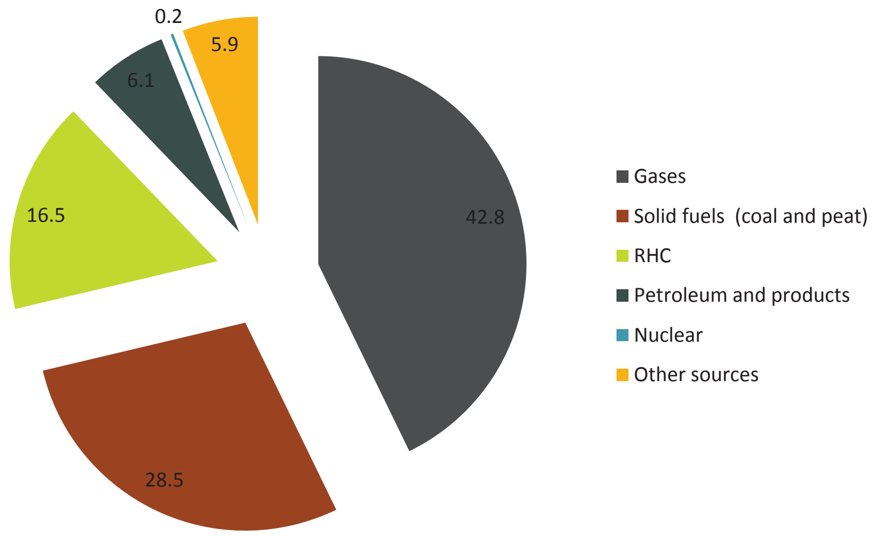

Figure 4: Fuel mix in the heat sector in the EU-27, 2011 (%).EU Energy in figures, Statistical Pocketbook 2013

Through the use of Renewable Energy Sources, heat and cold generation will become sustainable and secure with significant societal benefits. The RHC-Platform's Common Vision showed that the share of heat generated by renewable energy could be increased to 148 Mtoe in 2020 in comparison to some 82 Mtoe in 2012[14]. However, this requires stronger political support to boost the RHC sector in research and innovation as well as in market deployment.

In line with the three objectives of the EU energy policy, security of supply, competitiveness, and sustainability, this Chapter explores some of the short-term societal benefits expected to be realised through the implementation of this Common Roadmap and the relevant market deployment policies.

4.1 SECURITY OF ENERGY SUPPLY AND THE BALANCE OF TRADE

4.1.1 Improving EU's security of supply

53% of the energy consumed in the EU is imported. Energy import dependency relates to crude oil (almost 90%), natural gas (66%), and to a lesser extent, solid fuels (42%). The most pressing security of energy supply issue is the strong dependence on a single external supplier. As stressed by the European Commission in its Communication on a European Energy Security

[13] EU Energy in figures, Statistical Pocketbook (2013a), p. 99, the share of renewable differs slightly from the official reported share of renewable energy on heating and cooling due to statistical definitions.

[14] EUROSTAT, http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database.

Strategy, this is particularly true for gas[15], of which a very significant share is used for heating in the building sector[16].

Furthermore, domestic conventional gas production in EU Member States, originating mainly from mature production basins, has decreased by 25% over the last decade. In the same period, the overall EU gas consumption has increased by 10%[17]. Consequently, the import dependency rate for natural gas increased from 47.1% in 2001 to 65.8% in 2012[18].

However, as shown in Figure 5, the gross heat generation from gases has more or less stagnated over the last decade following a strong increase in the 1990s, while the use of solid fuels as well as petroleum and related products significantly decreased over the last 20 years. Only renewables have had a continued increase since 1990.

As the security of supply of natural gas becomes increasingly critical, the only secure way to reduce import dependency in the heating sector is to further accelerate the deployment of Renewable Energy for Heating and Cooling. Given the variety of renewable energy sources (e.g. biomass, geothermal, solar thermal, as well as in hybrid systems), EU member states will further benefit from an increased security of supply through the diversification of the energy sources used, when compared with today's fossil fuel dominated energy mix.

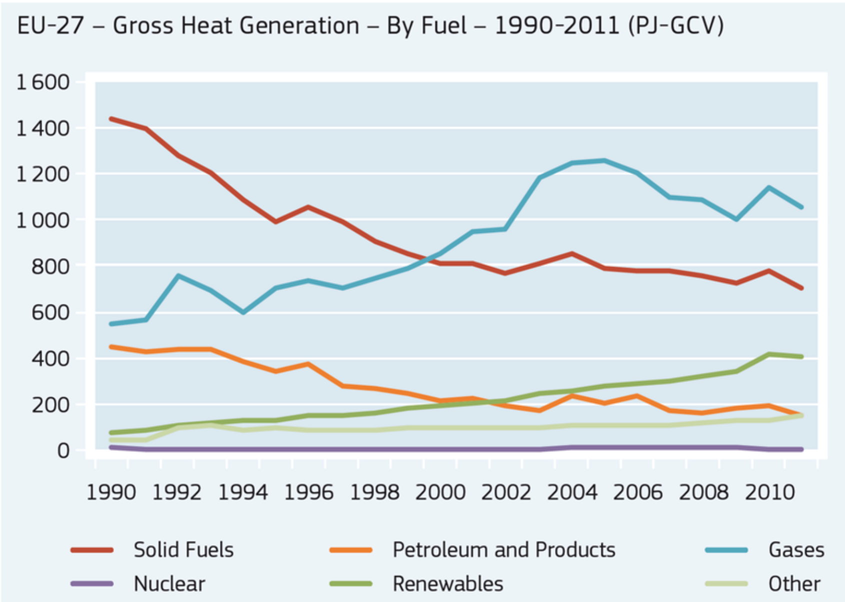

Figure 5: EU-27 – Gross Heat Generation by Fuel 1990 – 2011 (PJ-GCV) (GCV = Gross Calorific Value), renewable energy shows the strongest increase[19]

4.1.2 Saving EUR 49.8 billion in reduced fossil fuel imports

As a result of this energy dependency, the EU has a strong trade deficit in energy products with non-EU countries, which reached EUR 421 billion (3.3% of EU GDP) in 2012. The EU spent EUR 545 billion on the import of energy products from outside the EU, while extra-EU exports in this category amounted to EUR 124 billion. The deficit has increased in recent years, growing from just EUR 150 billion in 2004 (at current prices)[20].

According to the European Commission, the avoided costs of imported fuels, replaced by biomass used for heating, amounted to EUR 12.2 billion in 2010[21]. By increasing the share of RHC to 148 Mtoe in 2020 as described in the RHC Common Vision, we could therefore produce some additional 65 Mtoe from RHC compared to 2012. If this amount of heat generated by

15 European Commission (2014c), Communication from the Commission to the European Parliament and the Council, European Energy Security Strategy, p.2.

16 Natural gas is mainly used two sectors, i.e. 41% for heating of buildings (185 Bcm) and 31% in industrial processes (142 Bcm) and to a lesser extent in power plants (25% or 112 Bcm). Source: Eurogas Statistical Report 2013, p.5.

17 European Commission (2013b), "Member States' Energy Dependence: An Indicator-Based Assessment", Occasional Papers 145, p. 14.

18 EUROSTAT, http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

19 EU Energy in figures, Statistical Pocketbook (2013).

20 European Commission (2014a), Directorate-General for Economic and Financial Affairs, "Energy Economic Developments in Europe", European Economy 1/2014, p.112.

21 European Commission (2014a), p.116

renewable energy in 2020 would replace natural gas imports, the EU could save as much as EUR 49.8 billion in avoided costs of imported fuels. This is based on the assumption that the renewable energy consumption substituted imported natural gas at current average import prices ($11.5/ MMBtu or EUR 8.4/MMBtu)[22]. Taking into account that the price of fossil fuel are set to increase (see next section), the avoided costs could be much higher.

The results of the NREAPs (21.4% RHC) and RHC Common Vision scenarios are depicted in Figure 6 below; the evidence is overwhelming: RHC technologies, together with energy efficiency, stand out as a key factor to ensure security of energy supply, reducing foreign energy dependency.

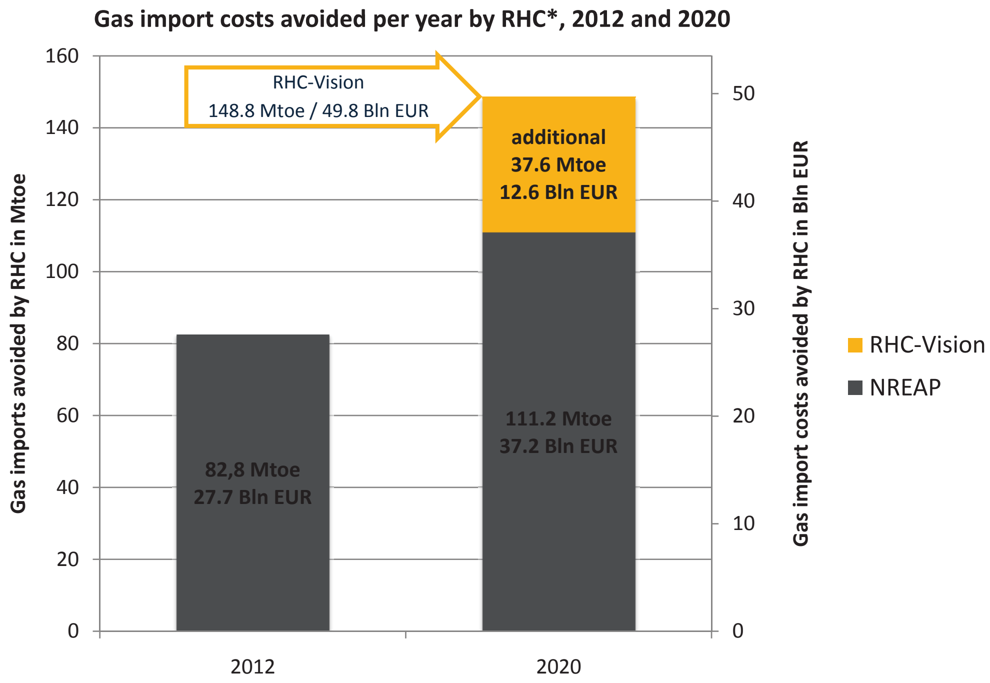

Figure 6: Gas import costs avoided per year by RHC, if the heat generated by RHC technologies would be generated by imported gas only (assumptions: gas import price 8.44 EUR/MMBtu, no price increase between 2012 and 2020)

4.2 COMPETITIVENESS

4.2.1 Stabilising energy prices

The price of electricity and fossil fuels has been significantly rising over the last years. According to European Commission's analysis, between 2004 and 2011 average household gas prices have increased by 77% over the same period compared to 50% for electricity, whereas average industrial prices have more than doubled compared to a 53% increase in industrial electricity prices[23].

Under the business-as-usual scenario of the European Commission, fossil fuels and electricity will become even more expensive in the future: between 2010 and 2020 oil and gas prices for heating will increase by 38% and 47% respectively, while average electricity prices are projected to increase by 31% in real terms between 2010 and 2030, from 131 to 172 €/MWh[24].

In this framework, it is worth highlighting that in most cases, today's business environment does not reflect the real costs of producing heat. Indeed, in most EU countries there is no carbon price for heat fuels (the sector is mainly made of installations below 20 MW and therefore largely falls under the non-ETS sector). The main consequence is that the end-user price of conventional sources of energy is always lower than the real costs to society.

22 In January 2014; Source: World Bank.

23 European Commission, (2014a), pp.58-59

24 European Commission (2014b), "Impact Assessment on energy and climate policy up to 2030", SWD(2014)15, pp.28-29.

Against this background, it is clear that wherever RHC technologies are able to provide a competitive alternative to fossil sources or direct electric heating solutions, price volatility is reduced and a more stable market to European consumers is ensured. Therefore, increasing the share of Heating and Cooling from renewable energy means reducing dependency on volatile fossil fuel prices and replacing price uncertainty (with a high probability of increasing prices) with stable and even decreased energy prices for RHC technology.

4.2.2 Creating local and sustainable jobs

A 2009 study by the bank HSBC[25] concluded that the three most promising sectors in terms of social return, job creation and relevance to the economic recovery are Renewable Energy, Building Efficiency, and Sustainable Vehicles. Based on a wide review of studies, mainly taken from the 2013 report "Renewable energy and jobs" by the International Renewable Energy Agency (IRENA), it is possible to estimate the following figures in terms of direct and indirect jobs:

ESTIMATE OF DIRECT AND INDIRECT EMPLOYMENT IN THE RHC SECTOR (THOUSANDS JOBS)				
Sector	Germany	Spain	Other EU	Total EU
Biomass and biogas (including for electricity)	107	40	198	345
Geothermal (including for electricity)	14	0.3	37	51.3
Solar Thermal	11	1	20	32
Heat Pumps (excl. geoth.) (source: EHPA, 2014)	-	-	-	41. 8
Total	132	41.3	255	470.1

Table 16: Estimate of direct and indirect employment in the RHC sector. Source: IRENA, EHPA[26]

With an accelerated deployment of RHC technologies, these numbers are expected to grow substantially. Heating and Cooling supply and demand is, by nature, local. This means that an important part of the value chain leads to local jobs in the planning, installing and maintaining of RHC systems. The manufacture of RHC technology hardware is mainly located in Europe, since the RHC systems and technology used in the different European markets are much more adapted to local requirements than in the electricity or transport sector. Therefore, detailed knowledge of national and regional markets is necessary for successful market penetration. This is why there are only minor imports of (fossil as well as renewable) heating technology to the European market. European technological leadership can be exported worldwide.

4.2.3 Fostering European industrial leadership

Supporting technological development in RHC technologies shall ensure that Europe retains its status as a world leader in the manufacturing and design of most RHC technologies, reinforcing its main competitive strengths and the high quality of its technologies. The following sections provide an overview for each RHC segment.

25 IRENA, Renewable energy and jobs, 2013.

26 HSBC, A Climate for Recovery. 25th February 2009.

Solar Thermal. China is the largest solar thermal market worldwide, representing 152.2 GW_{th} total operational installed capacity, which accounted for 65% of the total global operational installed capacity (234.6 GW_{th}) at the end of 2011[27]. Europe, with an installed capacity of 39.3 GW_{th}, represents 16.7% of this total. Since most of the solar thermal components are produced locally in China and Europe, China is the largest manufacturer in the world. However, the European Solar Thermal Industry is still seen as the technology leader with a strong innovation capacity. While in China, mainly simple systems for domestic hot water heating are installed, the European industry is providing a huge variety of products for domestic hot water, space heating, Solar-Active-Houses, solar systems for industrial processes, solar district heating, and solar cooling systems.

Biomass. The EU, together with the United States and Brazil (mainly for ethanol), is a dominant producer and employs the largest number of workers in the sector (345 thousand according to IRENA). As agricultural and forestry operations play a large role in the sector, bioenergy can support rural economic development as cultivation and harvesting biomass feedstock require large numbers of people.

To date, technically reliable, sustainable and economically attractive biomass heat solutions already exist. Biogas and solid biomass can already provide heat at temperatures above 250°C at costs competitive with fossil fuel alternatives. In the coming years, these solutions will continue to improve and new solutions should also be available in order to cover the different consumption types. With biomass supply set to increase significantly by 2020, a sustainable, innovative and cost-efficient advanced biomass feedstock supply will bring reductions in supply costs and a decrease in production costs.

The EU is a global leader in biomass technologies and provides a wide range of high quality biomass harvesting technology and conversion installations with high efficiency, controlled and clean combustion, and automated operation and modulation both for domestic and commercial uses. Through a permanent commitment in innovation and R&D, the European biomass industry keeps improving the quality of the products that are put to the market. To give an example, the most performant EU biomass small-scale boilers and stoves can today reach 90% energy efficiency with very low emission levels (NO_x, SO_x and particulate matters emission). Europe is also world leading manufacturer in large scale combustion technology e.g. fluidised bed combustion technology and large scale CHP plants.

Geothermal. With 1.2 million GSHP[28] units installed, Europe is the world leader, in terms of installed capacity, in the shallow geothermal market. It is also leading in innovation such as in underground thermal energy storage, with the main competition coming from heat pump manufacturers in China and the USA. With more than 200 geothermal district heating systems in operation, Europe is also the global leader in geothermal district heating where global competition exists mainly for heat exchangers and pipes. Regarding direct uses, even though this geothermal sector started in Europe, China is now leading the market due to the large demand there. Last but not least, EGS plants are so far only in operation in Europe, whereas research projects are on-going in the U.S. and Australia.

In the EU, employment in the geothermal sector appears to be fairly stable at about 50 thousand direct and indirect jobs, mostly in heat-related applications[29]. As geothermal technologies are site specific (geology is different all over Europe) and capital-intensive, many geothermal companies have developed customised products (for example: drilling rig manufacturers). The sector will move from a geological approach to an engineering approach where systems can be replicated but can hardly be industrialised. Because of the nature of the work, we can assume that construction and O&M cannot be relocated, meaning that they are truly 'European' jobs. Regarding equipment (rigs, turbines), the number of large manufacturers is not forecasted to boom internationally.

Heat Pumps. European heat pump manufacturers are often technology leaders. They benefit from strong know-how in R&D and from a developed value chain. While development and installation are truly local, sourcing is increasingly becoming global.

Today's market penetration of heat pumps is providing considerable, mostly local, employment.

27 European Commission, Solar Heat Worldwide: Markets and Contribution to the Energy Supply 2011. Edition 2013

28 GSHP = Ground Source Heat Pump

29 EurObserv'ER, 2012

An increased market share will contribute to this even further. An estimation on the total required employment to manufacture, install and maintain the 769,790 heat pump units sold in Europe in 2013 reveals that more 41,800 people full time employees are necessary (Source: EHPA 2014). However, this is a conservative estimation, as many employees are not working full-time on heat pump technology. Hence, the total amount of employees in this segment is certainly larger.

A large proportion of the employees needed are already active in the heating sector. For this reason, an up-skilling of the workforce towards obtaining the necessary knowledge to plan, install, and maintain heat pump technology is necessary. This particularly requires a better understanding of a building's energy demand and the influence of climate differences and user behaviour on the performance of the whole system. The majority of employers are local to Europe, as development, manufacturing and installation are located on the continent.

The European Industry has invested heavily in research and development, as well as in the education activities of the work force. Recent legislation such as Ecodesign (for heaters) and the F-gas regulation require more intense efforts; systems can and will be optimised, heating systems will have to be integrated into the larger energy landscape, in particular integrating renewable electricity via improved controls, and new refrigerants need to be developed. This requires in particular new laboratory capacity for the development of low GWP refrigerants, components and systems.

The European industry and the EU research arena are prepared for future market growth; it has invested in laboratory and manufacturing capacity over the past three years and is ready to continue to do so. This engagement should encourage further public funding.

District Heating and Cooling. District Heating has been well established in Europe for decades, and a large manufacturing sector - comprised of a diverse mix of local SMEs and global industrial players – has grown up around it. Europe remains the clear world leader within the global District Heating and Cooling sectors, both with regards to overall network design, performance and management, and with respect to technical components within systems and at the level of the interface with buildings. European know-how and products are exported to facilitate the development of DHC networks around the world, particularly in China and Russia.

Continued investment in R&D, both by operators within the sector and via the public sector, will help ensure that this leadership position is maintained. It is expected that District Cooling will cover an important share of the cooling demand in the coming decade in not only Europe, but in newly developed countries like Brazil, India, etc. where there is huge potential for penetration.

4.3 SUSTAINABILITY

As highlighted in the European Commission's Energy Roadmap 2050[30], Renewable Heating and Cooling will be vital to decarbonisation. Additionally, increasing the share of RHC in the EU will reduce the combustion of fossil fuels and therefore improve the air quality, especially in urban areas. Indeed, a reduction in emissions of pollutants such as nitrogen oxides, sulphur dioxide, heavy metals, etc. from reduced fossil fuel consumption has significant positive impacts on human health and lowers costs for air pollution control with benefits being disproportionately larger in lower income Member States, expressed as a % of GPD[31].

It would be worth assessing the abatement costs as well as the monetised health benefits from fuel substitution in the Heating and Cooling sector (industry, residential and non-residential) compared to other sectors such as electricity or other options like deep renovation of buildings.

In conclusion, decarbonising our energy sector should not be regarded as a burden, but rather as an opportunity for Europe's sustainable growth and industrial renaissance alike. Policy-makers should look at the overall benefits to society as clear commitments on RHC and energy efficiency will substantially alleviate EU's energy dependency, while improving our balance of trade, creating a significant amount of new local jobs and ensure stable and affordable energy prices to our consumers and industries.

30 European Commission (2011), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions "Energy Roadmap 2050", COM (2011) 885.

31 European Commission, (2014b), p.126-127.

5.

PROMOTING PUBLIC AND PRIVATE INVESTMENTS

in Research & Innovation and market deployment

RHC Renewable Heating & Cooling
European Technology Platform

5 PROMOTING PUBLIC AND PRIVATE INVESTMENTS IN RESEARCH & INNOVATION AND MARKET DEPLOYMENT

5.1 FINANCING THE RESEARCH & INNOVATION INVESTMENTS OF THE RHC INDUSTRY

The Strategic Research and Innovation Agenda (SRIA)[32] estimates that over the period 2014 - 2020, 4,032 mln EUR is required for research and innovation projects in order to successfully implement the SRIA; an average of 576 mln EUR annually. These resources are expected to come from industry (private sector) (60%), European Commission (20%) and Member States (20%).

In the RHC sector, typically 1%-4% of a company's turnover is invested back into research and innovation, depending on the type of industry and the position in the value chain.[33] The R&I budget calculated in the SRIA corresponds to the turnover generated by the expected market deployment. For this reason, the investment from the RHC industry in R&I is mainly dependent on market development and market perspectives, in turn dependent on public support. That said, some companies also look to finance their R&I projects on the capital markets, in which case R&I financing tools are also supportive.

5.2 STIMULATION OF MARKET DEPLOYMENT

Financing the market deployment of RHC, i.e. the installation of RHC systems, presents a significant challenge. In order to stimulate market growth in accordance with the RHC-Platform's Common Vision (2011), concepts and tools must be developed to encourage private investment in these technologies.

Usually it is not the unavailability of funds that hampers the investment but the attractiveness and competitiveness of the RHC-technology in comparison to fossil fuel based systems. For this reason it is necessary to both strengthen R&I investments and increase the budget for R&I projects, and strengthen the market deployment policy for RHC technology.

There are several instruments available to support RHC deployment. Their use varies largely from country to country and from technology to technology. However, it is always vital to focus on the quality of design and implementation, the correct setting, and the fine-tuning of the scheme, adapting it to the specific situation. The key quality aspects of a financial instrument are its continuity (no 'stop and go'), the coherence of the parameters, a clear target, quality criteria, a monitoring and evaluation system, simplicity of application and payment procedures, and flanking measures.[34]

The primary objective of financial incentive schemes is to compensate for market failures and unfair competition. They are also intended to favour the deployment of a given technology by creating a secure investment environment catalysing an initial round of funding and thereby allowing the technology to progress along its learning curve. Hence, support schemes should be temporary and can be phased out as a technology reaches full competitiveness in what will, at that stage, be a complete and open internal market where a level playing field is fully established.

In certain European states, many of the currently available financial support instruments for RHC technologies come in the form of investment aid (grants, loans and tax exemptions) and operational aid, while other financial incentives such as soft loans are less available.[35] Generally these types of incentives are funded from government budgets:

Grants. A grant is a direct support to project investment provided by a public authority and can be offered either to the investor/developer or to the manufacturer, thus reducing their

32 European Technology Platform on Renewable Heating & Cooling (RHC-Platform) (2013), Strategic Research and Innovation Agenda for Renewable Heating and Cooling (SRIA) p. 86 and 87.

33 See also SRIA, p. 86

34 See for example ESTIF (2006), Key Issues for Renewable Heat in Europe (K4RES-H) - Financial Incentives for Solar Thermal, page 19.

35 See Ecofys, Fraunhofer ISI, TU Vienna EEG, Ernst &Young (2011), Financing Renewable Energy in the European Energy Market.

investment costs. This is a very common type of support provided in a number of European countries by local, regional and national governments. As the budget is usually bound, the number of accepted applications is limited, which restricts further market growth. Grants could actually also provide cash payments based on the energy generation basis, however this latter scheme is not yet frequently implemented.

Operational aid. Feed-in tariffs: a fixed financial payment per unit of heat from renewable energy, or for feed-in premiums: a fixed or variable financial bonus for the green value of the renewable heat produced.

Fiscal incentives. A fiscal benefit such as a tax reduction has the advantage of not being tied to a limited budget and therefore a restricted number of accepted applications. However, such a reduction in tax will usually only take effect a year or two following the completion of the project, which for some investors is less attractive than a grant.

The structure of the RHC market differs a lot from the electricity market as the heat produced usually cannot be sold to the market since there is not one grid connecting all producers and consumers to one market. Usually in the Heating and Cooling market, the supply and demand are local, and the supply system tends to be individually designed for each consumer. An exception however, is District Heating grids, which serve a larger number of consumers. Concepts are currently being developed to allow the feed-in of RHC to the DH grid, however, since this will be limited to, and dependent on periods of heat demand, it is highly challenging to develop an attractive business model.

To conclude, financing RHC projects on the capital market and through institutional investors usually means financing companies that develop local solutions for heat supply, e.g. contracting projects for large multifamily homes, commercial buildings or factories, or District Heating systems with RHC technology.

5.3 INVESTMENTS AND MARKET BARRIERS

Beside the general need for increased public support, there are barriers which are hindering the scaling up of private financing in RHC.

Regulatory instability. As investments in RHC are highly dependent on a stable and predictable policy framework, part of the problem can be attributed to a lack of clarity and consistency in commitments from policy-makers. This uncertainty increases the risk and consequently the cost of these investments whose returns must be commercially competitive with existing investments in more polluting technologies.[36]

Lack of investor capability and shortage of data. Given the relative immaturity of the RHC market compared to traditional energy markets, investors may lack adequate expertise or even confidence in the RHC sector. Capital investments into RHC cannot be valued by a pure investment specialist if the liquidity (marketability) of the investment is very limited and the evaluation, according to the standard investment of insurance companies and pension funds, is still difficult. Most institutional investors do not invest in sectors that do not provide years of track records on performance data. The consequence for these aspects is that higher risks are included in project evaluations requiring a higher Return on Investment (ROI) to compensate for the risk.

Market fragmentation and scale problems. For the investor it is challenging to find companies that deal holistically with the issue of implementation, or to build up a network of manufacturers, planners, etc. to actualise the investment. For a company looking for capital it can be hard to mobilise funds due to the small size of the installations (e.g. solar thermal collectors or modern biomass heating systems at household level). Transaction costs and assessment and monitoring of energy savings are complex on the smaller scale and thus proportionally more expensive than in bigger projects.

[36] For examples, see discussion on social tariffs and carbon price in chapter 4.

High upfront costs. Renewable energy technologies such as solar thermal and geothermal energy have low running costs but require a high upfront investment when compared to conventional technologies. The decision of whether to go for a new RHC investment is closely linked to the cost of available capital and this is particularly challenging for private home-owners and small business owners. Most subsidy programs are dedicated towards SMEs and municipalities, so outside these groups, major investors also need additional investment sources and subsidies to overcome the high upfront costs.

Diverging investment criteria and split incentives. In some market segments, regulation hampers the development of business models. A classic example is the 'landlord-tenant problem', where the landlord provides the tenant with a heating system but the tenant is responsible for paying the energy bills; similarly, incentives diverge between the real estate developer and the buyer/owner.

Non-inclusion of external costs. The lack of competitiveness of RHC projects is not only due to the (relative) high costs of RHC technologies, but also to the subsidised prices of fossil fuels. Tariffs from traditional energy sources usually do not include external costs, e.g. carbon emissions, pollution, gas infrastructure, etc. A carbon tax, which could partly compensate for this disadvantage, is in place in only a limited number of Member States. In certain cases, such as Finland, Sweden, and Denmark, such a scheme has proven to be very successful for the market uptake of RES and energy efficiency.

To offer an example, five factors have been identified that limit the attractiveness of investment in biomass projects.[36] These were regulation: the need for long term confidence in the stability of the incentive regime, fuel availability: long term contractual arrangements between bioenergy plants and suppliers do not allow market liquidity, sustainability credentials: the need for biomass to be sustainably sourced with an overall lower carbon footprint than fossil fuels, supply chain: investment in biomass handling, logistics, port and rail facilities will be critical, financing: biomass projects must offer attractive ROI to potential investors.

5.4 ACTIONS TO ENABLE AND IMPROVE PRIVATE INVESTMENTS IN RHC

The following actions could be carried out by policy-makers, public financial institutions, RHC stakeholders and the investor community to remove or weaken some of the barriers presented, and to accelerate the scaling up of private investments in RHC.

A profitable investment opportunity and stable investment environment should be provided. The best way to mobilise private finance is to ensure the attractive profitability for the investment and create a long-term stable investment and regulatory environment in order to boost investor confidence. A long-term support strategy, consisting of a financial incentive scheme with stable framework conditions and suitable flanking measures (especially awareness raising, and training of professionals) has shown to have the highest impact on market growth.

Improving risk perception and addressing lack of knowledge. Risks in RHC are in many cases perceived to be higher than they are in reality. However, performance data on investments is becoming available thanks to pilot plants and growing markets. There is a need to address lack of knowledge by improving data flows and the understanding of sustainable energy investments by banks, financial institutions, investors etc. Some examples of recommended actions are, for example, establishing networks between finance, RHC industry and technology providers, and fostering training for banking and insurance company agents related to RHC technologies to support the development of appropriate financing products. It would also be beneficial to develop a pipeline of flagship projects and model innovative financing solutions to gain investor confidence and enable standardisation and aggregation.

Standardisation aspects. Markets would gain from more harmonisation and cross compliance and from strengthening energy performance certificates, energy codes and legislative enforcement. However, the indicators must not be too complex, and the certification process

[36] Deloitte, Knock on Wood (2012), Is Biomass the Answer to 2020?

not too demanding or costly. For example, the market penetration of efficient hybrid systems could be supported by improving energy performance labels, which should be required for all new Heating and Cooling systems in the EU by 2020. The information provided should not only include the relative efficiency, but also the annual running cost, greenhouse gas emissions and the expected system lifetime.[37]

Development of frameworks for standardisation and benchmarking is also important for the financing party: standardisation of measurement and verification for project evaluations will reduce risk perception, increase reliability and certainty. Measurement and verification approaches in the different European countries should be assessed in order to harmonise calculation methodologies.

5.5 BUSINESS MODELS

In addition to the need for financial support schemes, new business models are required to facilitate deployment in the sector. A number of new approaches have been identified and are described in more detail below.

Energy Service Company (ESCO) models. An ESCO invests in the heat generator, the heating infrastructure and sometimes in efficiency measures on behalf of the building owner. The investment is refinanced by selling the heat. ESCOs are particularly interesting for large commercial, residential and public buildings[38].

Two business models can be distinguished:

- Energy Supply Contracting (ESC): The ESCO is paid for each kWh heat supplied at a fixed heat price in the contractual period. The more efficient and cheaper the heat generation is, the higher the profit of the ESCO; RHC units are usually only integrated if they are cost effective.
- Energy Performance Contracting (EPC): The ESCO invests in an efficient heat generation and other efficiency measures and guarantees energy cost savings in comparison to an energy cost baseline. For its services and the savings guarantee, the ESCO receives a performance based remuneration.

District Heating and Cooling. There are monetary advantages for District Heating and Cooling compared to decentralised RES (economy of scale, logistics etc.) since DHC generation could be located in areas apart from the customer's premises. DHC is an existing business model to serve the request for the up-scaling RHC investments into a size that is interesting for institutional investors.

With the advent of low-energy houses, each customer will consume less heat and some consumers will produce their own heat. All these aspects will lead to a new way of operating the networks, allowing less investment in the production side and a smoother delivery flow for the benefit of the energy system and its customers. The DHC industry needs to adopt new business models to remain profitable even if less heat is sold. These new models should incentivise energy savings, delivering capacity and flexibility rather than delivering energy, and in general support more the integration of strategic thinking and sustainability objectives in the decision making processes.

Additionally, there are further solutions that can be particularly interesting to small residential and commercial buildings:

Property Assessed Clean Energy (PACE). PACE financing allows property owners to borrow money from a local government to pay for renewables and efficiency measures. The amount borrowed is typically repaid via a special assessment on property taxes over a period of 15 to 20 years through an increase in their property tax bills.

[37] European Technology Platform on Renewable Heating & Cooling (RHC-Platform) (2013), Strategic Research and Innovation Agenda for Renewable Heating and Cooling.

[38] See also ECN, IEA-RETD (2012), Business models for renewable energy in the built environment.

Business models for rental market. In order to overcome the 'landlord-tenant problem', where the landlord provides the tenant with a heating system but the tenant is responsible for paying the energy bills, a change in legislation could allow building owners to pass on the cost of the investment to the tenant through a rent increase. The cost reduction in the energy bill should be at least the same as the rent increase for the tenants. This model has the advantage to work well for existing buildings whereas building codes tend to be limited to new buildings and substantial renovations.[39]

On-Bill Repayment. The On-Bill Repayment business model foresees that the utility provides capital to a home owner for RHC installations by having them repaid in the energy or tax bill. Track record of customer payments with utilities and tax authorities have low default rates compared to other consumer finance.

Finally, there is an additional range of financial instruments with various terms (credit enhancement measures, low interest loans and/or loan guarantees, green bonds, Equity Investments in RES, and Efficiency funds etc.) which are or could be addressed in the promotion of RHC investments. Particular examples can be seen in the lending activities of the European Investment Bank in the Renewable Energy sector, even though most of the projects are related to electricity production. However, these financial instruments have thus far rarely been used in the RHC sector; they must be adapted to the specific conditions (including framework conditions) for RHC projects and investors in order to be supportive to market deployment.

39 Ibid.

APPENDIX 1 **References**

- AEBIOM (2013), European Bioenergy Outlook, European Biomass Association, available online: http://www.aebiom.org/blog/category/publications/statistics/.
- AEBIOM (2013), European Bioenergy Outlook, European Biomass Association, available online: http://www.aebiom.org/blog/category/publications/statistics/.
- Deloitte, Knock on Wood (2012), Is Biomass the Answer to 2020?
- ECN, IEA-RETD (2012), Business models for renewable energy in the built environment. Available at http://www.ecn.nl/docs/library/report/2012/e12014.pdf , last accessed June 2014.
- Ecofys, Fraunhofer ISI, TU Vienna EEG, Ernst &Young (2011), Financing Renewable Energy in the European Energy Market. Available at http://ec.europa.eu/energy/renewables/studies/doc/renewables/2011_financing_renewable.pdf , last accessed June 2014.
- Energy Efficiency Financial Institutions Group (2014), Energy Efficiency – the first fuel for the EU Economy, How to drive new finance for energy efficiency investments. Available at http://www.unepfi.org/fileadmin/publications/investment/2014_fig_how_drive_finance_for_economy.pdf, last accessed June 2014.
- ESTIF (2006), Key Issues for Renewable Heat in Europe (K4RES-H) - Financial Incentives for Solar Thermal.
- Eurogas (2013), Statistical Report 2013.
- European Commission (2011), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions “Energy Roadmap 2050”, COM(2011)885.
- European Commission (2013a), EU Energy in Figures: Statistical Pocketbook 2013, Luxembourg: Publications Office of the European Union.
- European Commission(2013b), “Member States’ Energy Dependence: An Indicator-Based Assessment”, Occasional Papers 145.
- European Commission (2014a), Directorate-General for Economic and Financial Affairs, Energy Economic Developments in Europe, European Economy 1/2014.
- European Commission (2014b), Impact Assessment on energy and climate policy up to 2030, SWD(2014)15.
- European Commission (2014c), Communication from the Commission to the European Parliament and the Council on European Energy Security Strategy COM(2014)330.
- HSBC Global Research (2009), A Climate for Recovery.
- IRENA (2014), Renewable energy and jobs 2013.

- OECD/IEA (2012) , Policies for renewable heat . Available at: http://www.iea.org/publications/insights/insightpublications/Insights_Renewable_Heat_FINAL_WEB.pdf, last accessed June 2014.
- RHC-Platform (2011), Common Vision for the Renewable Heating and Cooling sector in Europe: 2020-2030–2050. Luxembourg: Publications Office of the European Union. Available at http://www.rhc-platform.org/publications/.
- RHC-Platform (2012a), Strategic Research Priorities for Solar Thermal Technology, Brussels. Available at http://www.rhc-platform.org/publications/.
- RHC-Platform (2012b), Strategic Research Priorities for Geothermal Technology, Brussels. Available at http://www.rhc-platform.org/publications/.
- RHC-Platform (2012c), Strategic Research Priorities for Biomass Technology, Brussels. Available at http://www.rhc-platform.org/publications/.
- RHC-Platform (2012d), Strategic Research Priorities for Renewable Heating & Cooling Cross-cutting Technology, Brussels. Available at http://www.rhc-platform.org/publications/.
- RHC-Platform (2013), Strategic Research and Innovation Agenda for Renewable Heating and Cooling. Luxembourg: Publications Office of the European Union. Available at http://www.rhc-platform.org/publications/.
- RHC-Platform (2014a), Solar Thermal Technology Roadmap, Brussels. Available at http://www.rhc-platform.org/publications/.
- RHC-Platform (2014b), Geothermal Technology Roadmap, Brussels. Available at http://www.rhc-platform.org/publications/.
- RHC-Platform (2014c), Biomass Technology Roadmap, Brussels. Available at http://www.rhc-platform.org/publications/.
- RHC-Platform (2014d), Cross-Cutting Technology Roadmap, Brussels. Available at http://www.rhc-platform.org/publications/.
- Solar Heat Worldwide (2013) Markets and Contribution to the Energy Supply 2011.
- Swedish Energy Agency (2014), Energy in Sweden – Facts and Figures 2014, available at: https://energimyndigheten.a-w2m.se/Home.mvc.

APPENDIX 2 Scale of Technology Readiness Levels (TRL) adopted by the RHC-Platform[40]

TRL 1: Basic principles observed
The initial scientific research has been completed. The basic principles of the idea have been qualitatively postulated and observed. The process outlines have been identified. No experimental proof and detailed analysis are yet available.

TRL 2: Technology concept formulated
The technology concept, its application and its implementation have been formulated. The development roadmap is outlined. Studies and small experiments provide a "proof of concept" for the technology concepts.

TRL 3: Experimental proof of concept
The first laboratory experiments have been completed. The concept and the processes have been proven at laboratory scale, table-top experiments.

TRL 4: Technology validated in lab
A small scale prototype development unit has been built in a laboratory and controlled environment. Operations have provided data to identify potential up scaling and operational issues. Measurements validate analytical predictions of the separate elements of the technology. Simulation of the processes has been validated.

TRL 5: Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
The technology, a large scale prototype development unit, has been qualified through testing in intended environment, simulated or actual. The new hardware is ready for first use. Process modelling (technical and economic) is refined. LCA and economy assessment models have been validated. Where it is relevant for further up scaling the following issues have been identified: health & safety, environmental constraints, regulation, and resources availability.

TRL 6: Technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
The components and the process, the prototype system, have been up scaled to prove the industrial potential and its integration within the energy system. Hardware has been modified and up scaled. Most of the issues identified earlier have been resolved. Full commercial scale system has been identified and modelled. LCA and economic assessments have been refined.

TRL 7: System prototype demonstration in operational environment
The technology has been proven to work and operate a pre-commercial scale – a demonstration system. Final operational and manufacturing issues have been identified. Minor technology issues have been solved. LCA and economic assessments have been refined.

TRL 8: System complete and qualified
The technology has been proven to work at a commercial level through a full scale application. All operational and manufacturing issues have been solved.

TRL 9: Actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)
The technology has been fully developed and is commercially available for any consumers.

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40 The present scale of Technology readiness levels (TRL) is based on HORIZON 2020 – WORK PROGRAMME 2014-2015, General Annexes, G. Technology readiness levels (TRL), available at http://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf . The description of the TRLs is based on the related FAQs, available at http://ec.europa.eu/research/participants/portal/doc/call/h2020/h2020-lce-2014-1/1595100-faq_1_lce_call_en.pdf - last accessed June 2014.

APPENDIX 3 Abbreviations, acronyms

BFB Bubbling Fluidised Bed	**BHE** Borehole Heat Exchangers	**BIO** Biomass	**CAPEX** Capital Expenditure
CCS Carbon Capture and Storage	**CCT** Cross-Cutting Technology	**CEN** Comité Européen de Normalisation	**CFB** Circulating Fluidised Bed
CHP Combined Heat and Power	**CHP-C** Combined Heat, Power and Cooling (tri-generation)	**CO** Carbon Monoxide	**CO_2** Carbon Dioxide
DH District Heating	**DHC** District Heating and Cooling	**DHW** Domestic hot water	**EC** European Commission
EF-MGT Externally Fired Micro Gas Turbine	**EGEC** European Geothermal Energy Council	**EGS** Enhanced Geothermal Systems	**EHPA** European Heat Pump Association
EPBD Energy Performance of Buildings Directive	**EPC** Energy Performance Contracting	**EN** European Standard (French: norme, German: Norm)	**ESCO** Energy service company
ESC Energy Supply Contracting	**ESTIF** European Solar Thermal Industry Federation	**ESTTP** European Solar Thermal Technology Platform (or Panel)	**ETS** Emission Trading Scheme
EU European Union	**EUREC** The Association of European Renewable Energy Research Centres	**FC** Fuel Cell	**GDP** Gross Domestic Product
GHG Greenhouse Gas	**GSHPs** Ground Source Heat Pumps	**H&C** Heating and Cooling	**HP** Heat Pumps
HTC Hydrothermal Carbonisation	**HVAC** Heating, Ventilation and Air Conditioning	**IC** Internal Combustion Engine	**ICT** Information and communications technology
IED International Emissions Directive	**ILUC** Indirect Land Use Change	**ISO** International Organization for Standardisation	**KPI** Key Performance Indicators
LHV Lower Heating Value	**MGT** Micro Gas Turbine	**MSDS** Material Safety Data Sheet	**MSW** Municipal Solid Waste
MWD Measurement-While-Drilling	**NO_x** Generic term for mono-nitrogen oxides NO and NO_2	**NREAPs** National Renewable Energy Action Plans	**OGC** Organic Gaseous Carbon
ORC Organic Rankine Cycle	**PCM** Phase-Change Materials	**PER** Primary energy ratio	**PF** Power Factor
PM Particulate Matter	**R&D** Research and Development	**RD&D** Research, Development and Demonstration	**RES** Renewable energy sources
R&I Research & Innovation	**ROI** Return on Investment	**RDF** Refuse Derived Fuel	**RED** Renewable energy Directive (2009/28/EC)
RES Renewable energy source	**RHC** (RH&C) Renewable Heating and Cooling	**RHC-PLATFORM** European Technology Platform on Renewable Heating and Cooling	**RHC-SRIA** Strategic Research and Innovation Agenda for Renewable Heating and Cooling
SAH Solar-Active-House	**SAH 60** Solar-Active-House with 60% solar fraction	**SCOP** Seasonal Coefficient of Perfomance	**SCOHYS** Solar compact hybrid systems
SCR Silicon Controlled Rectifier	**SE** Steam Explosion	**SET-PLAN** The European Strategic Energy Technology Plan	**SH** Super Heater
SHC Solar Heating and Cooling	**SHIP** Solar heat for industrial processes	**SMEs** Small and Medium sized Enterprises	**SRP** Strategic research priorities
SO_x Sulphur Oxides	**SRF** Solid Recovered Fuel	**TC** Thermo-Chemical	**TCM** Thermo-chemical materials
TMF Thermal Material Fracking	**TOE** Ton Oil Equivalent	**TRL** Technology Readiness Level	**UTES** Underground Thermal Energy Storage

APPENDIX 4 **Units of measure**

Bcm Billion cubic meter	**˚C** Degrees Celsius	**€/EUR** Euro	**€ct/€cent** Euro-cents
cSt Centistokes	**g** Grams	**GCV** Gross Calorific Value	**GJ** Gigajoule = 109 joules
CHP Combined Heat and Power	**CHP-C** Combined Heat, Power and Cooling (tri-generation)	**CO** Carbon Monoxide	**CO_2** Carbon Dioxide
GW_e Gigawatt Electrical	**GW_{th}** Gigawatt of thermal capacity = 109 watts	**K** Thousand	**J** Joule
KJ/kg Kilojoules per kilogram	**kW_e** Kilowatt Electrical	**kWh** Kilowatt-hour = 103 x 1 hour	**kWh/m^3** Kilowatt hours per meter cubed
kWh/t Kilowatt hours per tonne	**kW_{th}** Kilowatt Thermal Capacity	**m** Meter	**M€/MW** Millions of Euro per Megawatt
m^2 Square Meter	**mg** Milligram	**MMBtu** Million British Thermal Unit	**MJ/kg** Megajoules per kilogram
M_t Megatonne = 106 tonnes	**Mtoe** Million tonnes of Oil Equivalent = 106 tonnes of oil equivalent	**MWh** Megawatt hour	**MW_e** Megawatt Electrical
MW_{th} Megawatt Thermal	**Nm^3** Normal cubic meter	**P** Power	**PJ** Petajoule
pH Measure of the acidity or basicity of an aqueous solution	**T** Tonne	**TWh** Terawatt-hour = 1012 watt x 1 hour	**W** Watts
W_{el} Watt Electrical			

APPENDIX 5 Secretariat of the RHC-Platform

This document was prepared by the **European Technology Platform on Renewable Heating and Cooling (RHC-Platform).**

The Secretariat of the European Technology Platform on Renewable Heating and Cooling is coordinated by EUREC, the Association of European Renewable Energy Research Centres

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The Association of European Renewable Energy Research Centres

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European Biomass Association (AEBIOM)

EGEC GEOTHERMAL

European Geothermal Energy Council (EGEC)

ESTIF European Solar Thermal Industry Federation

European Solar Thermal Industry Federation (ESTIF)

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Renewable Heating & Cooling
European Technology Platform

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