

# Cross-Cutting Technology Roadmap

European Technology Platform  
on Renewable Heating and Cooling







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Heating and Cooling



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# Introduction to Cross-Cutting Technology



Heat pump

# 1 INTRODUCTION TO CROSS-CUTTING TECHNOLOGY

## 1.1 INTRODUCTION TO CROSS-CUTTING TECHNOLOGY

The heating and cooling sector accounts for a significant proportion of Europe's energy demand. The use of renewable energy sources (RES) such as biomass, solar thermal, geothermal and aerothermal offer a safe, reliable and increasingly cost-competitive solution to all heating and cooling needs.

With the publication of the "Common Vision"<sup>1</sup> (RHC-Platform, 2011) the European Technology Platform on Renewable Heating and Cooling (RHC-Platform) provided strong evidence of the huge untapped potential of renewable heating and cooling (RHC).

Nevertheless, in order to realise this potential it is necessary to exploit synergies among the renewable energy production, distribution and consumption, by investing in "**Cross-cutting technology**". This term is used by the RHC-Platform to describe any energy technology or infrastructure which can be used either to enhance the thermal energy output of a RES, to enable a greater fraction of the output by the system to be used, or to allow the exploitation of RES which would be difficult or impossible to use in building-specific applications.

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

**District Heating and Cooling** increases the overall efficiency of the energy system by recycling heat losses from a variety of energy conversion processes. Heat which otherwise would be unutilised is recovered and used to meet thermal demands in buildings and industries. Renewable sources which otherwise would be difficult to use, such as many forms of biomass and geothermal energy, can also be exploited. By aggregating a large number of small and variable heating and cooling demands, District Heating and District Cooling allow energy flows from multiple RES to be combined while reducing primary energy demand and carbon emissions in the community served.

**Thermal energy storage** is the solution for a key bottleneck against the widespread and integrated use of RES, since the renewable supply does not always coincide with the demand for heating or cooling. Numerous technologies in sensible, latent or thermochemical form can time-shift renewable energy supply to periods of greatest demand, each of them characterised by different specifications and specific advantages.

**Heat pumps** transform thermal renewable 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, and can be combined with heat from other RES in hybrid systems (see below). These sources might be renewable in origin or waste energy from industrial processes and exhaust air from buildings. Heat pumps can be highly efficient, although their overall primary energy efficiency depends on the efficiency of the electricity production (or other thermal energy source) they use.

**Hybrid renewable energy systems**, combining two or more energy sources into a single system, can overcome the limitations of individual technologies. This is true for small scale applications such as heating and cooling systems for single family houses as well as for large scale systems suitable for district heating and cooling or industrial processes. The combination of RES available at different times within the system is especially useful if a more constant demand for heat exists, with the overall efficiency of the system depending strongly on the way the different sources are combined.

<sup>1</sup> *Common Vision for the Renewable Heating and Cooling Sector in Europe: 2020 - 2030 - 2050*. European Technology Platform on Renewable Heating & Cooling (RHC-Platform), May 2011. Available at <http://www.rhc-platform.org/publications/>

## 1.2 STRATEGIC RESEARCH PRIORITIES AND RHC-SRIA

In April 2012 the RHC-Platform produced a first-of-its kind publication: the **Strategic Research Priorities for Renewable Heating and Cooling Cross-cutting Technology** (RHC-Platform, 2012).<sup>2</sup> This study provides stakeholders with a structured view of the potential of cross-cutting technology to enable an increasing share of heating and cooling to be supplied by RES. A comprehensive set of research, development and demonstration priorities was defined to support the decarbonisation of the heating and cooling sector.

The contribution of renewable heating and cooling to the EU energy targets by 2020 and beyond will be determined by the availability of reliable, efficient and affordable cross-cutting technologies. While some of the systems, components and infrastructures that qualify as cross-cutting technology are already mature, additional efforts on the research, development and demonstration of these enabling technologies is critical for the on-time achievement of the European Union's objectives.

Based on the work performed by the experts of the four Technology Panels of the RHC-Platform, in 2013 the RHC-Platform launched the **Strategic Research and Innovation Agenda for Renewable Heating and Cooling (RHC-SRIA)**,<sup>3</sup> a milestone publication which addresses the short, medium and longer term R&D needs of RHC technology. The RHC-SRIA takes the innovative step of presenting research and innovation priorities according to three profiles of heat demand: residential buildings, non-residential buildings and industrial processes. While District Heating and Cooling is presented in a separated chapter, R&D priorities for all other cross-cutting technologies are looked at in each of the chapters. With this **Cross-cutting Technology Roadmap**, the RHC-Platform accomplishes one more of its core objectives: establishing a detailed implementation plan for the RHC-SRIA, defining how the combined spending of public and private resources should be strategically distributed among topics with commercial relevance in the short, medium and long term.

All R&D activities on cross-cutting technologies described in this document should be accompanied and supported by 2020, however the RHC-Platform recommends that policy makers allocate the budgets of European and national programmes according to an order of priorities which takes into account the readiness and proven interest of EU industry and research stakeholders to take part in the relevant R&D activities.

## 1.3 STRUCTURE AND SCOPE OF THE ROADMAP

This report is structured according to the following principles:

### References and assumptions

As previously mentioned, the Cross-cutting Technology Roadmap is based on two fundamental publications of the RHC-Platform: the Strategic Research Priorities for CCT and the RHC-SRIA.<sup>4</sup> By providing a thorough description and analysis of the status and needs of RHC technology, these publications are essential complements of the CCT Roadmap.

Moreover, the CCT Roadmap uses the same fundamental assumptions and terminology of the preceding publications. Research and innovation priorities are presented in a standard format which is presented in Figure 1.

<sup>2</sup> *Strategic Research Priorities for Renewable Heating and Cooling Cross-cutting Technology*. European Technology Platform on Renewable Heating & Cooling (RHC-Platform), April 2012. Available at <http://www.rhc-platform.org/publications/>

<sup>3</sup> *Strategic Research and Innovation Agenda for Renewable Heating and Cooling*. European Technology Platform on Renewable Heating & Cooling (RHC-Platform), April 2013. Available at <http://www.rhc-platform.org/publications/>

<sup>4</sup> Cfr. footnotes 2 and 3 for the complete references.

ID Code	Title of the priority
Objective	<i>The objective describes the intended outcome of the research and innovation activities. In most cases this includes a description of the benefits and improvements which the underlying R&amp;D work intends to achieve.</i>
State-of-the-art	<i>The state-of-the-art refers to the level of development of the cross-cutting technology in the year 2012. The information presented in this field provides a justification of the reason why research, development or demonstration activities should be performed (usually by illustrating today's limitations of the examined technology).</i>
Targets & KPIs	<i>Targets are specific, measurable, realistic and time-bounded results at which the priority aims.</i>  <i>Targets are usually defined with the support of quantitative values: the Key Performance Indicators. KPIs are also useful to evaluate the specific impact of the research and innovation activities related to each priority. In some cases in which the research activities are performed over several years, a series of progressive KPIs is identified.</i>
Type of activity and TRL	<i>The RHC-Platform distinguishes three types of activity required to implement each priority: Research; Development; Demonstration. This classification is based on the innovation cycle described in Figure 2, covering the scale of Technology Readiness Levels from value 1 (furthest to market) to value 9 (closest to market).</i>
Priority	<i>The level of priority refers to the time by when the respective activities should be performed. The level of priority is set according to the indications expressed by the authors, taking into account the overall interest expressed by industry and research stakeholders to participate in collaborative projects in order to implement the related activities. The RHC-Platform distinguishes three levels of priorities:</i>  <ul style="list-style-type: none"> <li>• Priority Group I: 2014 - 2016</li> <li>• Priority Group II: 2016 - 2018</li> <li>• Priority Group III: 2018 - 2020</li> </ul> <i>The level of priority should not be confused with the RHC-Platform "time scale" which refers to the year (e.g. 2020 or 2030) by when the results of the R&amp;D work covered in the RHC-SRIA and Roadmap are expected to have a significant commercial impact.</i>
Estimated Budget	<i>The Estimated Budget indicates the approximate total resources which are deemed necessary to implement the relevant R&amp;D activities, distinguishing the expected shares of public and private funding.</i>
Recommended n. of projects	<i>This value refers to the indicative number of projects which should be implemented to achieve a sufficient impact.</i>

Figure 1: standard format adopted by the RHC-Platform to describe the CCT Roadmap's research and innovation priorities

## Organisation of the priorities

This Roadmap categorises the priorities identified in the RHC-SRIA - the 21 cross-cutting technology priorities - and the 2 priorities with generic impact on RHC applications in the residential sector - by when the respective activities should be performed in order to effectively support the development of the related industries and spur market growth.

- 2014 - 2016: Priority Group I
- 2016 - 2018: Priority Group II
- 2018 - 2020: Priority Group III

To realise the potential of the RHC-Platform's Common Vision, activities of fundamental research, development and demonstration are necessary depending on the specific technological maturity of the relevant component or system, measured on the Technology Readiness Scale (Figure 2).

## Scale of Technology Readiness Levels (TRL) adopted by the RHC-Platform<sup>5</sup>

### 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.

Figure 2: Scale of Technology Readiness Levels (TRL) adopted by the RHC-Platform

<sup>5</sup> 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](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](http://ec.europa.eu/research/participants/portal/doc/call/h2020/h2020-lce-2014-1/1595100-faq_1_lce_call_en.pdf). Both webpages were accessed early March 2014.

The overarching objective of the Cross-cutting Technology Roadmap is to prioritise the development of innovative solutions which will respond to the needs of heating and cooling users by 2020, 2030 and beyond. This document can be used as guidance for the identification of the most appropriate areas to fund at European level under Horizon 2020, at national level and with private resources.

## 1.4 OVERVIEW OF RESEARCH AND INNOVATION PRIORITIES

### Research and Innovation Priorities for Heat Pumps and Hybrid Systems<sup>6</sup>

CCT	Research and Innovation Priorities	Predominant type of activity	Budget (Mln €)	Priority	Page in the document
CCT.1	Cost competitive heat pump kit for houses with existing boiler	Development	15	I	17
CCT.2	Optimisation of thermally driven heat pumps and their integration in the boundary system	Development	25	I	18
CCT.3	<i>Automation, control and long term reliability assessment</i>	Development	15	I	19
CCT.4	Development of a heat pump for near-zero energy buildings (single family house)	Development	12	III	43
CCT.5	<i>Next generation of highly integrated, compact hybrid systems</i>	Development/ Demonstration	25	III	44
CCT.9	High capacity heat pump for simultaneous production of cold and hot water for heating/cooling the building	Development	10	II	33
CCT.10	<i>Integration, automation and control of large scale hybrid systems for non-residential buildings</i>	Development/ Demonstration	60	II	34
CCT.11	Sorption cooling systems driven by hot water at moderate temperature	Development	20	II	35
CCT.12	Enhanced industrial compression heat pumps	Development	12	III	46
CCT.13	Process integration, optimisation and control of industrial heat pumps	Demonstration	15	I	22
CCT.15	Improvement of sorption cooling from renewable energy sources	Development	40	III	47
CCT.16	New concepts for industrial heat pumps	Research	25	II	37

<sup>6</sup> Priorities for Hybrid Systems are in italics

## Research and Innovation Priorities relevant to Thermal Energy Storage

	Research and Innovation Priorities	Predominant type of activity	Budget (Mln €)	Priority	Page in the document
CCT.6	Next generation of Sensible Thermal Energy Storages	Development	25	I	20
CCT.7	Improving the efficiency of combined thermal energy transfer and storage	Research / Development	16	III	45
CCT.8	Increased storage density using phase change materials (PCM) and thermochemical materials (TCM)	Research	40	II	31
CCT.14	Improvements in Underground Thermal Energy Storage (UTES)	Demonstration	40	II	36
CCT.21	Optimised integration of renewable energy sources in DHC systems and enhancement of thermal energy storage at system level	Demonstration	50	III	49

## Research and Innovation Priorities relevant to District Heating and Cooling

	Research and Innovation Priorities	Predominant type of activity	Budget (Mln €)	Priority	Page in the document
CCT.17	Large scale demonstration of Smart Thermal Grids	Demonstration	100	I	23
CCT.18	Booster Heat Pump for DHC	Demonstration	25	I	25
CCT.19	Develop and roll-out DHC driven white goods and low temperature solution for domestic hot water preparation	Development/ Demonstration	7	III	48
CCT.20	Improved, highly efficient substations for both present and future lower temperature networks	Demonstration	40	II	38
CCT.21	Optimised integration of renewable energy sources in DHC systems and enhancement of thermal energy storage at system level	Demonstration	50	III	49

## Research and Innovation Priorities with generic impact on RHC applications in the residential sector

	Research and Innovation Priorities	Predominant type of activity	Budget (Mln €)	Priority	Page in the document
RHC.1	Developing standards for the overall system design and for hydraulic and electrical interconnections of different building components	Development	15	II	39
RHC.2	Elaborating standards, tests and benchmarking for system efficiency	Development	15	I	26



2

# Priority Group I: implementation 2014 - 2016



Lab testing of hybrid systems

## 2 PRIORITY GROUP I: IMPLEMENTATION 2014 - 2016

This section presents a set of priorities which require immediate attention and that the RHC-Platform recommends to implement between 2014 and 2016. The priorities described here are expected to generate projects and clusters of projects which have been defined primarily for the strong and broad support expressed by the industry and research stakeholders of the RHC-Platform.

Complementarities should be sought and synergies exploited with the ongoing projects and programmes at EU and Member State levels. Moreover, these priorities should not be interpreted as an exhaustive list of all research, development and demonstration activities to be carried out in Europe in the next three years, since that is considerably broader than the priority areas defined here.

CCT.1	Research and Innovation Priorities	Technology focus	Predominant application
	Cost competitive heat pump kit for houses with existing boiler	Heat Pump	Residential buildings
CCT.2	Optimisation of thermally driven heat pumps and their integration in the boundary system	Heat Pump	Residential buildings
CCT.3	Automation, control and long term reliability assessment	Hybrid System	Residential buildings
CCT.6	Next generation of sensible thermal energy storages	TES	Residential buildings
CCT.13	Process integration, optimization and control of industrial heat pumps	Heat Pump	Industrial Processes
CCT.17	Large scale demonstration of Smart Thermal Grids	DHC	All
CCT.18	Booster Heat Pump for DHC	Heat Pump / DHC	All
RHC.2	Elaborating standards, tests and benchmarking for system efficiency	All	Generic impact on RHC applications in the residential sector

Figure 3: Research and innovation topics of Priority Group I

CCT.1	Cost competitive heat pump kit for houses with existing boiler			
Objective	Development of heat pump kit to be integrated in the heating system of houses with existing non-electrical boilers. The expected solution should present the following characteristics:			
	· High efficiency air to water heat pump producing heating water with a temperature lift of minimum 45 K.			
	· The supply temperature should be changeable between 50 and 35°C depending on the ambient temperature.			
	· The existing boiler will be kept and will only be employed as a back-up system under extreme ambient conditions when the heat pump is not able to attain 60°C or to increase the temperature of the sanitary hot water.			
	· Compact design in a form of kit with all the necessary components for an easy integration and installation with the boiler heating system. This should ideally be wall mounted recognizing current form factors and the installer work-flow.			
	· The control of the system must allow optimal management and automatic operation of the heat pump unit and boiler.			
· With a capacity in the range 4-8 kW, the system should be able to provide the required heat most of the time.				
State-of-the-art	Expensive hybrid systems have been developed in recent years, leading to efficient heating and sanitary water production. The proposed kit will not attain such an efficient operation but will help to save energy and reduce gas consumption at a competitive installation and system cost.			
Targets	· 25% decrease in the cost of the heat pump, including installation.			
	· The SCOP of the heat pump operating under the described conditions should reach at least a value of 5.			
	· Roughly doubling the PER with the heat pump kit, compared to gas boiler.			
Specific KPIs	Gas consumption reduction with 90% of the thermal load covered by the HP by 2020	2012: n.a.	2016: 80%	2020: 90%
	SCOP referred to electricity consumption	2012: n.a.	2016: 4.5	2020:5
	PER of the heat pump and gas boiler system referred to primary energy (ratio of: 1 kWh electric = 2.5 kWh primary energy, average boiler efficiency 0.8)	2012: 0.8 (gas boiler only)	2016: 1.4	2020: 1.7
	PER of the heat pump and gas boiler system referred to primary energy, with a ratio of: 1 kWh electric = 2 kWh primary energy, average boiler efficiency 0.8	2012: 0.8 (gas boiler only)	2016: 1.7	2020: 2.0
	Reference average cost of HP in the range 4-8 kW, including installation (Euro)	2012: 6.000 – 8.000	2016: 5.200 - 7.000	2020: 4000 - 5500
Type of activity and TRL	70% Development (TRL 4-5) 30% Demonstration (TRL 6-7)			
Priority Group	I			
Estimated Budget	TOTAL: 15 Mln Euro		PUBLIC: 60%	PRIVATE: 40%
Recommended n. of projects	3			

CCT.2	Optimisation of thermally driven heat pumps and their integration in the boundary system			
Objective	<p>The objective of this topic is to support the market penetration of thermally driven heat pumps for heating and cooling by enhancing the efficiency and the long term stability and by reducing their size, weight and cost.</p> <p>Significant short-term market penetration of thermally driven sorption heat pumps and chillers, especially in the area of existing buildings, can substantially speed-up the usage of renewable energy for heating, domestic hot water and cooling in residential and small commercial applications. The technology is well suited for the boiler replacement market, where the impact of emission reduction and energy efficiency regarding the market size and limited availability of renewable energy using alternatives might be considerable.</p> <p>This can be achieved through the improvement of materials, production processes, components, controls, as well as thermodynamic and hydraulic design with the final goal of enhancing the efficiency and long term stability of units and systems. It is very important to support the development process through large-scale field trials to evaluate the performance under a wide range of operating conditions.</p> <p>The technology of thermally driven cooling instead can be well combined with the expanding market of district networks, leading to the possibility of reducing electrical energy consumption (from traditional chillers) through the utilisation of waste heat.</p>			
	<p>Gas fired absorption heat pumps are successfully implemented mainly in large scale applications, such as multifamily residential and non-residential buildings (several thousand units sold); small scale adsorption units entered the market only recently.</p> <p>Due to recent developments in the field of legislation and standardisation, gas fired heat pumps may play a major role in traditional gas-dominated heating markets in near future as “next generation gas boilers”.</p> <p>Water fired sorption chillers are mainly applied in industry and coupled to cogeneration units. Solar, biomass or district combinations are still niche applications with some hundred systems being implemented.</p> <p>Based on increased application of district networks, distributed cogeneration units and solar thermal fields, the application possibilities of this technology are expanding too.</p>			
	<p>Targets</p> <ul style="list-style-type: none"> <li>Reduction in volume and weight of the thermally driven heat pump by 10%.</li> <li>Enhancement of thermal SCOP of the unit by 5% and thermal SCOP of the system by 10%.<sup>7</sup></li> <li>Cost reduction: 20 % by 2020.</li> <li>Reduction of electricity consumption of the overall thermally driven cooling system by 50%.</li> </ul>			
Specific KPIs	Reference specific weight per power	2012: 12 kg/kW(heating)	2016: 10 kg/kW(heating)	2020: 9 kg/W (heating)
	Reference thermal single unit SCOP <sup>7</sup> (e.g. for air source)	2012: 1.25	2016: 1.4	2020: 1.5
	Reference thermal system SCOP <sup>7</sup> (e.g. for air source)	2012: 1.15	2016: 1.25	2020: 1.4
	Reference specific unit cost (average for diff. technologies)	2012: 450 €/kW <sub>th</sub>	2016: 400 €/kW <sub>th</sub>	2020: 350 €/kW <sub>th</sub>
	Reference value of electricity consumption for single unit (e.g. for air source)	2012: 40 We/kWth	2016: 30 We/kWth	2020: 20 We/kWth
	Reference value of COP <sub>electric</sub> (water cooled)	2012: >10	2016: >15	2020: >20
	Reference value of COP <sub>electric</sub> (air cooled)	2012: >6.5	2016: >8.5	2020: >11

<sup>7</sup> Here, thermal single unit SCOP represents the seasonal thermal efficiency of the heat pump only, analogously to the SGUE (Seasonal Gas Utilisation Efficiency), as defined in EN 12309. The thermal system SCOP represents the overall system efficiency, including heat source, storage etc., analogously to thermal SPF (SPF<sub>th</sub>) as defined e.g. in IEA HPP Annex 34.

Type of activity and TRL	60% Development (TRL 4-5) 40% Demonstration (TRL 6-7)		
Priority Group	I		
Estimated Budget	TOTAL: 25 Mln Euro	PUBLIC: 60%	PRIVATE: 40%
Recommended n. of projects	5		

CCT.3	<b>Automation, control and long term reliability assessment</b>
Objective	<p>Within the development of new generation hybrid systems, special attention should be paid to the automation and control of systems. The scope of this research is to develop an integrated control platform, including the following functionalities:</p> <ul style="list-style-type: none"> <li>• Weather forecast, based on local observation and/or services available by Internet.</li> <li>• Heating/Cooling and DHW load forecast, based on the learning of system operation and occupants' behaviour.</li> <li>• New processing algorithms to supervise the complete system (adaptive control, learning process, etc.) while maintaining a high degree of comfort and a low consumption of auxiliary electricity.</li> <li>• Intuitive user interfaces which are able to provide information on the system to the user in an understandable language, and which let users adjust the system easily (set point temperature, etc.)</li> <li>• Monitoring and recording of energy production, cost of primary energy consumed, energy efficiency and amounts of GHG emitted.</li> <li>• With more data on the behaviour of systems operating under particular conditions it should be possible to develop performance guarantees.</li> <li>• Fault detection: intelligent analysis of the system behaviour should be included to detect possible malfunctioning before it occurs and to alert the end-user or service company.</li> <li>• Development of an easy to install system with a plug&amp;play function concept of the controller.</li> </ul> <p>All of these technical developments on control, monitoring and automation should improve the quality of the systems. In addition to it, specific design and commissioning will allow a reduction in the total cost of the systems on their life duration and lead to guaranteed levels of production.</p>
State-of-the-art	<p>Today hybrid systems are usually composed of customised combinations of components individually assembled by the installer. In several cases this is not one controller for the overall system, but one for each main energy unit, regulating the on and off switching of the unit. This leads to a certain occurrence of sub-optimal programming. Often the data exchanged by the controllers is limited and this affects the possibility of optimising the system.</p> <p>Monitoring is mostly done only in a very limited way or not at all. Parasitic electricity consumption is usually not measured. Mistake detection and optimisation of the system based on this data is possible only in a limited manner. Weather forecast, load forecast and adaptive control are usually not available.</p>
Targets	We expect that research into these two areas will deliver a 20% cost reduction and a 20% increase in thermal efficiency in the short term, thus leading to approximately a 40% decrease of the overall system cost.

Specific KPIs	Reference system final customer price (for Central Europe)	2012: 800 – 1,500 €/kW	2016: 720 – 1,350 €/kW	2020: 640 – 1,200 €/
	Primary Energy Ratio of a reference system	2012: 0.8	2016: 0.7	2020: 0.65
	Increase in the system efficiency as a result of the integration of smart controllers	2012: n.a.	2016: 10%	2020: 20%
	Market penetration (share of systems with integrated automation and control)	2012: n.a.	2016: 20%	2020: 40%
Type of activity and TRL	20% Research on low cost heat meters, sensors and monitoring concepts (TRL 3) 50% Development (TRL 4-5) 30% Demonstration (TRL 6-7)			
Priority Group	I			
Estimated Budget	TOTAL: 15 Mln Euro	PUBLIC: 45%		PRIVATE: 55%
Recommended n. of projects	3			

CCT.6	Next generation of Sensible Thermal Energy Storages
Objective	<p>Availability of high-efficiency sensible thermal energy storage devices with significantly reduced heat losses, increased exergy efficiency, efficient charging and discharging characteristics and high flexibility to adapt it to and integrate it in existing buildings with limited space for storages.</p> <p>Costs and thermal conduction of the containment materials will be reduced by replacing metal with polymer casings, with or without fibre reinforcement. Novel and compact heat exchangers using new materials, improved concepts and geometries will improve the charging and discharging process by increased heat transfer power and therefore reduce charging and discharging time and disturbances of the temperature stratification.</p> <p>Significant improvements on storage insulation will be achieved by the development of long lasting, low-cost and easy to apply high performance insulation (e.g. vacuum insulation). This will increase the overall system performance (the usable storage volume decreasing the gross volume of the storage including insulation) and the comfort for users by reduced room heating in summer.</p> <p>The exergy efficiency (or stratification efficiency) of sensible storage will become more important with increasing shares of renewables (heat pumps, solar thermal) and key performance indicators will be developed together with standardized test methods in order to measure exergy efficiency for sensible storage.</p> <p>The performance of sensible TES will be further increased by improved exergy efficiency and stratification devices. The integration of sensible TES into smart heating networks will be enabled by the inclusion of intelligent state of charge determination systems fully integrated in the storage.</p>

State-of-the-art	<p>The vast majority of today’s storages are based on sensible thermal energy storage, using water as the storage medium and therefore a lot of different concepts, materials and technologies for insulating and charging and discharging of the storages are available. However, the available technologies are not satisfying regarding energy and exergy performance, flexibility and costs especially since thermal storage will become much more important in the heating and cooling sector by using renewable energies.</p> <p>The present generation of sensible TES was developed at a time when fossil fuels played a predominant role and the surplus exergy of the fuel was high enough to compensate for exergy losses in the storage. Low exergy efficiency is a common downside of TES for renewable energy systems on the market, also determined by the lack of broadly accepted indicators of exergy efficiency in sensible stores.</p> <p>The current limitations of sensible storage technology have a major impact given that a large number of water stores are deployed in combination with renewable energy technology such as solar thermal and heat pumps.</p>			
Targets	<ul style="list-style-type: none"><li>· 20% cost reduction of mass produced containment.</li><li>· High performance insulation materials with 50% higher insulation effect than conventional materials and 70% lower cost than present vacuum insulation.</li><li>· Development and demonstration of innovative modular concepts.</li></ul>			
Specific KPIs	Cost of containment of 1000 litre tank (excluding insulation and VAT)	2012: 400 - 900 €	2016: 350 -800 €	2020: 300 - 700 €
	Heat loss related to storage vessel with capacity of 1.000 L. <sup>8</sup>	2012: 150W – 200W (Label C, D)	2016: 76W (Label A)	2020: 56W (Label A+)
	Cost to customer (excl VAT) of high performance insulation	2012: 300 €/m2	2016: 230 €/m2	2020: <100 €/m2
	Thermal Resistance (Rc) = 7 m²·K/W)			
Type of activity and TRL	30% Research (TRL 3) 40% Development (TRL 4-5) 30% Demonstration (TRL 6-8)			
Priority Group	I			
Estimated Budget	TOTAL: 25 Mln Euro	PUBLIC: 60%	PRIVATE: 40%	
Recommended n. of projects	5 projects on pre-industrial developments: insulation materials, heat exchangers, alternative geometries			

<sup>8</sup> Measuring heat loss of water storages is described in EN 12897. This method is also the basis for ErP classification. The heat loss in Watts is measured with a water temperature of 65°C in the storage in an environment of 20°C. The energy efficiency class is then calculated using these equations:

Energy efficiency classes of hot water storage tanks

Energy efficiency class	Standing loss S in Watts, with storage volume V in litres
A+	$S < 5,5 + 3,16 \cdot V^{0,4}$
A	$5,5 + 3,16 \cdot V^{0,4} \leq S < 8,5 + 4,25 \cdot V^{0,4}$
B	$8,5 + 4,25 \cdot V^{0,4} \leq S < 12 + 5,93 \cdot V^{0,4}$
C	$12 + 5,93 \cdot V^{0,4} \leq S < 16,66 + 8,33 \cdot V^{0,4}$
D	$16,66 + 8,33 \cdot V^{0,4} \leq S < 21 + 10,33 \cdot V^{0,4}$
E	$21 + 10,33 \cdot V^{0,4} \leq S < 26 + 13,66 \cdot V^{0,4}$
F	$26 + 13,66 \cdot V^{0,4} \leq S < 31 + 16,66 \cdot V^{0,4}$
G	$S > 31 + 16,66 \cdot V^{0,4}$

CCT.13	Process integration, optimisation and control of industrial heat pumps			
Objective	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. R&D topics to be addressed comprise: <ul style="list-style-type: none"><li>· classification of processes (temperature levels, time-based energy demand, etc.),</li><li>· process integration of industrial heat pumps (control and hydraulic design),</li><li>· impact of heat pumps on existing process (dynamic behaviour),</li><li>· selection of components (refrigerant, compressor, heat exchangers etc.) for the process identified</li></ul>			
State-of-the-art	First prototypes of compression heat pumps with evaporation temperatures of up to 40°C and condensation temperatures of up to 80°C are available but still need to be demonstrated on a large scale throughout Europe. First prototypes of absorption heat pumps using new working pairs without crystallisation effects are available, but not demonstrated yet in real-life operating conditions.			
Targets	<ul style="list-style-type: none"><li>· 5 lighthouse projects with a capacity of minimum 1 MWth implemented by 2020</li><li>· Compression heat pump: minim sCOP of 5 for a temperature lift of 35K, energy savings of at least 30%</li><li>· Absorption heat pump: minimum sCOP of 1,5; energy savings of at least 50%</li><li>· Cost target at system level for electrically driven heat pumps (unit plus installation): 400 to 500 Euro/kW</li></ul>			
Specific KPIs	Demonstration in real-life plants of absorption heat pumps using new working pairs (avoiding crystallisation effects)	2012: n.a.	2016: 1 demo plant with availability rate <sup>9</sup> of 70 %	2020: 4 plants with availability rates of 95 %
	Demonstration in real-life plants of compression heat pumps with high evaporation temperatures and high condensation temperatures	2012: $T_{\text{cond}}/T_{\text{evap}} = 80 / 40^{\circ}\text{C}$	2016: 1 demo plant with availability rate of 70 % with $T_{\text{cond}}/T_{\text{evap}} = 120 / 60^{\circ}\text{C}$	2020: 4 plants with availability rates of 95 % with $T_{\text{cond}}/T_{\text{evap}} = 130 / 70^{\circ}\text{C}$
Specific KPIs	CO <sub>2</sub> emission reduction compared to gas fired system ( $T_{\text{cond}}/T_{\text{evap}} = 80 / 40^{\circ}\text{C}$ ) <sup>10</sup>	2012: 20 %	2016: 30 %	2020: 40 %
	Reference sCOP value compression HP (at $\Delta T = 35\text{ K}$ <sup>11</sup> , $T_{\text{evap}} = 40^{\circ}\text{C}$ )	2012: 3.5	2016: 4	2020: 5
	Reference sCOP value absorption HP	2012: 1,1	2016: 1,3	2020: 1,5
	Average system cost	2012: 500-600 €/kW	2016: 400 -500 €/kW	2020: < 400 €/kW
Type of activity and TRL	30% Development (TRL 4-5) 70% Demonstration (TRL 6-7)			
Priority Group	I			
Estimated Budget	TOTAL: 15 Mln €		PUBLIC: 60%	PRIVATE: 40%
Recommended n. of projects	5			

<sup>9</sup> The availability rate describes the ability of a demo plant to function under stated conditions for a period of time of one year. A rate of 50% indicates that the plant can work continuously for 6 months over a 1-year period.

<sup>10</sup> CO<sub>2</sub> emission factor according to EN15603: gas = 277 g CO<sub>2</sub> / kWh final energy; electricity = 617 g CO<sub>2</sub> / kWh final energy.

<sup>11</sup> A constant temperature lift of  $\Delta T = 35 \text{ K}$  is chosen as this is a standard value used in heat pump certification schemes (e.g. EHPA, NF, MCS).

CCT.17	Large scale demonstration of Smart Thermal Grids
Objective	<p>Demonstration of large Smart Thermal Grids which have the following characteristics:</p> <ul style="list-style-type: none"> <li>· Able to adapt fast to changes in energy supply and demand, in a medium-term by adaptation of the temperature level in existing networks and the installation of new distributed micro-networks and in a long-term by adjusting the network development with urban planning.</li> <li>· Are intelligently planned and operated as well as enable the end-user to interact with the heating and cooling system.</li> <li>· Integrated in the whole urban energy system from a spatial point of view (related to urban planning parameters and processes) and from an energy system point of view (e.g. with optimised interfaces to other urban networks – electricity, sewage, waste, ICT, etc.).</li> <li>· Will help to achieve the highest overall efficiency of the energy system, by choosing the optimal combination of energy efficiency (e.g. maximum exploitation of available local energy resources by cascade usage) and renewable energy sources (e.g. solar thermal, geothermal, biomass etc.).</li> <li>· Effective implemented solutions will be effective when compared to non-integrated approaches. Solutions will have a significant impact on the overall urban energy system efficiency when the broad diffusion of the technology is given, together with benefits to consumers and to the environment due to the active use of thermal renewable energy sources.</li> <li>· Are attractive for the citizens and investors by increasing the cost efficiency, creating possibilities for the customers to participate and developing new business models.</li> </ul> <p>Advanced district heating and cooling systems must be developed that 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). In addition, 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.</p> <p>In terms of components, specific decentralised cooling and air-conditioning units for district heating systems are needed, as well as new cost-optimized forms of long-term heat storages. Integration and standardisation of thermal components are required to decrease their price and increase their efficiency. For existing heating grids the integration of heat pumps for active flue gas condensation may be a viable concept, which should be demonstrated. The development and demonstration of bi-directional grids may be an interesting system option for new grids.<sup>12</sup></p>
State-of-the-art	<p>The deployment of Smart Thermal Grids as described above is almost non-existent in Europe. The most advanced systems usually comply with only single elements of the characteristics described above. A barrier to broader use of smart thermal grids is the fact that despite the fact that cities are composed of a number of networks – ICT, electricity, heat, cooling, transport, water, etc. – they are often developed in parallel, sometimes with no real interaction or even on a competitive basis.</p>
Targets	<ul style="list-style-type: none"> <li>· Large scale demonstration of the technical feasibility and economic competitiveness of Smart Thermal Grids combining the above described smart aspects.</li> <li>· At least 50% share of renewable energy or industrial surplus heat in Smart Thermal Grids and overall efficiency gain of 30 % (including impact on heat generation efficiency) compared with state-of-the-art thermal grids.</li> <li>· Large scale demonstration of above described smart non-technical characteristic (end-user participation, integration of heat prosumers, new business models).</li> </ul>

<sup>12</sup> The concept of Smart Thermal Grids is further developed in the RHC-Platform's SRIA (2013).

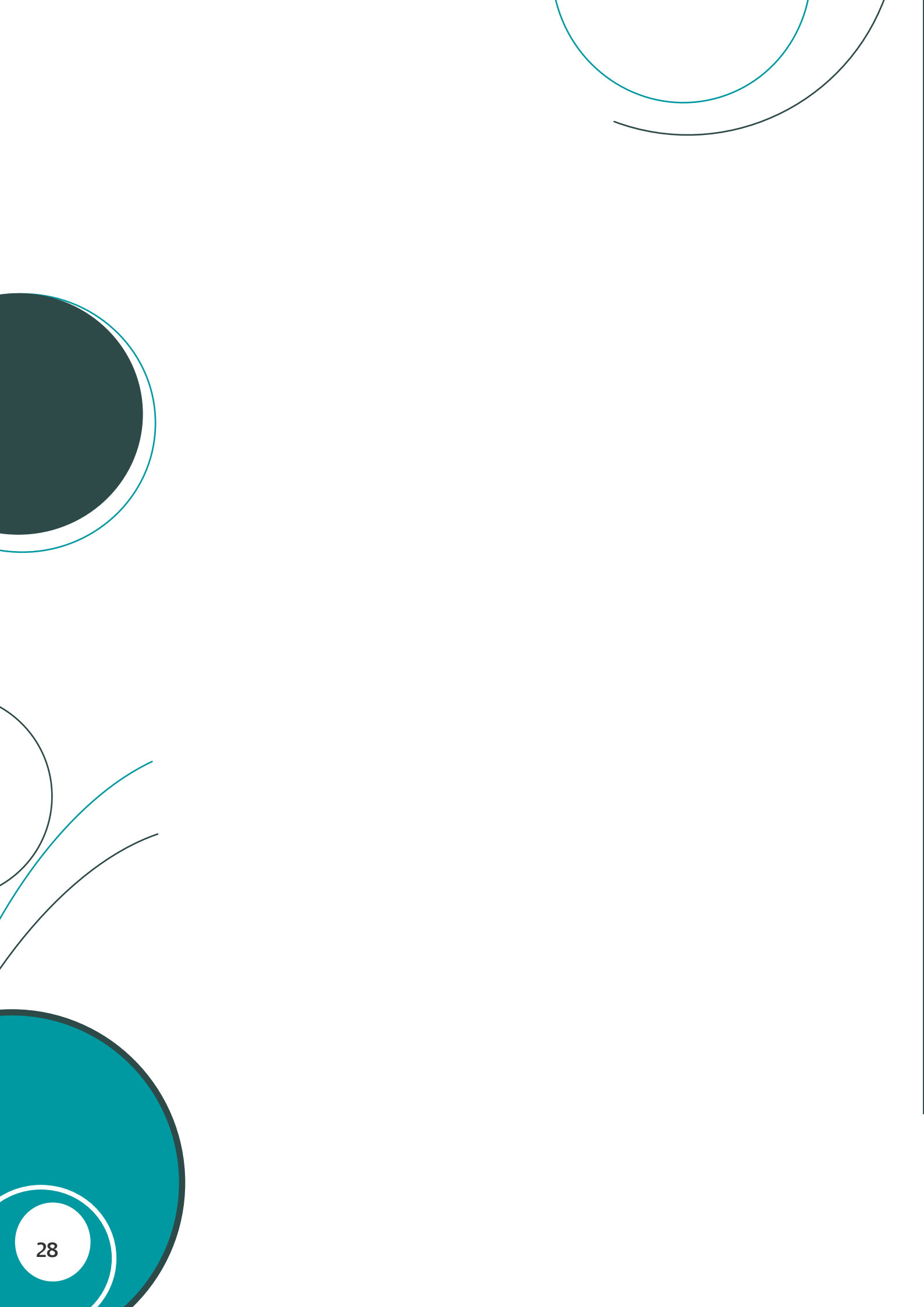
Specific KPIs	N. of smart thermal grids demonstrated with cost of delivered heat less than 90 €/MWh	2012: none, only single smart grid aspects demonstrated	2016: 5 demonstration projects started	2020: 5 large scale demonstration projects (> 20 GWh/a) realized demonstrating 30 % efficiency improvement compared to state-of-the-art thermal grids and 50 % RES or industrial surplus heat
	Cost of delivered heat (this average value must be adjusted on the basis of national indexes)	2012: 200 €/MWh	2016: 130 €/MWh	2020: 85 €/MWh that is a price competitive with conventional DHC
	Average share of RES and surplus heat from industrial processes in Smart Thermal Grids	2012: 11%	2016: 20%	2020: >50 %
	Efficiency Indicator (primary energy factor)	2012: 0.8	2016: +10%	2020: +30%
Type of activity and TRL	30% Development (TRL 4-5) 70% Demonstration (TRL 6-7)			
Priority Group	I			
Estimated Budget	TOTAL: 100 Mln Euro		PUBLIC: 55%	PRIVATE: 45%
Recommended n. of projects	At least 5 large scale Smart Thermal Grid RD&D projects with a predominant demonstration character complying with the strategic implications described above			

CCT.18	Booster Heat Pump for DHC			
Objective	This topic aims mainly at the demonstration of electrically driven industrial heat pumps in district heating and cooling networks. Heat pumps are used to upgrade heat from low temperature sources to temperatures high enough for direct use in a DH network. R&D topics to be addressed comprise: <ul style="list-style-type: none"><li>· classification of networks (temperature levels, time-based energy demand, etc.),</li><li>· integration of industrial heat pumps (control and hydraulic design),</li><li>· impact of heat pumps on existing networks (dynamic behaviour),</li><li>· use of the return flow from the DH network as heat source.</li></ul>			
State-of-the-art	First prototypes of compression heat pumps with evaporating temperatures of up to 40°C and condensing temperatures of up to 100°C are available but still need to be demonstrated.			
Targets	<ul style="list-style-type: none"><li>· Compression heat pump: sCOP 5 or more for a temperature lift of 35K.</li><li>· Development of small (3kW) booster heat pumps that can supply heating and cooling to individual apartments and are connected to a low temperature district heating grid.</li><li>· Energy cost reduction of min. 30%.</li></ul>			
Specific KPIs	Evaporating/ Condensing temperatures for industrial waste heat (°C)	2012: 40/80 Carnot efficiency factor: 0.3	2016: 50/90 Carnot efficiency factor: 0.3	2020: 70/130 Carnot efficiency factor: 0.4
	Evaporating/ Condensing temperatures (°C) for waste water used in low temperature DH	2012: 15/65 Carnot efficiency factor: 0.35	2016: 15/65 Carnot efficiency factor: 0.4	2020: 15/65 Carnot efficiency factor: 0.45
	N. of successful demo applications to industrial waste heat	2012: n.a.	2016: 2	2020: 5
	N. of successful demo applications to low temperature DH	2012: n.a.	2016: 1	2020: 3
	Reference sCOP value compression HP (at $\Delta T = 35 \text{ K}^{13}$ , $T_{\text{evap}} = 40 \text{ °C}$ )	2012: 3.5	2016: 4	2020: 5
	Reduction of heat generation costs (baseline 2012)	2012: n.a.	2016: 10%	2020: > 30 %
Type of activity and TRL	20% Research (TRL 3) 30% Development (TRL 4-5) 50% Demonstration (TRL 6)			
Priority Group	I			
Estimated Budget	TOTAL: 25 Mln Euro	PUBLIC: 60%		PRIVATE: 40%
Recommended n. of projects	5 lighthouse projects, each with a capacity of minimum 1 MWth			

<sup>13</sup> A constant temperature lift of  $\Delta T = 35 \text{ K}$  is chosen as this is a standard value used in heat pump certification schemes (e.g. EHPA, NF, MCS).

RHC.2	Elaborating standards, tests, and benchmarks for system efficiency		
Objective	<p>In the residential sector, 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 renewable heating and cooling systems are satisfactory in all aspects. Ideally, such procedures should be implemented in accordance with technical standards and for the certification of overall systems. Learning from driving cycle tests in the car industry, RHC system should also test by cycle, rather than by steady-state tests. Benchmarks have to be created to give end users and designers a judging system by which they can value its performance. Continuous monitoring campaigns are required to establish such benchmarks, but also to allow for feed-back on the success of R&amp;D activities.</p>		
State-of-the-art	<p>Consumers cannot effectively judge the appropriateness of design and the quality of installation. Comparing efficiency between different systems is difficult. There are no simple benchmarks to support such judgement. Existing tests reflect component performance under mostly steady-state conditions. But the combination of well performing single components must not lead to well performing overall systems. A “whole system test cycle” is necessary to evaluate the dynamic performance of the system acquired by the end consumer.</p>		
Targets	<p>In collaboration with industry, the target is to define reference test cycle(s) to measure real life performance of all kind of RHC systems, independent of their heat source. Harmonise international test procedures to ensure transparency for comparison of different RHC options.</p> <p>Produce a labelling scheme enabling end-users and manufacturers to evaluate and compare overall system performance of RHC systems with all kind of heat sources, and by that create a pressure towards and a market for more efficient overall systems.</p>		
KPIs	<ul style="list-style-type: none"> <li>Establishment of harmonised test procedure(s), recognised among industry, research and standardisation bodies in EU, in order to test different RHC systems</li> <li>The harmonised test procedure(s) should be tested in at least 5 EU countries by relevant research and/or standardisation bodies</li> </ul>		
Type of activity	25% Research / 50% Development / 25% Demonstration		
Priority Group	I		
Estimated Budget	TOTAL: 15 Mln Euro	PUBLIC: 75%	PRIVATE: 25%
Recommended n. of projects	1		





3

## Priority Group II: implementation 2016 - 2018



District Heating plant, Varna, Italy

### 3 PRIORITY GROUP II: IMPLEMENTATION 2016 - 2018

This section presents a set of priorities which the RHC-Platform recommends to implement between 2016 and 2018. The research and innovation activities described here are expected to build on the knowledge and advancements achieved through the 1<sup>st</sup> wave of projects related to the “Priority Group I”.

Some of the projects implemented during the previous period are likely to continue after 2016. In these cases, the preliminary results of the ongoing projects should be integrated and valorised in the implementation of all activities described in “Priority Group II”. Moreover, as previously mentioned, these priorities should not be interpreted as an exhaustive list of all research, development and demonstration activities to be carried out in Europe in the period of reference.

	Research and Innovation Priorities	Technology focus	Predominant application
CCT.8	Increased storage density using Phase Change Materials (PCM) and Thermochemical Materials (TM)	TES	Residential buildings
CCT.9	High capacity heat pump for simultaneous production of cold and hot water for heating/cooling the building	Heat Pump	Non-residential buildings
CCT.10	Integration, automation and control of large scale hybrid systems for non-residential buildings	Hybrid System	Non-residential buildings
CCT.11	Sorption cooling systems driven by hot water at moderate temperature	Renewable cooling	Non-residential buildings
CCT.14	Improvements in Underground Thermal Energy Storage (UTES)	TES	Industrial Processes
CCT.16	New concepts for industrial heat pumps	Heat Pump	Industrial Processes
CCT.20	Improved, highly efficient substations for both present and future lower temperature networks	DHC	All
RHC.1	Developing standards for the overall system design and for hydraulic and electrical interconnections of different building components	All	Generic impact on RHC applications in the residential sector

Figure 4: Research and innovation topics of Priority Group II

CCT.8	<b>Increased storage density using phase change materials (PCM) and thermochemical materials (TCM)</b>
Objective	<p>To increase the storage density of TES based on PCM or TCM in order to enable the implementation of TES in applications with less available volume and to enable the cost-effective long-term storage of renewable heat.</p> <p>To be effectively applied in heating and cooling systems, the technology should be improved as follows:</p> <ul style="list-style-type: none"> <li>• Further increasing the storage density to make it possible to integrate PCMs into buildings and thermal energy systems. For building-integrated applications, encapsulation and stabilisation, particularly of salt hydrate PCMs will be important.</li> <li>• Increasing the rate of heat discharge from PCMs that can be used for DHW production.</li> <li>• Finding solutions for problems such as subcooling (with the use of nucleators), phase separation, and hysteresis, typical when inorganic materials, such as salt hydrates, are used (the use of inorganic materials avoids the fire risk of organic materials such as paraffin).</li> <li>• Developing microencapsulated PCM for <math>300\text{ }^{\circ}\text{C} &lt; T &lt; 1,000\text{ }^{\circ}\text{C}</math>.</li> <li>• Developing new materials and/or mixtures that adjust the melting temperature, that is, that have several phase change temperatures, or that change their phase change temperature if stimulated to do so.</li> <li>• Developing heat exchangers that can also encapsulate the PCM.</li> </ul> <p>In order to optimise the performance of TCM, activities should focus on:</p> <ul style="list-style-type: none"> <li>• Development of novel or improved storage materials, using materials technology and novel numerical methods.</li> <li>• Development of testing and characterisation techniques for thermochemical materials, including new techniques to determine the state of charge.</li> <li>• Design and optimisation of specific charging and discharging technologies.</li> <li>• Large scale domestic stores to assess economic viability, construction and installation issues, and manufacturing efficiencies.</li> <li>• New concepts to combine solar collector and thermochemical reactor.</li> </ul>
State-of-the-art	<p>Phase-change heat storage can be used widely at a reasonable cost. Its main advantages are higher energy density, simplicity in system design and the delivery of heat at constant temperature.</p> <p>Thermochemical materials have the highest energy storage density and are seen as key materials for achieving loss-free thermal storages, also for long-term compact storage. The first generation of thermochemical materials are now being applied in system concepts.</p>
Targets	<ul style="list-style-type: none"> <li>• Developing microencapsulated PCM for <math>300\text{ }^{\circ}\text{C} &lt; T &lt; 1,000\text{ }^{\circ}\text{C}</math>.</li> <li>• Novel PCM with adjustable phase change T.</li> <li>• New heat exchangers with PCM included.</li> <li>• TCM target: 4 times more compact than water at system level.</li> <li>• Novel TC solar collector (directly charging of TCM in collector): first prototypes.</li> <li>• Control of TCM systems: new sensors developed.</li> <li>• Improved seasonal solar TCM solution for single-family houses.</li> </ul>

Specific KPIs	Stable, micro encapsulated salt hydrate PCM	2012: only paraffin PCM available; price over 8 €/kg	2020: novel materials in pilot applications	2030: production technology optimised; material available at <2€/kg
	micro-encapsulated PCM for medium and high T	2012: some pilot plants with bulk PCM for high T	2020: several materials developed; pilot applications	2030: production technology developed; materials available on a large scale at <2€/kg
	Novel heat exchangers including PCM	2012: few concepts	2020: proof of concept for at least 5 concepts; typical peak power 25 kW	2030: several applications commercialised
	Level of maturity of novel TC solar collector concepts	2012: first concepts (TRL 1)	2020: industrial prototypes (TRL 5)	2030: state of the art (TRL 9)
	New sensors for PCM and TCM state of charge	2012: First concepts (TRL 1)	2020: Industrial prototypes (TRL 5)	2030: State-of-the-art (TRL 9)
	Improved seasonal solar TCM	2012: 60 kWh/m <sup>3</sup> <sub>system</sub>	2020: 160 kWh/m <sup>3</sup> <sub>system</sub>	2030: 250 kWh/m <sup>3</sup> <sub>system</sub>
	Novel TC materials at laboratory stage	2016: 4	2020: 40	2030: 100
Type of activity and TRL	60% Research (TRL 2-3) 30% Development (TRL 4-5) 10% Demonstration (TRL 6-8)			
Priority Group	II			
Estimated Budget	TOTAL: 40 Mln Euro		PUBLIC: 80%	PRIVATE: 20%
Recommended n. of projects	10 projects on material, component and system development			

CCT.9	High capacity heat pump for simultaneous production of cold and hot water for heating/cooling non-residential buildings			
Objective	Development of a high efficiency, high capacity heat pump solution for 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 competitive cost, high reliability, optimised control and easy integration with other systems.			
State-of-the-art	A few European manufacturers have recently announced some models with similar features. An improvement on versatility, reliability and efficiency is required as well as a reduction of cost.			
Targets	Capacity around 100 kW, sCOP for heating and cooling 10 for production of hot water at 40 °C and chilled water at 10 °C. Minimum refrigerant charge.			
Specific KPIs	sCOP referred to electricity consumption of air-to-air HP	2012: 7	2016: 8	2020: 10
	Reference value of refrigerant charge (Kg of refrigerant per kW of HP capacity)	2012: n.a.	2016: 0.2	2020: 0.1
Type of activity and TRL	70% Development (TRL 4-5) 30% Demonstration (TRL 6)			
Priority Group	II			
Estimated Budget	TOTAL: 10 Mln Euro		PUBLIC: 65%	PRIVATE: 35%
Recommended n. of projects	2			

CCT.10	Integration, automation and control of large scale hybrid systems for non-residential buildings			
Objective	<p>Efforts should be put into developing large (&gt;100kW) hybrid systems with the following characteristics:</p> <ul style="list-style-type: none"> <li>Improved efficiency through: <ul style="list-style-type: none"> <li>well-designed systems (good hydraulic layout, exergetic optimization,...);</li> <li>control systems that optimise the energy consumption and take advantage of the availability of renewable energy (optimise solar gain, decrease PER, increase mean system efficiency,...);</li> <li>embedded equipment for energy monitoring to have a clear picture of the energy production, cost of primary energy consumed and amounts of GHG emitted;</li> <li>more rapid failure detection, signalled, for example, by excessive primary energy consumption and notification to the user and/or to the service company.</li> </ul> </li> <li>Weather forecast, based on local observation and/or services available by internet.</li> <li>Heating, cooling and DHW load forecast, based on the learning of system operation and occupants' behaviour.</li> <li>New processing algorithms to supervise the complete system (adaptive control, learning process, etc.) while maintaining a high degree of comfort and a low consumption of auxiliary electricity.</li> <li>Load shift potential to be used only with storages (buffer storages, building envelope used as thermal storage).</li> <li>Smart grid integration.</li> <li>Development of new business models and load shift tariffs.</li> </ul>			
State-of-the-art	A few demo projects exist; system efficiencies are rather low compared to single technologies and need to increase in terms of control and detection performances, etc.			
Targets	Payback time of 5 to 7 years of the additional investment cost for the hybrid system compared to a stand-alone solution due to the optimum use of RES and the use of flexible energy tariffs.			
Specific KPIs	Definition of processing algorithms and set of standards for the construction of large scale hybrid systems	2012: n.a.	2020: algorithms and standards are developed and tested in pilot projects	2025: next generation of hybrid systems
	Primary Energy Ratio of a reference system	2012: 0.8	2020: 0.6	2020: 0.5
	Average increase to the payback time, compared with conventional alternatives (n. of years)	2012: n.a.	2020: 5	2025: 1
Type of activity and TRL	50% Development (TRL 4-5) 50% Demonstration (TRL 6)			
Priority Group	II			
Estimated Budget	TOTAL: 60 Mln Euro		PUBLIC: 33%	PRIVATE: 67%
Recommended n. of projects	4 project (10 demo site)			

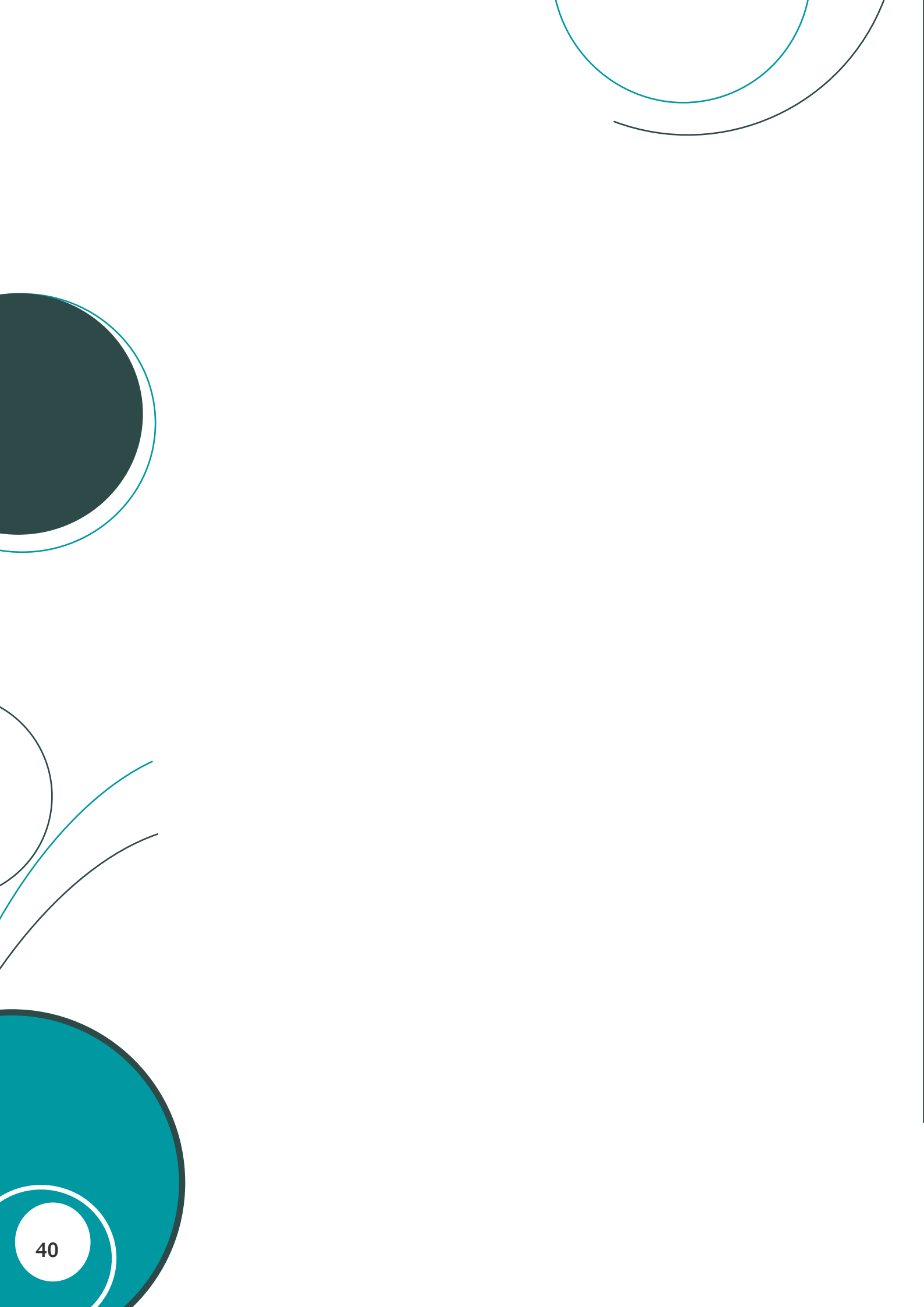
CCT.11	Sorption cooling systems driven by hot water at moderate temperature			
Objective	The development of new or improved sorption systems for production of chilled water for cooling of buildings driven by low temperature heat sources, as for instance solar. The expected outcome also includes the development of optimised solutions for the heat rejection, fully reliable and automated operation, and easy integration with other systems.			
State-of-the-art	Sorption technology has significantly improved in the past years. However an increase in the efficiency of the whole system, including heat rejection and auxiliaries, and an increase in reliability need to be carried out to improve its application potential in the mentioned sector.			
Targets	Assuming the system’s capacity is in the range of 20-100 kW and temperature of the hot source is in the range from 60 to 90 °C: <ul style="list-style-type: none"><li>the system should achieve at least a sCOP value of 0.7;</li><li>payback period of the investment must be less than 8 years, also in comparison with an electrical chiller.</li></ul>			
Specific KPIs	Carnot efficiency			
	$\xi_{Carnot} = \frac{COP_{real}}{COP_{ideal}}$	2012: 0.40 0.35	2016: 0.45 0.40	2020: 0.50 0.45
	Reference value of COP <sub>electric</sub> (water cooled)	2012: >10	2016: >15	2020: >20
	Reference value of COP <sub>electric</sub> (air cooled)	2012: >6.5	2016: >8.5	2020: >11
	Reference sCOP (water cooled)	2012: 0.5	2016: 0.6	2020: 0.7
	Reference sCOP (air cooled)	2012: 0.3	2016: 0.35	2020: 0.40
	Chiller power density (water cooled)	2012: 10 kW/m³	2016: 20 kW/m³	2020: 25 kW/m³
	Chiller power density (air cooled)	2012: 6 kW/m³	2016: 10 kW/m³	2020: 12 kW/m³
	Average payback time (years)	2012: <12	2016: <10	2020: <8
Type of activity and TRL	20% Research (TRL 3) 50% Development (TRL 4-5) 30% Demonstration (TRL 6)			
Priority Group	I			
Estimated Budget	TOTAL: 20 Mln Euro		PUBLIC: 60%	PRIVATE: 40%
Recommended n. of projects	4			

CCT.14	Improvements in Underground Thermal Energy Storage (UTES)			
Objective	<p>Improvement of system concepts and operational characteristics of UTES systems, investigation of optimum integration of UTES into industrial processes and DHC systems. In addition, the thermal efficiency of storage in different geological conditions should be increased and the thermal behaviour better understood (cf. Geothermal Technology Roadmap).</p> <p>Of high importance for the reliable operation of UTES is R&amp;D into water treatment technology preventing clogging, and into component selection to prevent scaling and corrosion.</p>			
State-of-the-art	<p>The first UTES applications were in fact used for industrial purposes, providing cold to the textile industry near Shanghai in China in the 1960s. Since then, system concepts have been developed and geological and hydrogeological constraints investigated. Within UTES, ATES systems are currently designed and operated following established routines, however further improvements are still possible and some aspects like hydrochemistry and water treatment await satisfactory solutions. With regard to BTES and CTES, system integration and innovative concepts should be further developed.</p>			
Targets	<ul style="list-style-type: none"> <li>• Increase energy efficiency of heat storage in the underground for industrial batch processes and DHC systems by 25 % (relative).</li> <li>• Improve system reliability and plant longevity at elevated temperatures, typically over 50 °C.</li> </ul>			
Specific KPIs	Energy efficiency (defined as the ratio “heat out” / “heat in”)	2012: 60 %	2016: 65 %	2020: 75 %
	Lifetime of the UTES at elevated T (n of years)	2012: 10 – 25	2016: 15 – 30	2020: 20 – 30
	Maintenance cost as share of operational costs	4-8 %	3-6 %	2-4 %
Type of activity and TRL	40% Development (TRL 4-5) 60% Demonstration (TRL 6)			
Priority Group	II			
Estimated Budget	TOTAL: 40 Mln Euro		PUBLIC: 50%	PRIVATE: 50%
Recommended n. of projects	8 in total (3 large research and development projects; 5 smaller demo projects).			

CCT.16	New concepts for industrial heat pumps			
Objective	<p>A broader range of operating temperatures and higher temperature lifts are needed to increase the application potential and the energy saving potential that heat pumps offer. The end users’ demands extend beyond the required temperature and cost of the system to topics such as the toxicity &amp; flammability of the working medium and the reliability of the system. No single heat pump technology can cover this entire range of demands, meaning different heat pump technologies should be developed in parallel.</p> <p>The main objective is the exploration of alternative thermodynamic cycles for heat-pumping and heat transforming for different industrial applications, with the goal to increase the operating window of industrial heat pumps so that they can deliver heat at medium pressure steam levels (around 200°C). Not only will these improvements allow larger energy savings, but they will also unlock the benefits of economies of scale for the European heat pump industry.</p>			
State-of-the-art	<p>The efficiency of any heat pump system increases as the temperature difference, or «lift», decreases between heat source and destination. Efficiently providing heat for industry at temperatures higher than 90°C with heat pumps is difficult. Industrial heat pumps (for heating purposes) currently consist of closed cycle vapour compression, open cycle mechanical vapour recompression and Lithium Bromide (LiBr) heat transformers.</p>			
Targets	<ul style="list-style-type: none"><li>· Deliver heat at a temperature up to 200°C</li><li>· Temperature lift ≥ 70 K</li><li>· 20% increase in the energy output compared to current technology, resulting in a reduction of the payback time</li></ul>			
Specific KPIs	Temperature of the delivered heat	2012: 100°C	2018: ≥150°C	2020: ≥200°C
	Temperature lift	2012: 60K	2018: 70K	2020: >70K
	Payback time (years)	2012: 5	2018: <5	2020: <3
Type of activity and TRL	70% Research (TRL 2-3) 30% Development (TRL 4)			
Priority Group	II			
Estimated Budget	TOTAL: 25 Mln Euro		PUBLIC: 67%	PRIVATE: 33%
Recommended n. of projects	4			

CCT.20	Improved, highly efficient substations for both present and future lower temperature networks			
Objective	Substations should become smarter, softer, and cheaper. The following priorities are identified: <ul style="list-style-type: none"><li>· Improving in the manufacturing process</li><li>· Costs reduction</li><li>· Efficiency gains</li><li>· Capacity to adapt to changes in the energy demand profile</li></ul>			
	To reach these objectives, R&D must also look at ways to harmonise substations' standards, to reduce materials' cost, to invest in the automation of manufacturing methods and to achieve good performances also at temperatures below 70° C.			
State-of-the-art	Substations, namely the heat exchangers, are currently designed for temperatures above 70°C. In low temperature DH networks (below 70 °C), the temperature drop across a heat exchanger will be decreased. More efficient heat exchangers will be required to maintain or even reduce the costs for the customer.			
Targets	<ul style="list-style-type: none"><li>· Reducing energy consumption for the customer by 8% through the use of eco-efficient substations</li><li>· Reduce manufacturing cost by 15% compared to current standards.</li></ul>			
Specific KPIs	Substations' reference manufacturing cost (in EU, residential buildings)	2012: 5.000 to 10.000 €	2016: 5.000 to 8.000 €	2020: 4.000 to 6.000 €
	Average electricity consumption of substations for residential building	2012: 4.380 kWh/year	2016: 3.400 kWh/year	2020: 2.600 kWh/year
	No. of “smart substations” (efficient pumping systems and intelligent control system) installed as a proportion of all new substations	2012: 15% to 20%	2016: 50%	2020: 80%
Type of activity and TRL	10% Research (TRL 3) 20% Development (TRL 4-5) 70% Demonstration (TRL 6)			
Priority Group	II			
Estimated Budget	TOTAL: 40 Mln Euro		PUBLIC: 60%	PRIVATE: 40%
Recommended n. of projects	5, each project including at least 50 buildings			

RHC.1	<b>Developing standards for the overall system design and for hydraulic and electrical interconnections of different building components</b>		
Objective	<p>The main objective is to elaborate and validate new standards for the design and inter-connection of RHC systems. In particular, these activities aim at:</p> <ul style="list-style-type: none"> <li>· ensuring cost-efficiency and interoperability</li> <li>· enabling low-cost, easy and fail-safe installation (plug and function or plug and flow)</li> </ul> <p>The expected outcome is a set of harmonised EU standards for the connection of renewable heating and cooling equipment and systems. This will unlock new market opportunities for manufacturers and system developers and should lead to the fact that the gap between predicted and in operation measured energy consumption figures can be reduced.</p>		
State-of-the-art	A lot of components in consumer-type RHC (i.e. in the residential sector) are still designed to national standards, company rules, or just individually hand-made. Also, different types of equipment can belong to different clusters of standardisation, preventing easy combination e.g. in hybrid systems. The interchange of components from different countries or manufacturers is thus limited, and designers as well as installers are confronted with challenges in interconnection.		
Targets	Reduce the first cost of components and time and cost of installation. Improve system functionality, reliability and longevity as well as inter-component compatibility.		
KPIs	<ul style="list-style-type: none"> <li>· Installation time is reduced by 30%</li> <li>· Material cost reduction for the end-user of 20% (cfr CCT.3)</li> <li>· 20% reduction of human interventions for maintenance / reparation</li> </ul>		
Type of activity	25% Research / 50% Development / 25% Demonstration		
Priority Group	II		
Estimated Budget	TOTAL: 15 Mln Euro	PUBLIC: 40%	PRIVATE: 60%
Recommended n. of projects	3		



4

## Priority Group III: implementation 2018 - 2020



Water frozen by providing energy to a heat pump

## 4 PRIORITY GROUP III: IMPLEMENTATION 2018 - 2020

This section presents the last wave of priorities included in the RHC-Platform's Cross-cutting Technology Roadmap. The topics presented here are recommended to be implemented between 2018 and 2020. The reason for the inclusion of these topics in the "Priority Group III" should not be sought in the relative importance or stakeholders' interest for these activities. On the contrary, some of these projects are expected to generate ground-breaking results which would have significant impact in the future heating and cooling systems.

This Roadmap is based on the logic of sequential series of (clusters of) projects. The selection of priorities of Group III are characterised by:

- complementarities with the expected findings of the projects implemented in the period 2014 – 2018;
- the need to leverage adequate private resources, which are not available at the time of writing;
- the need to build a critical mass of industry and research stakeholders willing to take part in the implementation of these activities.

	Research and Innovation Priorities	Technology focus	Predominant application
CCT.4	Development of a heat pump for near-zero energy buildings (single family houses)	Heat Pump	Residential buildings
CCT.5	Next generation of highly integrated, compact hybrid systems	Hybrid Systems	Residential buildings
CCT.7	Improving the efficiency of combined thermal energy transfer and storage	TES	Residential buildings
CCT.12	Enhanced industrial compression heat pumps	Heat Pump	Industrial Processes
CCT.15	Improvement of sorption cooling from renewable energy sources	Renewable Cooling / DHC	Industrial Processes
CCT.19	Develop and roll-out DHC driven white goods and low temperature solution for domestic hot water preparation	DHC	All
CCT.21	Optimised integration of renewable energy sources in DHC systems and enhancement of thermal energy storage at system level	DHC / TES	All

Figure 5: Research and innovation topics of Priority Group III

CCT.4	Development of a heat pump for near-zero energy buildings (single family house)			
Objective	Development of a small capacity reversible heat pump (around 3-4 kWth), with low cost, easy installation, operation and maintenance for the new low-energy consumption houses of the EU with optimal integration with the ventilation heat recovery, cooling, dehumidification and domestic hot water production. Additionally, the unit should employ a low Global Warming Potential (GWP) refrigerant. Different designs will be necessary to accommodate for the European climate zones.			
State-of-the-art	The latest developments in this sector are the exhaust air heat pumps which are efficient devices that extract heat from the exhaust air and produce a small extra amount of heat for the house.			
Targets	sCOP> 5. The exhaust air heat pump should be able to keep reasonable performance even at low outdoor temperatures like 10°C.			
Specific KPIs	sCOP (for heating and cooling)	2012: 3.5	2020: 5	2025: 6
	Contribution to the production of DHW	2012: n.a.	2020: 30%	2025: 40%
Type of activity and TRL	60% Development (TRL 4-5) 40% Demonstration (TRL 6)			
Priority Group	III			
Estimated Budget	TOTAL: 12 Mln Euro	PUBLIC: 60%		PRIVATE: 40%
Recommended n. of projects	4			

CCT.5	Next generation of highly integrated, compact hybrid systems			
Objective	<p>Efforts should be put into developing compact / prefabricated hybrid systems with the following characteristics:</p> <ul style="list-style-type: none"> <li>Improved efficiency through: <ul style="list-style-type: none"> <li>well-designed systems (having smart hydraulic layouts, energy storage management, being exergetically optimised);</li> <li>control systems that optimise the energy consumption and take advantage of the availability of renewable energy (optimised integration of both energy systems giving priority to the utilisation of renewable / more cost efficient source);</li> <li>embedded equipment for energy monitoring in order to have a clear picture of the energy production, cost of primary energy consumed and amounts of GHG emitted;</li> <li>immediate failure detection, signalled e.g. by excessive energy consumption and notification to the user and/or service company.</li> </ul> </li> <li>Inexpensive and simplified installation to reduce damage, high degree of prefabrication.</li> <li>Adapted to the various configuration of heating systems (low/high temperature) and climates.</li> <li>Inexpensive and simplified installation.</li> </ul> <p>Activities must include the development of suited testing procedures allowing for comparability of performance data and as a reference for the technology development.<sup>14</sup></p>			
State-of-the-art	<p>Today most hybrid systems are customised combinations of single components assembled by the installer. The efficiency of the overall system strongly depends on the installer's skills, technical knowledge and choice of the right components. The PER of the whole system is rarely known. The inefficient assembling of the hybrid system produces average energy losses of around 20%, which are hardly detected by the customer. Several manufacturers offer installation guidelines for the combination of the core component with a second thermal energy source. However prefabricated, highly integrated hybrid systems have only recently become available. The state-of-the art is represented by the combination in a single system of biomass / solar thermal technology or heat pump / solar thermal system, including a joint heat storage and control.</p>			
Targets	<ul style="list-style-type: none"> <li>Development of prefabricated, fully integrated hybrid systems using at least one RES contributing over 50% to the final heating and cooling consumption. These systems should be suitable for both new and existing building; including performance monitoring and a customer information system.</li> <li>20% cost savings on system installation in comparison with customised hybrid systems dependent on the installer's design.</li> <li>PER reduced of 20% / system efficiency increase of 20% in comparison with hybrid systems based on customised design and assemblage by the installer.</li> </ul>			
Specific KPIs	Renewable fraction of the reference hybrid system	2012: n.a.	2020: 50%	2030: 75%
	Reference system cost	2012: 800 – 1,500 €/kW	2020: 640 – 1,250 €/kW	2030: 500 – 1,000 €/kW
	Capacity of the system to automatically detect failure and react	2012: limited	2020: advanced	2030: complete
	Primary Energy Ratio of a reference system	2012: 0.8	2020: 0.65	2020: 0.6
Type of activity and TRL	10% Research (TRL 3) 45% Development (TRL 4-5) 45% Demonstration (TRL 6)			

<sup>14</sup> Cfr. also priorities RHC.1 and RHC.2

Priority Group	III		
Estimated Budget	TOTAL: 25 Mln Euro	PUBLIC: 33%	PRIVATE: 67%
Recommended n. of projects	5		

CCT.7	Improving the efficiency of combined thermal energy transfer and storage			
Objective	Further development and improvement of fluids that combine the heat transfer function with thermal energy storage. These will lead to smaller required storage volumes, an increase in heat transfer efficiency and a reduction in auxiliary energy for pumping.			
State-of-the-art	Low-viscosity, non-corrosive fluids capable of storing large quantities of heat and able to work at low pressure are needed for the next generation of TES systems. For medium temperatures, molten salts could offer the ultimate solution. For low temperatures, additional research is needed on PCM slurries and PCM emulsions as well as demonstration of innovative concepts for cooling in buildings with ice slurries.			
Targets	<ul style="list-style-type: none"> <li>Development of new fluids for thermal energy transfer and storage. New materials for both high temperature applications for solar cooling or process heat, with working temperatures between 120 and 250 °C, and for low temperature applications for heating and cooling.</li> <li>Development of PCM slurries or emulsion or molten salts or any other fluid with a long life-time, reducing the pumping energy of 25% with respect to conventional water based heat transfer fluid system.</li> <li>A reduction of 20% of the storage volume through the use of PCM heat transfer fluids for room heating.</li> </ul>			
Specific KPIs	Viscosity of the fluid [ $\mu$ (Pa·s)], which positively relates with the energy required for pumping	2012: Water: 0.001002 Slurries: > 0.001 Mineral Oil (Therminol VP-01 at 400°C): 0.00000039049 Silicone (Syltherm 800 at 400°C): 0.00025 Molten salts: 0.000031-0.0005435 depending on the mixture	2020: 25% reduction of the viscosity of the relevant fluids	2030: 30% reduction of the viscosity of the relevant fluids
	Reduction of annual electricity consumption for pumping (reference: DHW system <sup>15</sup> )	2012: 75 kWh	2020: 60 kWh	2030: 50 kWh
	Energy density (Kg/m <sup>3</sup> ), which is inversely related with storage volume (kJ/m <sup>3</sup> )	2012: Water at 20 °C: 1000 Slurries: n.a Mineral Oil at 400°C: 694 Silicone at 400°C: 547 Molten salts (60%NaNO <sub>3</sub> + 40%KNO <sub>3</sub> ) at 400°C: 1787 depending on the mixture	2020: 20% reduction storage volume through increase of energy density	2030: 30% reduction storage volume through increase of energy density
Type of activity and TRL	40% Research (TRL 1-3) 40% Development (TRL 4-5) 20% Demonstration (TRL 6)			

<sup>15</sup> 5-15 m<sup>2</sup> solar collector; 1500 operating hours, 50 W conventional pump.

Priority Group	III		
Estimated Budget	TOTAL: 16 Mln Euro	PUBLIC: 60%	PRIVATE: 40%
Recommended n. of projects	3 projects on medium T materials and low T PCM slurries and emulsions		

CCT.12	Enhanced industrial compression heat pumps			
Objective	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). Applications of these novel heat pumps include process heat generation as well as waste heat recovery in industrial processes yielding substantial increases in energy efficiency. R&D topics to be addressed in this context comprise: <ul style="list-style-type: none"><li>· new working media (low GWP, non-inflammable) or natural refrigerants (water),</li><li>· improved compressors and lubrication methods for high evaporating temperatures (up to 100°C),</li><li>· heat exchangers with improved design for direct using of condensing gases (flue gas, exhaust air, drying processes, etc.).</li></ul>			
State-of-the-art	Current vapour compression systems deliver heat at a maximum temperature of ~80 °C.			
Targets	<ul style="list-style-type: none"><li>· Carnot efficiency of at least 0.35</li><li>· At least 2 demonstration projects should be realised by 2020.</li><li>· Condensation temperatures up to 150°C</li><li>· Temperature lift up to 60 K</li><li>· Energy saving up to 30%</li><li>· Cost target heat pump unit: 200 to 300 Euro/kW</li></ul>			
Specific KPIs	Carnot efficiency factor (to be achieved through optimized components and integration)	2012: ≥ 0.30	2018: ≥ 0.35	2025: ≥ 0.40
	Maximum Evaporating Temperature of the heat source	2012: ≥ 40 °C	2018: ≥ 70 °C	2025: ≥ 100 °C
	Maximum Condensing Temperature for process integration	2012: ≥ 80 °C	2018: ≥ 120 °C	2025: ≥ 150 °C
	Production cost of the heat pump unit	2012: 300 €/kW	2018: 200-300 € / kW	2025: <200 €/kW
Type of activity and TRL	20% Research (TRL 3) 60% Development (TRL 4-5) 20% Demonstration (TRL 6)			
Priority Group	III			
Estimated Budget	TOTAL: 12 Mln Euro	PUBLIC: 70%		PRIVATE: 30%
Recommended n. of projects	3			

CCT.15	Improvement of sorption cooling from renewable energy sources			
Objective	Providing cold from a constant and dependable heat source (like deep geothermal energy, surplus heat from biomass or district heat) could be done by various sorption technologies. The cold might be used in industry, but could also be fed into district cooling systems.			
	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 chillers.			
	Reduce medium temperature waste heat by increase of efficiency and solve waste heat disposal (re-cooling) issues.			
State-of-the-art	Absorption chillers are available in the capacity range up to 1 MW. In the field of deep geothermal, despite several project ideas, no large absorption cooling yet has been demonstrated. Chillers need to be better matched to the energy source. The market penetration of district cooling is still relatively low, resulting in little experience achieved by now.			
Targets	<ul style="list-style-type: none"><li>· Develop a new, reliable and clean technology for cold production.</li><li>· Reduce weight and size of absorption chillers.</li><li>· Have at least 10 pilot plants in the 1-MW-range operational by 2025, associated to district cooling networks.</li></ul>			
Specific KPIs	Cost for absorption chiller : €/kWc	2012: 160	2020: 120	2025: 100
	Specific weight : kg/kWc	2012: 7	2020: 6	2025: 5
	N. of plants in operation	2012: n.a.	2020: 2	2025:10
Type of activity and TRL	60% Development (TRL 4-5) 40% Demonstration (TRL 6-7)			
Priority Group	III			
Estimated Budget	TOTAL: 40 Mln Euro		PUBLIC: 40%	PRIVATE: 60%
Recommended n. of projects	10			

CCT.19	Develop and roll-out DHC driven white goods <sup>16</sup> and low temperature solution for domestic hot water preparation			
Objective	<p>DHC networks can supply a wide variety of household appliances that nowadays produce heat or cold internally with electricity. White goods already exist and are commercially available but they are expensive. The cost of these white goods should be reduced by bringing them from demonstration to mass production. There is a need for demonstration projects to show the feasibility of using in-house appliances which directly use thermal energy from the thermal district energy system</p> <p>The sector should also develop customised solutions for the hygienic supply of domestic hot water (DHW) using low supply temperatures that are beneficial for the whole energy system. 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.</p>			
State-of-the-art	<p>Most often white goods use electricity to produce thermal energy (heat or cooling). Solutions exist which use DHW provided through DHC networks for domestic appliances.<sup>17</sup> If the building is connected to the local thermal district energy network, it is much more efficient and more environmental friendly to directly use thermal energy delivered by the network.</p> <p>DHW today must be stored and supplied at temperatures over 60°C in order to avoid the development of bacteria (legionella). With the development of low temperature systems, the preparation of DHW in DHC networks should be given appropriate attention to avoid the development of legionella.</p>			
Targets	<ul style="list-style-type: none"><li>· Decrease the electricity consumption of white goods by 50% in household using DHC. White goods using DHC becoming cost-competitive with traditional ones.</li><li>· Develop new plug-and-play solutions which allow the operation of DHC at temperatures below 50°C without risk of bacterial infections.</li></ul>			
Specific KPIs	Electricity consumption of white goods per year, average household <sup>18</sup>	2012: 850 kWh	2020: 153 kWh	2030: 130 kWh
	Operating temperature of white goods connected to DH	2012: 80 °C	2020: 60 °C	2030: 40 °C
	N. of plug-and-play white good products available on the EU market	2012: 3	2020: 7	2030:20
Type of activity and TRL	50% Development (TRL 4-5) 50% Demonstration (TRL 6)			
Priority Group	III			
Estimated Budget	TOTAL: 7 Mln Euro		BLIC: 60%	PRIVATE: 40%
Recommended n. of projects	4			

<sup>16</sup> This term defines a range of household appliances which require thermal energy to perform their function. The most notable examples are refrigerators, dishwashers and washing machines.

<sup>17</sup> Askø Appliances (2013).

<sup>18</sup> It is assumed for an average household that the total use of electrical energy by the white goods (dishwasher, washing machine and tumble drier) is 153 kWh per year. In the baseline scenario (year 2012) these machines are not connected to DH network; instead the values for 2020 and 2030 are derived from the connection to DH network.

CCT.21	Optimised integration of renewable energy sources in DHC systems and enhancement of thermal energy storage at system level			
Objective	<p>Further research activities are needed to allow DHC networks to efficiently integrate all types of RES without jeopardising the quality of the service provided to the consumers. In the same way, it is important to explore new synergies between various customer groups with different thermal needs. The DHC sector must be able to exploit and upgrade all available renewable energy, as well as any surplus recovery heat.</p> <p>Reaching high penetration of RES in DHC requires applied research to develop smart thermal networks connecting diverse types of buildings and industrial processes, including <i>prosumers</i> (producer and consumer) where appropriate.</p> <p>Energy storage is a central component for enhancing the flexibility of district and heating systems, matching variable renewable energy sources with a fluctuating thermal demand. TES solutions already exist for district heating systems but they mainly suit short term storage. There is a need to develop flexible, efficient, multifunctional and cost-effective TES and to integrate these solutions in smart thermal networks.</p>			
State-of-the-art	<p>Currently DHC networks are mainly based upon few individual heat/cold sources, operated proportional to the heat/cold demand of the network. For integration of variable supply from renewable or surplus heat, the system structure and operational strategy must be changed radically.</p> <p>Today's systems for short-term and seasonal storage use the underground or water tanks located close to the heating source. In seasonal storage, especially when two tanks are used (cold and hot tank, or charged and discharged tank), twice the volume is required.</p>			
Targets	<ul style="list-style-type: none"><li>· Increase by 20% by 2030 the energy efficiency of DHC systems (maximise the energy output (heat delivered) for each unit of the energy input) by integration of thermal energy storage.</li><li>· The activities of research, development, demonstration and integration of TES solutions should result in a 30% reduction of heat costs.</li><li>· Increase the efficiency and performance of thermal energy storage technology, in particular seasonal storage.</li></ul>			
Specific KPIs	Reference heat cost <sup>19</sup>	2012: 200-50€/MWh	2020: 90-40€/MWh	2030: 70-35€/MWh
	Reference energy efficiency of DHC systems (index using baseline = 100)	2012: 100	2020: 110	2030: 120
	Efficiency and performance of TES applications in DHC networks	Depending on the technology and TES application, refer to the KPIs of priorities CCT.6; CCT.7; CCT.8; CCT.14.		
Type of activity and TRL	30% Research (TRL 3) 40% Development (TRL 4-5) 30% Demonstration (TRL 6)			
Priority Group	III			
Estimated Budget	TOTAL: 50 Mln Euro		PUBLIC: 58%	PRIVATE: 42%
Recommended n. of projects	10 projects. Demonstrate in at least 5 projects innovative DHC concepts combining multiple RES and different demand profiles, including multifunctional heat storage solutions			

<sup>19</sup> The specific impact of TES application on the cost of heat delivered through DHC systems depends on the specific energy mix and boundary conditions of the system.



# 5

## The implementation strategy



Test of a thermochemical storage prototype

## 5 THE IMPLEMENTATION STRATEGY

This Roadmap provides a comprehensive view of the research and innovation priorities for cross-cutting technology by 2020. The primary aim of this publication is to set up an implementation strategy to support the decarbonisation of the heating and cooling markets.

Research, development and demonstration projects on renewable heating and cooling technology currently suffer from being dispersed and insufficiently coordinated between EU, national and private level. This Roadmap provides a framework to help policy and decision makers planning technology advancements of crucial strategic importance. It follows the logic of three consecutive “waves” of projects and clusters of projects which can support the achievements of the EU energy and climate targets as well as to provide a stimulus to private investors to make Europe a resource-efficient and renewable economy beyond 2020.

Figure 7 illustrates the relations and synergies among the 23 priorities of the Roadmap (the different colors correspond to different technologies). According to the European Commission’s R&D programming, this implementation strategy is focused on 7-year period between 2014 and 2020. Concerted action by all public and private stakeholders is critical to stimulating investments on the scale required to achieve the RHC-Platform’s short and long term vision. Albeit some of the results of the R&D activities are expected to have a significant commercial impact only after 2020, it is very important to provide today the appropriate framework to ensure the transition to tomorrow’s energy systems.

For the first time, this Roadmap provides policy makers with a quantitative and qualitative analysis of the resources which should be mobilised to pursue the objectives described in the 23 topics. The information provided is based on the views expressed by a wide range of experts representing the most innovative European companies and research centres. Nonetheless, the figures associated with the KPIs as well as the estimated budgets should be regarded as indicative values rather than as exact measures.

Consistently with the previous publications of the RHC-Platform,<sup>20</sup> this report recommends that investments are strategically distributed among priorities related to all parts of the innovation value chain. Figure 6 illustrates the cumulated distribution of resources among activities of fundamental research, development and demonstration, as resulting from the 23 topics of the Roadmap. The budgets for the topics are indicated at page 12 and page 13.

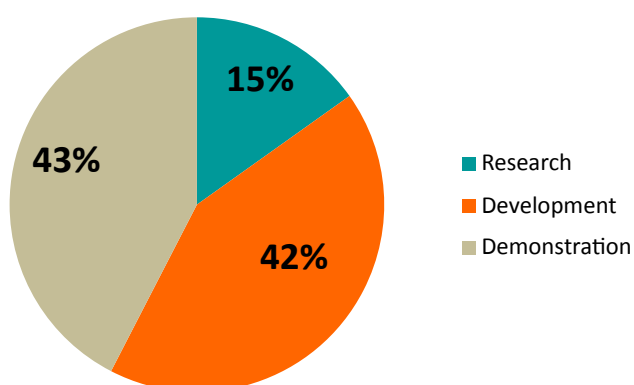


Figure 6: Estimated distribution of resources by type of activity

<sup>20</sup> In particular the RHC-SRIA (2013) and the Strategic Research Priorities for Cross-cutting Technology (2012).

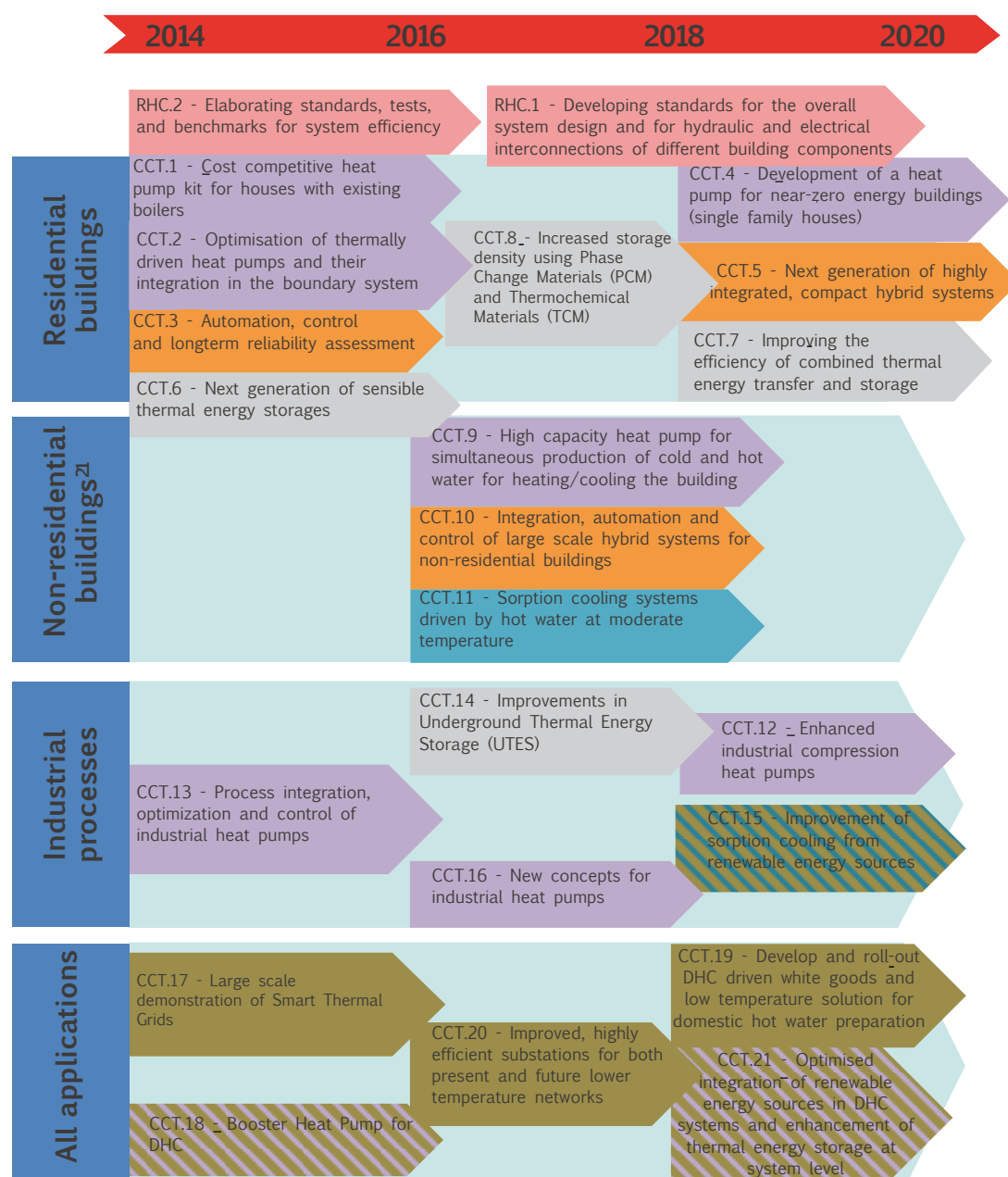


Figure 7: Implementation Strategy for the Cross-cutting Technology Roadmap

**Organisations endorsing the Cross-cutting Technology Roadmap available at the link:**

<http://www.rhc-platform.org/structure/cross-cutting-technology-panel/cross-cutting-technology-roadmap/>

<sup>21</sup> CCT.2 and CCT.6 are also applicable to non-residential building.

## APPENDIX

### SECRETARIAT OF THE RHC-PLATFORM

This document was prepared by the **Cross-Cutting Technology Panel of the European Technology Platform on Renewable Heating and Cooling (RHC-Platform)**, managed by **EUREC**, the Association of European Renewable Energy Research Centres.



The Secretariat of the European Technology Platform on Renewable Heating and Cooling is coordinated by EUREC and jointly managed with:



European Biomass Association (AEBIOM)



European Geothermal Energy Council (EGEC)



European Solar Thermal Industry Federation (ESTIF)

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