RHC-ETIP INPUT TO H2020 Energy Work Programme 2018 - 2020

Brussels, 1st December 2016

Executive Summary- Main messages

In H2020, all renewable energy technologies have to compete for the same budget in the related LCE calls, including electricity against the heating technologies. **The analysis of the results of the H2020 calls 2014 – 2016 shows the unintended result of this concept: RHC technologies receive significantly less funding than technologies related to Renewable Electricity**.

The only way to overcome this shortcoming for the RHC technologies in H2020 funding and to create a level playing field between the sectors is to separate, starting from the WP2018-2020, the H2020 LCE calls in calls for RHC technologies and calls for Renewable Electricity technologies. This approach would pay due respect to the fact that the RHC sector is, in contrast to the Renewable Electricity sector, much more diverse in technological applications and in markets, is mainly dominated by SMEs and has much smaller R&D capacities in industry as well as in universities and research institutes. This is the result of continuously neglecting the huge innovation potential of RHC technologies and the low R&D funding of RHC technologies both at European as well as at national level.

The competition between RHC technologies and Renewable Electricity technologies in the same call is a systematic fault. If non-electricity RHC technologies are needed to decarbonize the H&C sector (as shown above), it is not constructive to allow that almost only R&D projects on electricity technologies are funded (which is not intended, but obviously almost the case). The continuation of this mechanism will never enable the RHC technologies to regain the leeway of technological development in comparison to Renewable Electricity technologies. **This is why it is absolutely necessary to separate the RHC from Renewable Electricity related topics in H2020 calls and allocate separate budgets for them in order to create a level playing field.**

This document presents selected priorities by the experts of the RHC-ETIP related to the different fields which are covered by it: biomass; district heating and cooling; geothermal; heat pumps; hybrid systems; solar thermal; thermal energy storage.

For more information, please, contact the RHC-secretariat.

Biomass R&D priorities

R&D topic - BIO1: Sustainable, innovative and cost-efficient advanced fuel feedstock supply (for advanced fuels replacing coal, fossil oil and natural gas in heat and CHP production)

Specific challenge: As costs of feedstock now account for around 50% of bioenergy system costs, efforts need to be directed at reducing these costs in the feedstock supply chain. Ensuring the security of the biomass fuel supply constitutes a key challenge in the provision of reliable and environmentally friendly biomass technologies.
Scope: For biomass to be able to easily replace fossil fuels, the development of standardised, sector-oriented, innovative and sustainable biomass based fuels at competitive production costs is crucial.
Type of actions:

- Optimization of feedstock selection, storability, pre-treatment and quality (blended raw material use, reduction of impurities and losses, use of residues and by products such as bark, saw dust)
- Develop new methods to improve biomass production and intensification of biomass supply to reduce supply costs.
- Lowering carbon foot print by reducing the use of fossil fuel consumption in harvesting, transportation and pre-treatment of biomass.

R&D topic – BIO 2: Innovative production and upgrading technologies for bioenergy carriers

Specific challenge:
Despite of being market ready, some of the bioenergy carriers such as bio-oil and torrefied pellets do not currently have satisfying market shares to attract private investments. While some of them are still subject to R&D activities but the process is rather sluggish due to lack of incentives to accelerate the process.
Scope: Reducing the production costs and improving the quality of the bioenergy carrier is key to increase the replacement of fossil fuels.
Type of actions:

- **Bio-oil**: Bio-oil exists on the market and demonstrations have been made successfully in heat plants and larger peak electricity plants. Despite of its high potential, the number of commercial producers is low in Europe (Fortum and Empyro).
  R&I activities to be undertaken in the coming years to make bio-oil a cost-competitive fuel to replace fossil fuels

    - Reducing the overall production costs by increasing the scale of production
    - Developing bio-oil upgrading technologies: reducing the water content, increasing net calorific value
    - Feedstock flexibility: increasing the share of agricultural residues
- **Thermally treated biomass fuel production:** There are three main technologies for thermal treatment of biomass: torrefaction, pyrolysis and hydrothermal carbonisation (HTC). While the first two are almost market ready technologies, the latter is still in the development phase and therefore few years away from market implementation. HTC is a promising technology of tapping potential additional inexpensive, regional raw material such as high moisture biomass (biogenic municipal waste, wastewater sludge, digestate residues from agriculture and food industries) which is currently not highly mobilised.
  R&I activities to be undertaken in the coming years:
    - Torrefied biomass: Further industrial scale demonstrations and market development are needed to accelerate the market integration of torrefied biomass.
    - Hydrothermal processes: Further research and demonstration is necessary
- **Upgrading biogas to bio methane**: In order to address growing sustainability concerns with respect to the use of energy crops (specifically maize) for biogas and biomethane production, R&I activities need to focus on the diversification of raw materials for biogas production aiming at increased biogas yields for alternative feedstock.
  R&I activities to be undertaken in the coming years:
    - Diversification of raw materials for biogas production
    - Biogas up-grading: cost reduction and increasing efficicency
    - Increasing the load flexibility and efficiency of biogas CHP systems

R&D topic – BIO 3: Cost and energy efficient, environmentally friendly micro and small scale CHP

Specific challenge: The development in the sector has been difficult due to different competing technologies. The research funding received by micro and small CHP is rather low.
Scope: Small and micro-scale CHP constitute a high energy efficient solution providing reliable and decentralised renewable energy production for residential sector, small scale industries and service sector.
Type of actions:
- Reduce conversion system costs
- Increase the load flexibility and fuel flexibility
- Development of efficient storage systems (electricity, heat) to avoid grid losses

- Emissions reductions

R&D topic – BIO 4: Development of highly-efficient, low-emission medium- and large-scale biomass-based CHP systems:

Specific challenge: The challenge is to increase both technology performance and resource efficiency, while reducing environmental impacts.

Scope: CHP has a high potential for heat and electricity production in particular for decentralised applications.

Type of actions:

- Cost effective, robust and low emission (both CO2 NOx and particles) medium and large-scale industrial CHP (>1MW) : A significant step forward in the technology efficiency together with a reduction in resource consumption and reduced emissions is needed, to deliver reduced costs, both operation and maintenance, and increased attractiveness of renewable heating).
- High thermal and electrical efficiency and increased high-temperature heat potential up to 600°C: Compared to other renewables, biomass based heating and cooling technologies are the most promising to supply high temperature (>400°) heat to the industry.
- Increasing the use of a wider base of solid, liquid or gaseous sustainable biomass and recovered feedstock
- Ash use or removal, as well as ash challenges during combustion, requires particular attention.

District Heating and Cooling R&D priorities

R&D topic – DHC 1: Optimised integration of renewable and recovered energy sources in DHC systems and enhancement of thermal energy storage at system level

- Further research activities are needed to allow DHC networks to efficiently integrate all types of RES end recovered heat sources without jeopardising the profitability of DHC networks and 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. Reaching high penetration of RES in DHC requires applied research to develop smart thermal networks connecting diverse types of buildings and industrial processes, including prosumers (producer and consumer) where appropriate.
- Energy storage is a central component for enhancing the flexibility of district and heating systems, matching variable renewable energy sources witkh 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 for short (hours to days) and long (weeks to month) term, for central and decentral applications and to integrate these solutions in existing and new smart thermal networks. This should consider power-to-heat applications as part of an overall energy strategy and synergies between the networks (power-to-heat/gas, CHP); Further on, business and financing models as well as new control strategies needs to be developed in order to make the storages more cost competitive.

- Further development and implementation of network control strategies including decentralized supply and hybrid operation
- Further development and integration of cooling technologies

Expected Impact:

- Increase the share of RES end recovered heat sources by 20%
- Increase the primary energy efficiency of DHC systems (maximise the energy output (heat delivered) for each unit of the primary energy input)
- The activities of research, development, demonstration and integration of TES solutions should result in reduction of heat costs.
- Increase the cost-competitiveness, efficiency and performance of thermal energy storage technology, in particular seasonal storage.

R&D topic – DHC 2 : Digitalisation and emerging technologies for (district) heating and cooling systems and networks

Specific challenge: In our current (district) heating and cooling systems the integration of ICT and the digitalisation of our thermal energy systems at building and district level becomes important in order to increase the energy efficiency of these systems and to create/provide flexibility in our energy systems and to offer additional (grid)services for other energy networks. Different systems and components will be interconnected to different platforms sharing and exchanging information between them. The applicability however faces a number of challenges, such as the transition to technology maturity and standardisation/integration, the need to develop new or transform (district) heating and cooling systems in buildings and districts and the need to change the perception of what the digitalisation can bring to consumers.

Scope: Actions are needed to develop, demonstrate, validate and improve the overall benefit of digitalisation by:

- ICT and emerging technologies that are able to upgrade (existing) (district) heating and cooling systems. Necessary attention should be paid to improving system reliability, standardisation, automated operation and to identify the benefits to the consumers of creating/providing energy flexibility in (district) heating and cooling systems.

- Integrated (district) energy management systems based on different control approaches (model predictive, multi-agent, self learning, etc) to maximize the interaction and integration of smart thermal and ICT grids. Intelligent control and metering of the network and system performance should be envisaged. The development of flexible control interfaces and systems in building and/or district management systems.
- Developing and demonstrating grid flexible (district) heating and cooling technologies in buildings and districts that can provide additional grid services. Plug and play energy modules and approaches should be developed and demonstrated.
- Clustering approaches and capabilities of different energy systems at building and district level should be developed. To create technologies and services for smart homes that provide smart solutions to energy consumers. Data management and storage. Use of big data systems and platforms.
- Providing additional benefits to the district heating network by reducing the peak loads and the return temperatures in the buildings
- Development of planning and design tools for new network types including hybrid networks, low- and multi-temperature networks, including cascading options, dynamic effects and new control strategies

Proposals are expected to address one or more areas mentioned above, as necessary. The activities are expected to be implemented at Technology Readiness Level (TRL) 4-6.

Expected Impact:

Proposals are expected to demonstrate the impacts listed below, using quantified indicators and targets wherever possible:

- Primary energy savings and GHG emission savings triggered by the proposed solutions (compared to best available solution existing today);
- Competitiveness of the heat and cold delivered by the proposed solutions (compared to best available solution existing today);
- Increased share of residual and renewable sources of thermal energy in the supply of heating demand;
- Increase the share of renewable sources in the electricity network, if applicable
- Viable business model showing the economic and commercial viability of operating the proposed solutions
- Scale of the replicability potential of the proposed solutions

Type of Action: Research and innovation action (RIA)

R&D topic – DHC 3: Optimization of technologies for district heating and cooling networks and systems

Specific challenge: District heating and cooling networks and systems are seen as a valuable option to increase the energy efficiency and the integration of a higher share of renewable energy in buildings and districts. Still, technologies are needed to improve the overall energy efficiency in those systems.

Scope: Actions are needed to develop, demonstrate and validate:

- Improved, standardized, plug & play, highly efficient district energy substations for both present and future lower temperature networks, including innovative heat exchanger designs that will provide the capacity to operate with low mean logarithm temperatures difference values, without a significant size and cost increase.
- Development of standardized, compact and cost effective bidirectional thermal substations, with the capacity to produce a bidirectional interaction with thermal energy networks required to enable the district level demand and distributed production aggregation existing in smart thermal grids.
- The development and demonstration of strategies to minimize the return water temperature in DHC systems when the connected customers require significantly different water supply temperatures. The benefits to the end-consumlers should be addressed as well as suitable business models developed. The control and exergetic efficiency improvements of thermal energy storage systems should also be targeted.
- Development and demonstration of the potential of installing local micro thermal networks next to larger-scale DHC networks. Development of methods for evaluating the possibilities and potentials of thermal networks next to existing structures by connecting a few buildings or a neighbourhood with local sources and storage units for optimal efficiency. This should be applied to new development areas, existing buildings and the compound of both including the peripheral heat storage devices and their control an dintegration.
- Retrofitting strategies for DH networks and related components considering a higher number of load and temperature changes and other future operation modes.

Proposals should aim at moving technologies from TRL 5-6 to TRL 7-8. In all cases TRL-7 or TRL-8 should be achieved at the end of project activities (please see part G of the General Annexes).

Expected Impact:

Proposals are expected to demonstrate the impacts listed below, using quantified indicators and targets wherever possible:

- Primary energy savings and GHG emission savings triggered by the proposed solutions (compared to best available solution existing today);

- Competitiveness of the heat delivered by the proposed solutions (compared to best available solution existing today);
- Increased share of residual and renewable sources of thermal energy in the supply of heating demand;
- Reduction of heat distribution losses of the proposed solutions (compared to best available heat distribution network solutions existing today);
- Viable business model showing the economic and commercial viability of operating the proposed solutions
- Scale of the replicability potential of the proposed solutions

Geothermal R&D priorities

A1 – Developing the next generation of renewable electricity and heating/cooling: TR L0-5

- *Topic 1: A large scale prototype of UTES with deep wells (>1 Km) and higher temperature in intended environment*

TRL 3-5

Budget: 10 €mio

- *Topic 2: Optimisation of deep open and closed loop heat exchangers*

Decrease costs, replication, improve efficiency (pumping)

TRL 5-7

5 €mio

A2 – Close-to-market demonstration of competitive renewable electricity and heating/cooling technologies: TRL 5-8

- *Topic 3: Shallow geothermal – GSHP Systems, integration and environment*

TRL 6 – 8

4 € mio

1) Shallow geothermal system integration with other renewable technologies – PV and solar thermal - demand response and storage technologies

2) Integrated control of ground source heat pump systems to include ground side, heat pump, building circuits and building characteristics; multiple input – multiple output control approaches (linking to R&D in IT)

3) Shallow geothermal system integration in historical buildings

4) Shallow geothermal system for infrastructures & construction

- *Topic 4: Shallow geothermal – Improvement in Shallow Geothermal Ground-Coupling technologies, and environmental protection*

TRL 6 – 8

4 € mio

1) European-wide Geoactive Structures Alliance, including development of a network of laboratories to create 4 testing sites.

2) Improvement in shallow geothermal drilling technology and machinery for cost reduction and reduced impact (automatisation, minimum invasiveness, drilling for refurbishment incl.historical)

3) Borehole characterization by geophysical logging, tools for quality control and monitoring

4) Optimisation of the borehole-grout-pipe system, solving current grouting problems (fractures, freezing, and other), and development of measuring and control tools

- *Topic 5: Shallow geothermal – New concepts and materials for Shallow Geothermal ground-coupling*

Possible link to nano-materials research

TRL 4 - 8

4 € mio

1) Materials research on heat exchanger materials (PE, PEX, etc.).

2) New antifreeze fluid.

3) New and advanced grouting material incl. recycled degradable material

- *Topic 6: Shallow geothermal – for industry and municipalities*

Demonstrate applicability of shallow geothermal for industry and district heating, including use of high-temperature heat pumps or UTES at elevated temperature, and for smart thermal grids

TRL 6 to 8

8 € mio

- *Topic 7: Deep Geothermal production*

TRL 6 – 8

8 € mio

1) Demonstrate a complex (well completion – reservoir engineering – hydrogeology) methodology of 100% brine reinjection into sandstone reservoirs

2) Demonstrate the innovative heat energy optimization of operating balneological systems supplied with thermal water

3) Innovative tools of handling extreme polluted

- *Topic 8: Deep geothermal - Direct use for industry and municipalities*

Demonstrate new innovative and multiple uses for geothermal energy and side-products, incl. hybrid systems and thermal networks

TRL 6 – 8

8 € mio

- *Topic 9: Geothermal: shallow & deep, availability of geological & geophysical information*

Creation of relevant data, interpretation and evaluation criteria, information through databases and GIS systems, with linking to EGDI

Link with ERANET geothermal

TRL 7 – 8

2 € mio

A3 – Support to market uptake of renewable electricity, heating and cooling technologies TRL>8

- *Topic 10: Deep & Shallow geothermal*

Modelling decarbonisation of the heat sector, buildings and industry

2 € mio

- *Topic 11: Shallow geothermal*

Promotion and information activities in countries with low shallow geothermal use

1 € mio

- *Topic 12: Deep geothermal*

Innovative Risk mitigation financial tools including exploration and also operation risks

2 € mio

- *Topic 13: shallow & deep geothermal*

Focus on specific industrial processes and sectors, identifying quick wins that can be easily promoted to non-technical stakeholders and transferred across EU markets

Efficiency improvement , GHG emissions reduction

2 € mio

Heat pumps R&D priorities

R&D priority HP1- Balancing smart grids with heat pumps[1]:

Short introduction:

The need for flexibility in the power system is frequently motivated by an increase in renewable energy and the resulting need for an ability to react or plan ahead for safe and efficient power system operation. Heat pumps are considered to be a major technology to provide flexibility to the power system and efficiently heat to residential buildings. In the context of a smart grid, heat pumps are seen as part of the demand side that can be actively managed to support the realization of a smart grid. Coupling heat pumps to thermal storage or actively using buildings' thermal inertia offers the possibility to decouple electricity consumption from heat demand, which brings flexibility in operation that can be used in a smart grid.

Scope

The concept of a smart grid integration of heat pumps can thus be considered as proven. However to enable a large scale integration of heat pumps into the power system, further research should focus on application topics in three levels:

- The first level is the integration and management of heat pumps in the power system.

Here the following points should be addressed:

1) The use of large numbers of heat pumps in a pool needs further exploration. Here the development of scalable control concepts and knowledge about the flexibility of a heat pump pool in contrast to single entities should be in the focus.
2) Development of business cases to build the foundation for integrating heat pumps in smart grids.
3) A techno-economic analysis of heat pumps in the reserve markets.

Type of action: Research and Innovation action

- The second level is the integration and management of heat pumps in buildings energy systems.

Here the following points should be addressed:

1) The design of optimal flexible systems for a given application, should be addressed in a more clear and structured way. This includes recommendations for sizing heat pumps, storage, the

[1] This whole topic was based on the scientific article " Heat pumps in smart grids: A review" by Hatef Madani and David Fischer, http://dx.doi.org/10.1016/j.rser.2016.11.182

layout of building energy systems and the choice of control approach.

2) The impact of different control approaches and smart grid applications on system cost and efficiency needs to be investigated further. A focus should be on the practical relevance and feasibility of many suggested solutions.
3) Model predictive control is used in many studies for operating heat pumps in a smart grid context. Although benefits are well known implementation rate in the field is low. A comprehensive study about strength, weakness and opportunities especially when compared to expert systems should be conducted to give advice to system engineers and researchers to improve MPC for practical use.

Type of action: Research and Innovation action

- The third level is the heat pump unit itself. Here the focus should be on the impact of smart grid use on the heat pump units and address the following points:
  1) The use of variable speed compressors enables a continuous regulation of power consumption. This option should be further investigated with respect to possible benefits for smart grid applications.
  2) Many studies consider a heat pump as a black box which can be easily used for smart grid purposes. However, this can strongly influence the performance of heat pump cycle and system. Therefore the design of the whole heat pump system should be investigated with respect to be optimally adapted to the requirements from the electric system.
  3) Minimum run and pause times and ramping rate constraints are examples for limitations to consider when integrating heat pumps in a smart grid. Finding and improving such smart grid bottlenecks in heat pump component and circuit design can improve flexibility characteristics and lifetime of a heat pump unit.

Type of action: Research and Innovation action

Budget requested: 2-6 million per project

R&D priority HP2- Improvement of refrigeration cycle efficiency (COP)

Short introduction

If the heat sink and the heat source have a small variation in temperature, the well-known Carnot cycle is the most advantageous refrigeration cycle. If however, as in many cases, goods or water require cooling or heating by 10 K or more, the so-called Lorenz process is the most efficient process. Referring to the current state of the art in vapor compression cycles, the Lorenz process can be approximated by cycles with multiple pressure levels, where the cooling or heating is divided into several steps. A second option is to select a multi-component refrigerant with a suitable temperature glide fitting to the referring heat sink or heat source. A third option is to work in the supercritical temperature range of refrigerants. A fourth option is to apply cycles with variable pressure.

Scope

The efficient adaption of the temperature spread of the refrigerant to the temperature spread of the heat sink and / or heat source is a main factor of further COP improvement in vapor compression cycles. The possible COP improvement correlates with the extent of the temperature spread in the heat source and / or heat sink. The application targets all sized of heat pumps and all refrigerant types.

Specific targets:

- Loss reduction of dissipation in the condenser and / or evaporator
- Temperature difference on the water side of the heat exchangers ≥ 6 K
- Minimum 10% increase of COP depending on the temperature difference.

Type of action: Research and Innovation action

Budget requested: 2-3 million per project

R&D priority HP3- Cost-competitive plug-in Heat pump kit for houses with existing boiler

Short introduction

Buildings are the first consumers of heating and cooling. Space heating accounts for more than 80% of heating and cooling consumption in colder climates. In warmer climates, space cooling is the most important - and is growing. Almost half of the EU's buildings have individual boilers installed before 1992, with efficiency of 60% or less. 22% of individual gas boilers, 34% of direct electric heaters, 47% of oil boilers and 58% of coal boilers are older than their technical lifetime[2]. Heat pump represents a versatile energy technology that can provide heating, cooling and sanitary hot water in a great variety of building contexts. Its application can generate about 2-3 times more heat then the amount of the electricity consumed.

Scope:

Development of cost-competitive plug-in heat pump kit to be integrated in the heating system of houses with existing non-electrical boilers. The proposed kit will help to save energy and reduce gas consumption at a competitive installation and system cost.

[2] An EU Heating and Cooling strategy COM(2016) 51

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 35oC 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.
- Gas consumption reduction, with over 90% of the thermal load covered by the HP by 2020
- Roughly doubling the PER with the heat pump kit, compared to gas boiler.

Budget requested: 4-6 mil per project

Type of action: Innovation action

R&D priority HP4- Booster Heat Pump for DHC

Introduction:

District heating (DH) enables the utilization and distribution of heating from sources unfeasible for stand-alone applications. Applying booster HPs enables the DH system to operate at substantially lower temperature levels, improving the COP of central DH HPs while simultaneously lowering DH grid losses significantly. Thus, DH performance is increased significantly.[3]

Scope:

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 further demonstrated and deployed in Europe. This topic aims mainly at the demonstration of electrically driven industrial heat

[3] Booster heat pumps and central heat pumps in district heating, Poul Alberg Østergaarda, Anders N. Andersen, http://www.sciencedirect.com/science/article/pii/S0306261916303105

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:

- Classification of networks (temperature levels, time-based energy demand, etc.), • integration of industrial heat pumps (control and hydraulic design),
- Impact of heat pumps on existing networks (dynamic behavior),
- Use of the return flow from the DH network as heat source.
- Compression heat pump: sCOP 5 or more for a temperature lift of 35K.
- 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.
- Energy cost reduction of min. 30%.

Budget requested: 5 – 8 Mil

Type of action: Innovation action

Hybrid Systems R&D priorities

R&D priority HS1- Automation, control and long term reliability assessment

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.
Monitoring is mostly done only in a very limited way or not at all. Parasitic electricity consumption is usually not measured. Fault 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.

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 operating system cost.

Budget: 3 projects for 15 million EUROS

R&D priority HS2- Commercialised solutions facilitating the integration of hybrid systems

Specific challenge: The ambitious EU 2030 and 2050 targets, together with COP21 agreement, represent a tremendous challenge to the decarbonisation of the European heating and cooling sector.

The coupling of technologies that exploit a large share of renewable sources (e.g. heat pumps, solar PV and ST) can easily allow to cover buildings thermal loads with more that 70% of fossil fuels free energy.

The proper integration of the different technologies maximising the energy performance is however not straightforward. This is even more evident when hybrid solutions are integrated into existing systems and with relation to old buildings with high energy demand for heating and cooling.

Scope:

- To develop specific commercialised hydronic/aeraulic solutions allowing the easy integration of heating and cooling devices into hybrid systems allowing optimised control, monitoring and metering of the system.
  Affordable, remote supervised solutions should be made available allowing optimal operation of the system and early fault detection for preventive maintenance of system malfunctioning and underperformance.
- To develop sustainable business models allowing collaboration of different actors of the value chain behind the hybrid system installed and guaranteeing full warranty on rated operation for at least 10 years.

Expected impact: improved reliability of the systems installed and real performance closer to design (difference < 20%) based on monitored management after commissioning

Development of business models sustainably guaranteeing 10 years maintenance and

Higher confidence by customers assessed after installation

Type of action: IA TRL 5-7

R&D priority HS3- Next generation of highly integrated, compact hybrid systems

Hybrid energy systems, integrating more than one energy source into a single system, can accommodate renewable energy sources and overcome the limitations of individual technologies. This priority holds at different scales: either small scale applications such as heating and cooling systems for single family houses or large scale systems suitable for district heating and cooling or industrial processes. These new energy systems introduce new challenges in their integration and management at different stages. At the thermo-hydraulic level combining different thermal cycles with unlike requirements and inserting efficient energy storage units. Beyond hardware characteristics, new control strategies must be implemented taking into account, for instance, weather forecast, heating and cooling load forecast, new supervising algorithms controlling the efficiency and the cost effectiveness of the hybrid systems, intuitive user interfaces able to provide information on the system to the user in an understandable language, monitoring and assessing of energy production, cost of primary energy consumed, energy efficiency and amounts of GHG emitted. The common objective of these measures should be the assessment of the system capabilities making possible to develop performance guarantees.

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.

R&D priority HS4- Smart Thermal Grids

Smart Thermal Grids should be able to adapt to fast changes in energy supply and demand, be integrated in the whole urban energy system from a spatial point of view with other utility networks (electricity, sewage, waste, ICT, etc) and capable to reach 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.). They should be a medium to make renewable energy source technologies available at the city level and be attractive for the citizens and investors by increasing the cost efficiency, creating possibilities for the customers to participate and developing new business models.

Targets*:*

- 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.

R&D priority HS5- Dynamic hybrid system test cycle for small hybrid systems for space heating, cooling and DHW preparation

For the Heating and Cooling sector in general, and for the Hybrid systems sector especially, it would be of fundamental importance to define a European dynamic system test cycle, comparable to the car driving test cycle in the automotive sector. This would allow defining clear reference figures, to give customers a chance to understand which systems are more fuels effective than others, and to directly compare heating systems which deploy different technologies. It would also justify higher investment costs in more efficient systems. In order to do so, a European research project would be needed allowing key actors from research and technology providers to cooperate for comparing different existing test cycles and develop new ones, implement dynamic simulations in order to support this process and finally agree on one or a set of reference test cycles. At the same time, it would provide a common basis for a scientifically sound comparison of key performance figures for hybrid systems that we report in this document.

Specific challenge: Energy rating of hybrid systems for space heating, cooling and DHW is today a complicated task that requires a large number of different tests on different components. Major influencing effects such as thermal storage stratification efficiency are not taken into account today, which leads to suboptimal results, including unreliable information about the efficiency of hybrid systems. New and innovative products can often not be rated because a test standard for this particular product is not available, or because a highly integrated combination of different technologies cannot be split up into its pieces for single technology rating and calculation of assumed combined efficiency.

Scope: To develop and propose solutions for performance rating of highly integrated hybrid systems that are composed of different components that are usually tested and rated separately, but cannot be separated anymore from the integrated system, as well as for new and innovative products for which no component test standards are available.

Expected Impact: Energy rating of innovative products and systems can be done uniformly with a one-and-only test cycle for all products that provide the same service (space heat, cold, DHW) and different systems can be compared with each other. New and innovative products do not face the problem anymore that they cannot be rated because of a lack of a test standard and procedures for this particular new

Solar Thermal Energy

R&D priority ST1- Bringing solar compact hybrid systems to the next level; Upgrading the innovation, efficiency and cost-effectiveness level of SCOHYS.

Challenge: Solar thermal systems alone do not cover 100% of domestic demand for hot water and space heating, due to daily available hours of the sun. Installing two different systems for domestic energy demand would result in higher costs, more maintenance complexity and suboptimal operation due to operational conflicts of the two separate systems. SCOHYS (solar compact hybrid systems which include the main solar system, its storage tank and the backup-heater in one compact unit) can automatically solve this challenge, by becoming a compact solution for providing solar heat at reduced costs due to simplified design, only one controller, high grade of prefabrication and reduced installation effort. Due to optimized combination of components and prefabrication the performance and reliability will improve. Smart technologies (predictive approaches) mixing solar and back up management will lead to higher solar fractions.

Scope: Proposals shall focus and optimally combine the following R&D categories to develop and improve system processes and components:

- R&D smart controller and monitoring technology: optimized operation strategy for improving the thermal performance or/and higher solar fraction, and improved performance thanks to remote and cheap/affordable monitoring.

- R&D: Compact, simplified and robust component and system design of solar thermal and back-up heater for reduced costs of solar heat. Very reduced need of maintenance on the long term.
- R&D: New materials, design concepts and coatings for collectors, storage and other components to reduce costs and increase performance and reliability.
- R&D installation process: failsafe and highly economic system concepts, mounting processes and hydraulic connections.

Expected Impact: Depending on the focus of the proposal the following objectives should be achieved to an extent:

- Reduction of the solar heat costs to reach fuel parity (solar kWh at same level as fossil fuel kWh) by innovative materials and production/installation methods, increased efficiency and energy output at the level of the system as well as multifunctional components like façade integrated solar thermal systems or heat stores charged by excess electricity.
- Increased compactness with reduced space requirements and improved environmental performance resulting e.g. in a reduced energy payback time.
- Improved reliability and performance by new materials and innovative control strategies offering also additional features such as integrated function control algorithms, self-optimising control strategies, low cost monitoring, user interactions via web and smartphone applications.

Type of Action: Research, Development & Demonstration. A variety of projects with TRL 3 to 9 depending on scope focus.

R&D priority ST2- Solar Active Houses Plus (SAH+): Optimal standalone combination of solar thermal and solar power (PV)

Challenge: Buildings create the largest part of energy demand. Currently this demand is heavily dependent on fossil fuels and the grid for the supply of energy. Common solutions in the market address separately the need for heat and the need for electricity. Developing integrated solutions using solar technologies can create synergies allowing to address the demand in a more effective way, based on the solar active house concept. The SAH+ concept, combining solar thermal and solar photovoltaics in energy efficient houses, need to become a widely acceptable, functional and preferred economical solution for near zero energy buildings.

Scope: The integration of a solar thermal system and a photovoltaic system needs to be optimized with research and development in the following areas:

- R&D: Improved integration of the collector array (mounting concepts and structures to integrate large collector arrays in existing roofs) to optimize technical & architectural quality of integration at minimized costs
- R&D: Development of system designs for cost-optimal solutions and control strategies to stabilize the electricity and/or heat grid by optimized operation of SAH and SAH+
- R&D: Improved controller and monitoring technology such as self-adapting control concepts, improved sensors, extended function control, integration in Smart Home technologies to avoid malfunction, increase reliability, improve the user-equipment communication and stabilize the electricity and/or heat grid by optimized operation of SAH and SAH+
- R&D: New developments on solar thermal cooling leading to significant Iimprovements so as to reduce complexity, capacity, size and costs of components and to optimally interact with photovoltaic driven systems with a common objective to be integrated in future generations of SAHs and SAHs+ beyond 2020

Expected Impact:

- reduction of size of solar collector field and storage volume to ease the integration of SAH and SAH+ in existing building concepts
- development of reliable, well-functioning and aesthetical concepts for SAH and SAH+
- development of technologies and concepts for the conversion of already existing buildings into SAH and SAH+ by means of solar refurbishment.
- reduction of solar heat costs of SAH with solar fraction of over 60% to the same level of solar heat costs of today's combi systems with 25% solar fraction

Type of Action: Research, Development & Demonstration. A variety of projects with TRL 3 to 9 depending on scope focus.

R&D priority ST3- Optimal integration of innovative thermal storage systems with solar thermal systems

Challenge: Thermal energy storage addresses the key bottleneck against the widespread and integrated use of renewable energy sources, as the renewable supply does not always coincide with demand for heating or cooling. Hot water stores are today a common solution used in combination with renewable technologies, such as solar thermal energy, providing cost competitive solutions for energy storage. In order to provide enhanced solutions for the market, it is important to provide more compact solutions, with higher performance, either for daily or for seasonal storage. Numerous technologies in sensible, latent or thermochemical form can provide innovative storage solutions, each of them characterised by different specifications and specific advantages when coupled with time-shift renewable energy, time shifting supply to periods of the day or of the year with greatest demand., each of them characterised by different specifications and specific advantages.

Scope:

- R&D: Simplified integration of large water storage volumes in or near by existing buildings such as design, on-site-mounting, separated volumes, underground installation, new storage wall and insulation materials to reduce space requirements, ease refurbishment, optimize performance, reduce costs, and increase the acceptance of the owner
- R&D: Storage and system technology adapted to MFHs to optimize performance and storage integration to minimize costs and space requirements
- R&D: Development of high density heat stores based on phase-change-materials or thermo-chemical storage technologies, basic research on PCM and TC-materials is necessary as well as on charging-discharging concepts etc.
- Development and optimisation of the heat management of large-scale thermal storages

Expected Impact:

- Optimized integration of thermal storage systems with solar thermal systems for increased performance.
- Development of more efficient materials for thermal storage systems with an increased capacity to maintain heat for longer periods of time.
- Lower costs and more affordable medium and larger scale systems both for domestic use (single and multi-family houses) and commercial use (industrial and district heating)

Type of Action: Research, Development & Demonstration. A variety of projects with TRL 5 to 9 depending on scope focus

R&D priority ST4- Development of next generation Solar Heat for Industrial Processes (SHIP) and Solar District Heating (SDH) systems with increased solar fraction

Challenge: Even though SHIP and SDH have proved to be sufficient for a heat demand of up to 250oC, they are not as widely yet chosen for industrial production purposes and district heating systems due to doubts of efficiency, system complexity as well as costs. Medium and large-scale solar thermal systems need to become cost competitive based on Levelized Cost of Heat (LCOH) for different temperature ranges and to be adapted to all types of district heating as well as all relevant industrial applications and sectors.

Scope: Proposals need to achieve a high potential penetration and acceptability of SHIP and SDH by focusing on the topics below:

- R&D: Improved large-scale solar collector arrays with optimised hydraulic designs for uniform flow distribution and low pumping power.
- R&D: Improved medium temperature collectors with new materials and production processes for high vacuum, non-tracking CPC-vacuum tube and flat plate collectors, stagnation proof flat-plate and evacuated tube collectors and systems, next generation air collectors and solutions for façade integration
- R&D: Improved reflectors for concentrating collectors with very high reflection, dirt-proof or self-cleaning, and high durability to reduce costs for production, cleaning and maintenance, and increase performance
- Development and optimisation of the heat management of large-scale thermal storages
- DEVELOPMENT and IMPLEMENTATION: Standards and certification schemes as well as accelerated ageing tests for medium-temperature collectors and collector systems; test procedures for different concentrating collectors, CPC-vacuum tube collectors, high vacuum flat plate collectors, components and systems in order to achieve long term operation with high efficiency
- Development of simple simulation and energy yield forecasts based on solar keymark data (ScenoCalc) as basis for issuing a guaranty for energy yield and serving as basis for national and international tendering processes for solar-thermal SDH and SHIP projects.

Expected Impact: SDH and SHIP should opt to make the difference in turning large scale energy demand into a totally environmental friendly process. More specifically proposals should expect to achieve:

- Integration of SHIP systems in relevant industrial applications
- Integration of SDH systems in all types of district heating systems
- Adaptation of SHIP systems to industry machinery standards and development of new ways to feed in solar heat into the industrial processes.
- Advanced low and medium temperature collectors and optimized concepts to feed in solar heat into district heating networks and industrial processes in an optimized way will be developed.

Type of Action: Research, Development & Demonstration. A variety of projects with TRL 3 to 9 depending on scope focus.

Thermal Energy Storage R&D priorities

R&D priority TES 1- Next generation of Sensible Thermal Energy Storages

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 to and integrate into existing buildings with limited space for storages.

Costs and thermal conduction of the containment materials will be reduced by replacing metal with polymer casings, with or without fibre reinforcement, and by low pressure storage solutions that reduce containment material use and allow for prismatic storage volumes that adapt better to the limited space available in existing buildings. Novel and compact heat exchangers using new materials, improved concepts and geometries improve the charging and discharging process by increased heat transfer power and therefore reduce charging and discharging time and disturbances of the temperature stratification. Significant improvements on storage insulation will be achieved by the development of long lasting, low-cost and easily applicable high performance insulation (e.g. vacuum insulation, aerogels). 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 by heat loss of the storage in summer. 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. The performance of sensible TES will be further increased by improved exergy efficiency and stratification devices, in combination with smart algorithms for the control of mass flow rates and supply temperatures of heat pumps and solar thermal systems that improve the overall energetic performance. The integration of sensible TES into smart heating networks will be enabled by the inclusion of intelligent state of charge determination systems fully integrated into the storage.

Targets*:*

- 20% cost reduction of mass produced containment.
- High performance insulation materials with 50% higher insulation effect than conventional materials and 50% lower cost than present vacuum insulation.
- Development and demonstration of innovative modular concepts.

Budget: 25 Million Euros (5 projects on pre-industrial development)

R&D priority TES2- Increased of both storage energy and power density using phase change materials (PCM) and thermochemical materials (TCM)

General objective is 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. To be effectively applied in heating and cooling systems, the technology should be improved as follows.

Further increasing the storage density, enabling integration of PCMs into buildings, heat exchanging components and thermal energy systems. For building-integrated applications, encapsulation and stabilisation, particularly of salt hydrate PCMs will be important. Increasing the rate of heat discharge from PCMs that can be used for DHW production by increased thermal conductivity of the material and improved heat exchanger performance by adaptation of heat exchanger design to the specific storage material. Finding solutions for PCM problems such as supercooling (with the use of nucleation agents), 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). Developing microencapsulated PCM for 300 ºC<T<1,000 ºC, for the very important application area of industrial processes and solar thermal power. 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. Developing heat exchangers that can also encapsulate the PCM.

In order to optimise the performance of TCM, activities should focus on the following.

Development of novel or improved storage materials like salt hydrates, aluminophosphates, metal organic frameworks or composite materials, using materials technology and novel numerical methods. Improvement of materials production technologies in close cooperation with chemical industry in order to lower the bulk price of storage materials, like zeolites and salt hydrates. Development of testing and characterisation techniques for thermochemical materials, including new techniques to determine the state of charge. Design and optimisation of specific charging and discharging technologies by targeted design of components in combination with the storage material. Large scale domestic stores to assess economic viability, construction and installation issues, and manufacturing efficiencies. New concepts to combine solar collector and thermochemical reactor in order to further reduce the required volume and to lower component and system costs.

The development and demonstration of improved and low cost methods to determine the state of charge of thermal energy storage systems is important for all technologies (sensible heat storage, latent heat storage and thermochemical storage). The accurate determination of the state of charge is crucial to control thermal systems (like heat pumps, combined heat and power, binary cycles) in an optimal way to deliver services in the electrical and/or thermal grid.

Targets:

- Developing microencapsulated PCM for higher temperatures.

- Novel PCM with adjustable phase change T and high cycle stability (above 7,300 full cycle).
- Novel PCM system to minimize sub-cooling effects.
- New heat exchangers with PCM included.
- New heat exchanger for PCM storage with high dis- and charge power
- New anti-separation and anti-sedimentation techniques for PCM-storage systems.
- PCM/ TCM target: 4 times more compact than water at system level.
- TCM target: Increasing of the cycle efficiency by a factor of two at least
- Novel TC solar collector (directly charging of TCM n collector): first prototypes.
- Control of TCM systems: new sensors developed.
- Reduction of production costs for zeolites and salt hydrates.
- Improved seasonal solar TCM solution for single-family houses.
- Improved and low cost methods to determine the state of charge of thermal energy storage systems.

Budget: 40 Mln Euro (10 projects on material, component and system development)

R&D Topic 3: Improvements in Underground Thermal Energy Storage (UTES)

General objectives for this topic are the improvement of system concepts and operational characteristics of UTES systems and the 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 better understood (cf. Geothermal Technology Roadmap) and increased, and optimal control of UTES to improve energy savings and to reduce the use of back-up systems should be developed and demonstrated. 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 technology preventing clogging, scaling and corrosion await satisfactory solutions. With regard to BTES and CTES, system integration and innovative concepts should be further developed. Regarding large pit storages, the development of cheap and long lasting liners that separate the storage water from the ground and can withstand temperatures of up to 90 °C on the long term and development of low cost and reliable solutions for insulated top covers including escape mechanisms for gas-bubbles underneath as well as draining of rain or meteor water from the top are important, next to development of improved low-cost stratification measures. Improvement of the experience base for UTES by demonstration projects aiming at high replication potential will help to drive down system costs and accelerate the growth of the installed base.

Targets:

- Increase energy efficiency of heat storage in the underground for industrial batch processes and DHC systems by 25 % (relative).
- Improve system reliability and plant longevity at elevated temperatures, typically over 50 °C.
- Increase the uptake of UTES technologies by demonstration projects aimed at knowledge base increase and system costs reduction.

Budget: 40 Mln Euro (3 large R&D projects, 5 smaller demo projects)