Renewable Heating & Cooling

European Technology and Innovation Platform

STRATEGIC RESEARCH INNOVATION AGENDA FOR DISTRICT HEATING & COOLING AND THERMAL ENERGY STORAGE TECHNOLOGIES

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Renewable Heating & Cooling

European Technology and Innovation Platform

EUROHEAT & POWER

DHC+ TECHNOLOGY PLATFORM

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EXECUTIVE SUMMARY

This document outlines the strategic research priorities of the District Heating and Cooling (DHC) & Thermal Energy Storage (TES) Technology Panel and complements the Strategic Research and Innovation Agenda of the RHC-ETIP, that was published in 2020. The research actions outlined cover a seven-year time period, from 2021-2027.

DHC is a proven solution for delivering heating, hot water and cooling services through a network of insulated pipes, from a central point of generation to the end user. DHC networks are well suited to supply locally available, renewable and low-carbon energy to end-users in urban environments. The ability to integrate diverse energy sources means customers are not dependent upon a single source of supply. By aggregating a large number of small and variable heating and cooling demands, District Heating and District Cooling allow energy flows from multiple RES (Renewable Energy Sources) to be combined while reducing primary energy demand and carbon emissions in the community served.

TES is the solution for a key bottleneck against the widespread and integrated use of RES, since renewable supply does not always coincide with the demand for heating or cooling, and electricity. 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. TES contributes to energy system integration, offering flexibility to the wider energy system and storage of variable renewable electricity.

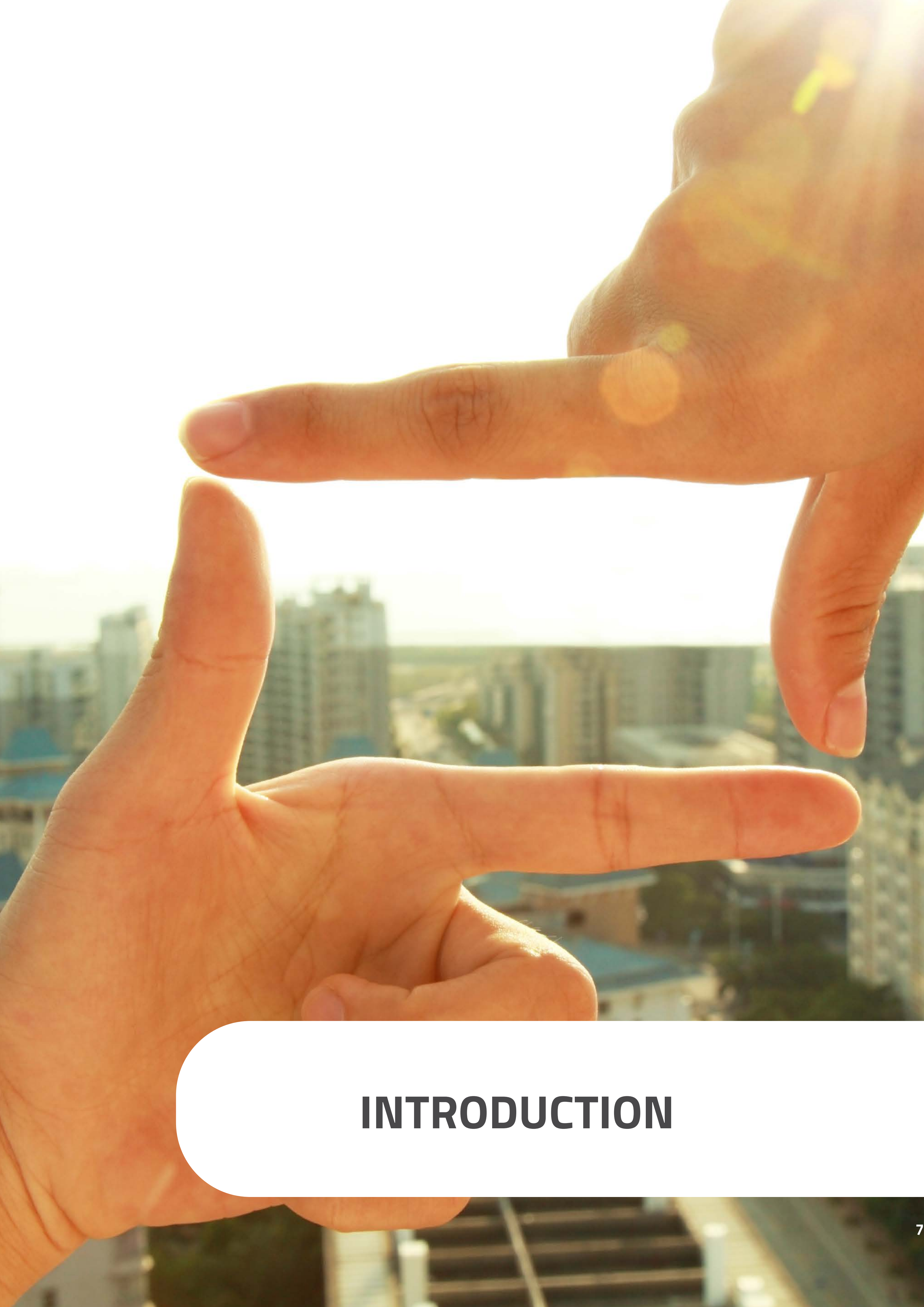
Research and Innovation (R&I) are the two cornerstones for the further development of DHC and TES and their market uptake. A new generation of low-temperature networks and storage technologies will drive the decarbonisation of the European heating and cooling sector, and the wider economy. This document outlines the current state of the art for these technologies and details Key Performance Indicators (KPIs) for the research actions during the specified time period as well as the wider sector. Relevant SET Plan targets are also listed. The research actions are grouped under the following headings:

- Waste Heat
- District Cooling
- Low Temperature District Heating and Cooling
- Energy System Integration
- Digitalisation
- Thermal Energy Storage

For each topic, the status of current research is described. The final section of the document details a plan for the implementation of the research actions, including the required budget, financing issues and available funding instruments.

GLOSSARY

3GDH	3rd Generation District Heating
4GDH	4th Generation District Heating
5GDH	5th Generation District Heating
ATES	Aquifer Thermal Energy Storages
BTES	Borehole Thermal Energy Storage
CAPEX	Capital Expenditure
CHP	Combined Heat and Power
CO2	Carbon Dioxide
CSA	Coordination and Support Action
DC	District Cooling
DH	District Heating
DHC	District Heating and Cooling
GDP	Gross Domestic Product
GIS	Geographical Information System
GWP	Global Warming Potential
H&C	Heating and Cooling
HTDH	High-Temperature District Heating
ICT	Information and Communications Technology
IEA	International Energy Agency
IoT	Internet of Things
KPI	Key Performance Indicator
LCOE	Levelised Cost of Energy
LTDH	Low-Temperature District Heating
Mtoe	Million tonnes of oil equivalent
O&M	Operation and Maintenance
OPEX	Operation Expenditure
PCM	Phase Change Materials
PDA	Project Development Assistance
PED	Positive Energy Districts
PIT	Pit Thermal Energy Storages
R&D	Research and Development
RES	Renewable Energy Source(s)
TCM	Thermo-Chemical Materials
TES	Thermal Energy Storage
TRL	Technology Readiness Level
TTES	Tank Thermal Energy Storages



INTRODUCTION

The document aims to support research and development, while stimulating market pull. The research priorities cover the time period 2021-2027, and will complement the existing RHC Strategic Research and Innovation Agenda, promote research into DHC and TES and provide guidance to the new Horizon Europe programme.

In a recent study carried by the Celsius Initiative for the European Commission, projects funded under the H2020 programme focussing on district heating and cooling have been analysed.

The funded projects focussed on the following topics:

- Smart Cities & Communities Lighthouse Projects;
- Low Temperature District Heating & Cooling;
- Renewables for District Heating & Cooling;
- Waste Heat Recuperation for District Heating & Cooling;
- Heat Pumps for District Heating & Cooling;
- Digitalisation of District Heating & Cooling Networks and Smart Energy System Integration;
- Heat Planning Studies and Tools; and
- Support Activities for District Heating & Cooling.

Notably, almost all of the FP7 and H2020 Smart Cities and Communities (SCC) Lighthouse projects include demonstration activities on heating and cooling networks. The most recent SCC projects are conceptualised around Positive Energy Districts (PEDs), which shows the significance of the district level for heating and cooling planning and project implementation.

The analysis shows that only two dedicated projects on thermal energy storage, and only one on district cooling have been financed. In light of the identified research priorities for 100% renewable heating & cooling districts in this document, the new Framework Programme should put a clear emphasis on these topics. In addition, going beyond the state of the art for the other identified research priorities will ensure a cost-effective, fast and fair heat transition in cities.

DHC, which is also referred to as district energy or heat networks, delivers sustainable heating and cooling (H&C), connecting local resources to local needs. DHC is a proven solution for delivering heating, hot water and cooling services through a network of insulated pipes, from a central point of generation to the end user. DHC networks are suited to feed in locally available, renewable and low-carbon energy sources such as solar thermal and geothermal heat, waste heat from industry and commercial buildings, and heat from combined heat and power plants. The ability to integrate diverse energy sources means customers are not dependent upon a single source of supply.

DHC networks are inherently diverse and variable in terms of size and load; while employing similar operating principles, each network is designed according to specific local circumstances and adapts to continuous innovation. A growing number of cities worldwide are adopting modern DHC solutions, as they are the best way to bring sustainable heating and cooling to dense urban environments.

The refurbishment, construction, and expansion of DHC networks (combining district heating and district cooling, integrating and balancing a large share of renewable energy, serving as thermal storage) are prerequisites for smart energy systems of the future. The constant evolution of DHC mirrors that of the broader energy transition. More efficiency, more renewables, reduced greenhouse gas emissions and more flexibility leading to a better energy system.

Thermal energy storage will be a key enabler for the deployment of renewable heating and cooling, in buildings, districts, cities and industries, be it at small or large scales. The use of high-capacity underground storage shared by several heating or cooling systems, instead of a high number of small decentralised storages, can unlock further potential. Additionally, the combination of TES and predictive control algorithms will help to increase the share of renewables and at the same time stabilise the electric grid by integrating coupling points such as heat pumps. Increased reliability, resilience and security of energy supply, regional value creation and higher efficiency can be achieved as a result.

State of the Art

District Heating and Cooling has been widely acknowledged as the future of urban heating and cooling, as the priorities of actors across the heating and cooling sector shift towards delivering sustainability objectives and reducing greenhouse gas emissions. Based on a mature and proven technology, modern DHC networks are characterised by high efficiency, and are increasingly evolving to cater for distributed renewable technologies, with the aim of complete decarbonization.

Currently, approximately 60 million EU citizens are served by DH, with an additional 140 million living in cities with at least one DH system. According to reports by the EU and the International Energy Agency (IEA), DH currently meets around 11-12% of the EU's heat demand via 6,000 DHC networks. While industry experts estimate this share to be as high as 13%. It should be noted that the share of DH varies significantly from one region to another e.g. DH is by far the most common urban heating solution in traditionally cold-winter countries in Northern/Eastern Europe (Nordic and Baltic regions, Poland, etc.) whereas it has historically played a very minor role in Southern Europe as well as some Western European countries (e.g. Ireland, Netherlands, United Kingdom).

Some European countries have achieved very high shares of renewables in their DH supply (more than 40%, in at least eight countries), helping to boost overall renewable energy penetration in the region's heat demand. Today, 4th generation district heating (4GDH) is expanding as a new standard to gradually replace the existing design and operational principles of 3rd generation district heating (3GDH). 4GDH is also known as low-temperature district heating (LTDH). Benefits are delivered in both heat distribution and heat generation. On the distribution side, heat losses in the network are reduced, the gap between heat supply and heat demand is narrowed, and thermal stress and risk of scalding are reduced. On the generation side, lower network supply and return temperatures facilitate the utilisation of low-temperature waste heat and renewable energy, achieve higher coefficient of performance values (efficiencies) for heat pumps and allow combined heat and power plants to improve their power-to-heat ratio and recover waste heat through flue gas condensation. Although still a novel and somewhat controversial topic, the concept of 5th generation district heating (5GDH) is emerging in scientific literature. 5GDH represents a fundamental change in the design and operation of the system, changing from a collective heat/cold supply to an end-user heat/cold supply, with individual heat pumps. Optimised networks with a high degree of digitalisation harvest a wide range of decentralised, sustainable energy sources and operate at ultra-low temperatures. 5GDH can be distinguished from 4GDH by the use of temperature adjustment (e.g. heat pumps, specialised substations) at the end-user side to achieve the required operational temperatures at building level.[1]

The state of the art revolves around applying new technology e.g. AI, optimising existing technology, optimising the transport of energy, efficiently planning and deploying networks using the latest modelling/data, integrating energy storage and heat pumps, and adapting to local renewable resources like biomass, solar thermal and geothermal energy. High shares of intermittent renewable energy that are used in district heating or cooling require large scale storages, that are low cost and allow multifunctional usage and digital management of all heat sources and heat deliveries. New financial conditions, including the development of business models and financial schemes, enable large public and private investments to be mobilised by focusing on the green dimension of investments, encouraging a paradigm shift towards heat being delivered as a service rather than sold as a commodity.

Modern networks are capable of effectively integrating multiple urban energy sources, including prosumers, while operating at low and ultra-low temperatures[2] and in some cases, providing heating and cooling through the same pipelines. The networks benefit from prefabrication, standardisation, circularity and modularity in an effort to streamline design and installation. A centralised digital management system allows the DHC network to use multiple, unpredictable heat sources and more complex elements (e.g. waste heat), and the integration of complex and highly efficient heat pumps and thermal energy storages on different time scales (from hourly to seasonal). This highly adaptable centralised system can apply dynamic modelling, machine learning and instantaneous analysis of incoming data, from a diverse set of sensors and measurements.

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1 Lund et al. (2021) Perspectives on fourth and fifth generation district heating. https://www.sciencedirect.com/science/article/pii/S0360544221007696?dgcid=coauthor

2 4GDH or low-temperature district heating networks operate at temperatures between 40-70°C. 5GDH or ultra-low temperature networks operate at temperatures less than 40°C. Earlier generations, known as high temperature district heating (HTDH) operate at temperatures closer to 100°C.

A significant number of European and nationally-funded innovation projects are currently being carried out, to advance the state of the art of district heating and cooling and thermal energy storage technologies, driving the clean energy transition in the process. As noted in the introduction, these projects cover a wide variety of topics. Research, practical applications (via pilot sites), modelling (of technology and financials via business models) and dissemination to all relevant stakeholders is being carried out. The following H2020 projects are carrying out cutting-edge research into low-temperature DHC: the COOL DH project is assessing technological solutions for the exploitation of low-grade heat sources; RELATED aims to lower the network operating temperature through renewables integration at building and district level; while the TEMPO and REWARDHeat projects are developing innovative business models, with the aim of selling heat as a service.

The decarbonisation of the heat supplied to DHC networks is essential to the future provision of sustainable heating and cooling. The GeoHex and GEOCOND projects focus on advancing geothermal technologies, while WEDISTRICT looks at covering a broad set of potential RES and consumer combinations. The recovery and integration of waste heat into networks is vital to avoid wasting thermal energy. EMB3Rs and INCUBIS are researching the recovery of industrial waste heat, while ReUseHeat and Heat4Cool look at unconventional urban sources of waste heat. Aside from the technical innovations, these projects also address business models, market uptake measures and stakeholders support, as part of efforts to increase the replication of the solutions developed. THE RES-DHC project aims to overcome market uptake challenges related to the transformation of DHC systems to higher shares of RES, focusing on specific regions across Europe.

Energy system integration and the linking of different energy carriers and storage solutions are key to the optimization of the energy system. The SMILE project aims to demonstrate real-life operating conditions targeting distribution grids to enable demand response schemes, smart grid functionalities, storage and energy system integration. The MAGNITUDE and PLANET projects look at the integration of different multi-energy systems and storage solutions, to provide flexibility to the energy system.

In terms of TES, new and innovative building technologies are at various stages of development, depending on the technology considered. The main developments in technology can be subdivided into large, sensible thermal energy storage and compact thermal energy storage technologies. Large scale TES applications are important for providing flexibility and enabling higher shares of RES usage in DHC networks and industrial heating up to 100°C. These applications can also facilitate higher degrees of renewable power generation, as they can absorb “unlimited” amounts of excess electricity at short notice. For many years, TES R&D has focused on seasonal storage of RES. Expected advances in the coming years will enable multifunctional usage of TES, allowing for the seasonal storage of RES, avoidance of fossil fuel-based peak load cover, and interaction with renewable electricity market via sector integration.

In Austria, an ongoing flagship project (giga_TES) aims at developing materials, constructions and concepts for the next generation of TES and for very large TES systems (up to 2 Million m3). In a Danish-German project, the performance of a number of Danish large TES systems were monitored and assessed (HEATSTORE). In October 2020, a new Annex in the IEA technology collaboration program on Energy Storage on large thermal energy storages for district heating started (IEA ECES Annex39). At European level, sensible thermal energy storage for DHC systems were developed in HighCombi, SunStore 4, PIMES, EINSTEIN, PITAGORAS and TESSAS.

Demonstration projects for sensible, large scale TES were realized in a lot of European countries: Pit Thermal Energy Storages (PIT) are under development mainly in Austria, Denmark and Germany. Tank Thermal Energy Storages (TTES) made of a concrete shell that is partially buried underground are at R&D phase in both Germany and Austria. High temperature Borehole Thermal Energy Storage (BTES) have been realized in Germany, Denmark and Belgium and developments are ongoing in the Netherlands deploying Aquifer Thermal Energy Storages (ATES). Pilot plants that store heat up to about 70°C are in operation in some places like in Neubrandenburg, Germany. The COMTES, MERITS, CREATE, SOTHERCO and HEAT INSYDE projects are exploring compact thermal storage of solar energy, employing a range of different concepts, outlined in Section F. While the projects SAM.SSA and EUROPA are developing PCM systems for these low-temperature applications over medium to long storage periods.

Renewed investment is needed to ensure the transformation of existing DHC networks and a higher penetration of new and smart networks in heating and cooling markets, contributing to the European recovery plan in the process. With the continuing trend of urbanisation, together with Europe’s enormous heat demand and increasing cooling demand, DHC networks combined with flexible thermal energy storage applications across multiple time-scales, will play an increasingly important role in the energy system in the coming decades. The topics outlined below, require a concerted Research, Development and Innovation approach.

TARGETS AND KEY PERFORMANCE INDICATORS

Key Performance Indicators (KPIs)

The specific KPIs associated with each of the research actions apply to the time period 2021-2027. Unless otherwise stated, the general KPIs outlined in this section also refer to this time period.

District Heating and Cooling

KPIs for the deployment of innovative DHC networks:

- Increase the share of non-combustible, low-emission heat sources (ambient heat, solar- and geothermal energy, waste heat from both industry and unconventional urban sources) to 50%.
- Seasonal storage capacity corresponding to 30% of the winter heat demand.
- Reduce system temperature by 10°C (applies to the retrofitting of existing networks).
- Reduce costs of project implementation.

KPIs for DHC sector:

- Increase the share of district energy in the overall EU heat demand from 12-13%[3] in 2019, to 20% in 2030, to 50% in 2050.
- Increase the share of fossil-free heat sources in the DHC supply to 50% by 2030 and 100% by 2050 (compared to 26% renewables in 2017[4])[5].
- Plug the data and knowledge gaps in the DHC sector to enable detailed analysis and planning at European level and position Europe as leader in DHC development worldwide.
- Reduce energy consumption for heating in buildings by 30% by 2050 compared with 2015 levels (requires a doubling of the current renovation rate (1%) over the next 10 years[6]). Building renovation should go hand-in-hand with heating decarbonisation as part of a district approach to greening European cities. Taking a district approach links district heating to the energy efficiency of buildings and thus accelerates the decarbonisation of a district/ city.

Thermal Energy Storage

- Position heat and cold storage as an integral part of the heating and cooling system, increasing system efficiency, providing energy security and enlarging RES usage in the energy production systems of districts, cities and industry.
- Lower the costs by 25% for used heat of sensible TES in DHC and industrial systems compared to 2015 levels.
- 10 novel PCM (Phase Change Materials) or TCM (Thermo-Chemical Materials) developed and tested.
- 10 new demo systems with sensible TES realised in Europe with a usage of RES to more than 60% of the yearly heat demand.
- 20 systems for compact thermal energy storage demonstrated at TRL 6 or TRL 7 with a storage density at system level increased to 200 kWh/m^3.
- 2 new simulation softwares available on the European Market for simulating digital twins of systems with TES integration.
- 3 European technology transfer projects realised or ongoing for knowledge transfer about TES and their system integration to the market.

3 https://books.google.be/books/about/District_Heating_and_Cooling.html?id=vH5zngEACAAJ&redir_esc=y
4 Based on the Clean Energy Policy Forecast outlined in the SRIA, the share of renewable heat in final energy consumption will increase from 98.7 Mtoe in 2018 to 124.4 Mtoe in 2030, representing a 25.4% increase.
5 http://www.districtenergyinitiative.org/sites/default/files/publications/towardsadecarbonisedhcsectorineufinalreport-111220191046.pdf
6 https://ec.europa.eu/commission/presscorner/detail/en/IP_20_1835

SET-Plan Targets

These strategic targets and indicators serve as the foundation for the definition of the main targets set out in this document.

SET-Plan Action 3.2 on Smart Cities and Communities:

This implementation plan aims to support the planning, deployment and replication of 100 'Positive Energy Districts' by 2025 for sustainable urbanisation. The strategic target of the Implementation Plan was inspired by discussions in the European Innovation Partnership on Smart Cities and Communities, especially by the Initiative on Positive Energy Blocks (at least three connected buildings) and the "Zero Energy/Emission Districts".

A PED is a district with annual net zero energy import, and net zero CO_2 emissions working towards an annual local surplus production of renewable energy. A PED makes optimal use of elements such as advanced materials, local RES and other low carbon energy sources (e.g. waste heat from industry and service sector, such as data centres), local storage, smart energy grids, demand-response, cutting edge energy management (electricity, heating and cooling), user interaction/involvement and Information and Communications Technology (ICT).

SET-Plan Action 4 on increasing the resilience and security of the energy system:

Activity	Target
A4-IA2.1-1 Reduction of return temperatures in current DH networks	Increase the efficiency of networks on the primary side (>10%) Decrease return temperatures on the building side so that the efficiency of the connecting systems is increased (>10%)
A4-IA2.1-2 Optimised low temperature and highly flexible (micro) DHC networks	Deploy efficient DHC networks (>10% reduction of heat losses compared to standard grids) for the efficiency exploitation of locally available sources Contribute to climate goals by enabling a high level of utilisation of local energy sources (>80%)
A4-IA2.1-3 Increasing the short-term flexibility of DH and DC networks and enabling its efficient utilisation	Deliver sustainable DHC by increasing flexibility and reducing fossil fuel peak technologies (reduction to 0% use of oil and gas heat only boilers) by integration of digital management and thermal energy storages.
A4-IA2.1-4 Increasing the long-term flexibility of heating and cooling Systems	Integrate seasonal (>4 weeks), large-scale thermal energy storage systems in DHC networks to increase counter-seasonal integration of seasonal surplus heat resources (>20% of seasonal demand covered)

SET-Plan Action 5 on Energy Efficiency Solutions for Buildings:

Activity	Target / Indicator
AF 5.2 – 2: Multi-source District Heating integrating renewable and recovered heat sources, higher temperature District Cooling and optimization of building heating system, to minimize the temperature levels in district heating networks	Increase the share of renewable heat to 25% compared to 2015 Increase the number of 4th generation DHC networks Decrease the cost of DHC substations for residential buildings by 20% compared to 2015
AF 5.2 – 4: Compact thermal energy storage materials, components and systems	Improve the performance of above ground and underground thermal energy storages by 25% compared to 2015 levels Increase storage density at the system level by 200% (including pumps, valves, pipes, short term buffers) Number of new products and materials Total available storage capacity of compact storages compared to total storage capacity

SET-Plan Action 6 on "Increase efforts to make EU industry less energy, resource and emissions intensive and more competitive":

Activity	Target
5.1 New technologies for utilization of high temperature waste heat in industrial systems, considering the whole energy cycle	By 2025, develop and demonstrate (to TRL 8) cost effective excess heat/cold recovery solutions.
5.2 Heat or cool upgrade from low to high grade (heat pump / refrigeration)	By 2025, develop and demonstrate (to TRL 8 for temperature up to 200/250°C and to TRL 6 for temperature above 250°C) solutions enabling small and large industries to cost effectively reduce their energy consumption by 5% by cost effectively upgrading excess heat / cold for more valuable application elsewhere in the process.
3.4. Polygeneration (heat, cold, electrical power) and hybrid plants	Develop and demonstrate (to TRL 8) cost effective excess heat/cold recovery solutions.

RESEARCH PRIORITIES

Photograph: @EGEC - European Geothermal Energy Council

A. Waste Heat

Current Status

The EU produces more waste heat than the demand of its entire building stock and industrial emissions currently make up about 21% of EU GHG emissions. The energy efficiency of the industrial sector can be improved through the recovery of waste heat. Recovered heat not consumed within the plant can be fed into heat networks and consumed externally, either in another plant within an industrial cluster or as space and water heating for buildings. It is estimated that industrial waste heat could cost effectively cover at least 25% of district heating generation. Moreover, there is significant heat recovery potential from unconventional waste heat sources (e.g. sewage water, data centres, supermarket refrigeration, metro stations, tertiary buildings), which could cover 10% of the EU's total energy demand for heat and hot water.

Waste heat represents a viable source of low-carbon energy for DH networks. Tapping into waste heat sources could displace a significant amount of primary energy demand for heating. However, due to a multitude of barriers, waste heat recovery is far from reaching its full potential. These barriers include general barriers (limited availability of DH networks in some countries, challenges in the identification of waste heat sources and a low interest of the waste heat owners), technical barriers (temporal, locational and quality mismatch), economic and financial barriers (long payback periods and limited contractual standardisations), legislative and regulatory barriers (waste heat is not considered on par with renewable energy sources and unfavourable primary energy factors, absence of level playing field within the heating sector) as well as societal & cognitive barriers (little awareness of the potential of current role of waste heat in national decarbonisation strategies, the difficulty to sell waste heat as a sustainable product to end-users and customers), see also[7].

Topic A.1 Integration of waste heat in decarbonisation strategies

Objective:
Support the utilization of waste heat within local, regional, national and European energy efficiency, supply and decarbonization strategies

Key Actions
A1.1: **Raise awareness and develop modelling tools and approaches to better integrate waste heat utilisation in decarbonisation strategies on a national and European level.**

A1.2 **Integrate and evaluate waste heat recovery solutions and identify where it is possible to develop heat networks and thermal storage facilities near sources of excess heat**
The utilization of the various waste heat sources should be recognized as an important contributor for the decarbonization of the heating and cooling sector, and at the same time support the electric grid via the smart use of the corresponding heat pumps and storages. Therefore, the currently used energy modelling and scenario tools should fully consider waste heat sources. This can be done e.g. by following a circular economy approach, i.e. by applying energy conservation principles at the end use side. This includes top-down methodologies for a systematic identification of waste heat sources. Additionally, the different temperature levels of waste heat, district heating networks and end users should be taken into account, allowing a cascading approach for optimizing the primary energy utilization. Here, reduction strategies for the district heating network temperatures should be taken into account. Since waste heat (as well as heating and cooling in general), is a rather local issue, energy strategies should be geographically differentiated. However, long heat transport networks, spanning up to 10 to 100 km should be considered, since they can connect multiple waste heat sources, consumers and storages and thus mitigate the risk of losing one waste heat source.

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1 Schmidt, R.-R., Geyer, R.; Lucas, P: DISCUSSION PAPER: The barriers to waste heat recovery and how to overcome them? June 2020, https://www.euroheat.org/news/policy-updates/recommendations-waste-heat-recovery-urban-agenda-energy-transition-partnership/

Type of Action: (Research/Innovation/Demonstration or TRL)
Coordination and support

Key Performance Indicators
- Involving 3-5 national energy planners in the development of decarbonisation strategies, integrating waste heat recovery.
- Developing 4-5 decarbonisation strategies including a minimum share of waste heat of 10% in the DH supply

Topic A.2 Business and financing models to boost waste heat recovery

Objective:
Boost the waste heat recovery and use in district heating and cooling networks via new business and financing models, to help decarbonise cities.

Key Actions:
A2.1 **Develop and harmonise best practice of waste heat recovery in different market conditions and regulatory frameworks** Finding the right commercial agreement that benefits all parties (either through profit or energy/emissions savings e.g. free cooling for data centres) remains a major challenge. Sample contracts are needed. Case studies outlining business model description would be useful for determining how the infrastructure (e.g. the heat pump or pipes) is financed and who should pay the upfront costs.

A2.2 **Research and development for business models and contractual models to raise the potential of waste heat in industrial plants to pave its way into district heating and cooling systems.**

Type of Action (Research/Innovation/Demonstration or TRL):
From TRL 6-7 to TRL 9

Key Performance Indicators:
- Creating business models with attractive return on investments (i.e. improving the return on investment by 20% compared to the usual value)
- Shortening the negotiation process time for waste heat recovery by 30%

Topic A.3 Utilization of waste heat in district heating networks as well as within industrial processes

Objective:
Develop new technologies for utilization of high and low temperature waste heat (including heat pumps, heat-to-power recovery, polygeneration and hybrid plants)

Key Actions:
A3.1 **Research and development for new technologies, materials, design and integration options for key components such as heat pumps, seasonal storages and heat exchangers with improved performance in order to increase waste heat recovery and to balance between waste heat temperature/availability and heat demand in DH systems**

A3.2 **Recover waste heat in European ports and their related industries, e.g. petro-chemical industry**
Waterborne transport accounts for approximately 90% of global trade and 13% of EU transport GHG emissions, while also experiencing continuous growth. There is an urgent need to reduce transport GHG emissions. The recovery of waste heat in ports and its integration into on-site or nearby industrial processes is essential to reduce primary energy demand.

Type of Action (Research/Innovation/Demonstration or TRL):
The start TRL is very heterogeneous, but the overall goal should be to move from TRL 4-5 to TRL 6-7.

Key Performance Indicators:
- Decrease the lifetime cost of waste heat integration by 20%

Topic A.4 Evaluate and manage the risks related to waste heat recovery

Objective:
Develop advanced risk management strategies and tools for considering uncertainties related to waste heat recovery

Key Actions:
A4.1 **Develop advanced risk management strategies and tools**
The use of waste heat is connected to a number of risks for the district heating network operator, i.e. possible adaptations of the industrial processes might change the availability or quality of the waste heat, thus reducing its profitability. Further on, the industry might go bankrupt or move to other premises, leaving the investments into waste heat recovery stranded. For low temperature waste heat, the corresponding heat pump creates a dependency on the electricity markets and thus introduces a risk due to the uncertainty of future developments. For managing those risks when investing into waste heat recovery (including the investment into seasonal storages for supplying significant amounts of waste heat), **advanced decision support tools need to be developed and implemented, considering pooling of risks to multiple waste heat (and other renewable) sources, decarbonization pathways of the related industrial production processes and the energy sector**. These tools should be tailored for DH companies, banks, insurance companies etc. Risk mitigation mechanisms, such as the creation of investment funds, are needed to provide confidence to private investors. Research projects should focus on the establishment of risk insurance across Europe to cover risks associated with the development and the operation of waste heat recovery.

Type of Action (Research/Innovation/Demonstration or TRL):
Although risk management is a well known methodology, it hasn't yet been applied extensively to waste heat recovery. Start TRL can be considered to be 4-5, target is TRL 6-7

Key Performance Indicators:
- Evaluation of the investment risks for minimum 20 different scenarios
- Minimum 3 different types of investors / stakeholders considered

B. District Cooling

Current Status

District cooling is a commercially available technology based on the concept of connecting multiple customers to a cold source via a pipe network. Chilled water is distributed to the customers where it extracts unwanted heat from the building. District cooling can reach an efficiency rate of often 5 or even 10 times higher than traditional, local, electricity-driven technologies. Due to global warming and new applications, the demand for cooling services is increasing in almost every part of the world, which will increase electricity peak loads and place significant pressure on electricity grids. District cooling offers a solution to alleviate some of this pressure and offers a route to meet this increased energy demand in an environmentally sustainable way, thanks to thermal storage and a variety of possible renewable and recovered energy sources, substantially reducing the need for individual chillers driven by electricity or gas, thus having a beneficial impact on primary energy consumption and GHG emissions.

Cooling can be provided in two different ways. Traditional district cooling networks operate at lower temperatures with centralized cooling generation. Sorption chillers can also enable cooling production from higher-temperature sources (e.g. waste incinerators, existing DH networks), further valorising the existing heating infrastructure and enabling an increase of the operating hours of these systems. These chillers operate best with high temperature sources over 100°C. Following recent developments, cooling is now also provided by low-temperature distribution networks, valorising renewable or locally-recovered heat sources (e.g. geothermal loops, sewage treatment, free cooling from seas, lakes and rivers), exploited by decentralised heat pumps. The network essentially operates as a heat sink for end-user cooling generation. The temperature of the DHC network (heat sink) can be determined by the temperature range of the individual heat pump. These modern networks operate at higher temperatures when compared to traditional district cooling. The ability to use the waste heat from buildings is possible in both types of system, but in traditional DC networks, it would be achieved centrally and in the heat sink configuration, at the end-user level.

At present, the majority of the European cooling demand is supplied by electricity, through compression chillers. This fact hinders a precise quantification of the overall cooling demand and innovative methods need to be developed to improve the results of cooling potential assessments. From the technology perspective, it is then a priority to develop innovative and robust chillers and heat pumps, using natural or low-GWP refrigerants, low-maintenance compression solutions (e.g. magnetic bearings) and flexible systems.

Topic B.1 Operating temperatures in district cooling networks

Objective:
Increase the operating temperature of district cooling networks

Key Actions:
B1.1 **Develop higher temperature DC for the integration of more natural cooling and increased efficiency. Local cooling can be added if cooler temperatures are needed.**

Type of Action (Research/Innovation/Demonstration or TRL):
TRL from 4-5 to 6-7

Key Performance Indicators:
- Increase the DC supply temperature by 5°C
- Decrease the system lifetime cost by minimum 20%

Topic B.2 Design of innovative cooling networks

Objective:
Develop cooling networks' design and solutions integrating recovered heat sources, free cooling and exploiting synergies with existing heating infrastructure.

Support R&D to test innovative concepts (such as hybrid systems) and technologies.

Key Actions:
B2.1 **Develop specific tools that can provide more confidence and thus more openness to district cooling systems' deployment and use.**
The development of new district cooling networks relies on the availability of specific simulation and optimisation tools, which integrate performances and characteristics of existing systems, but also include technology modules and functionalities to simulate the most recent developments (e.g. integration of waste heat, higher temperature - combined heating and cooling systems, free cooling). The availability of reliable and specific tools, together with more detailed demand assessments and the availability of higher-granularity data, will enhance the trust of project developers and increase awareness towards these solutions.

B2.2 **Development of a highly efficient and intelligent district cooling system based on an innovative and optimized district cooling system management strategy, and the integration of predictive controllers at component and system level.**
District cooling systems will become more complex in the future, integrating waste heat sources, taking into account buildings' characteristics to adjust demand forecasts and exploiting, through sorption machines, synergies with existing heating infrastructure nearby. New district cooling concepts should consider all the different options locally available to reduce their energy and environmental footprint. Continuous dissemination on realised projects and on return of experience will allow easier replication and adaptation to local contexts of successful examples.

B2.3 **Develop combined district cooling and district heating or bi-directional heating and cooling networks using renewable or recovered heat to supply both heat** and cold through the same pipes. This requires innovative substations that will increase the flexibility of the system and allow for lower operating temperatures, and enable the integration of heat pumps, electric boilers and thermal energy storage. Depending on the requirements of the end-users and the surrounding environment, networks can be configured to either A) provide heat and cold at the same time or B) supply heat during the winter and cold during the summer

B2.4 **Develop small DC networks connected to DH trough absorption heat pumps**

Type of Action (Research/Innovation/Demonstration or TRL):
TRL from 3-5 to 6-8

Key Performance Indicators:

- Decrease the system lifetime cost by minimum 20%

Topic B.3 Demand side

Objective:
Integrate technologies and control systems with demand side response to exploit all the benefits delivered by district cooling

Key Actions:
B3.1 **Development and demonstration of optimization and control tools enabling increased use of intermittent renewable cooling options by exploiting the flexibility potential in the district cooling system.**
The development of methods and tools for optimization and control of the operation of the distribution, storages and buildings exploiting the controllable load flexibility on the demand side together with the thermal energy capacity in the grid and storage will enable an increased uptake of intermittent renewable coolings options. It will be beneficial for both consumer comfort requirements and cooling requirements in industrial settings, e.g. small-scale data centers. It is foreseen that load prediction techniques, flexibility quantification, assessment and aggregation methods, and optimization-based methods for control and operation are further developed. The tools are demonstrated in realistic settings and benchmarked with the current state of the art and the foreseen effect on the uptake of intermittent renewable cooling options is assessed.

B3.2 **Improve results of cooling potential assessments (e.g. granularity, temperature levels, competing locally available solutions).**
A detailed assessment of the cooling demand (load curves, installed technologies) is currently often not available, as cooling production is mostly ensured behind the electricity meters. Advanced tools for cooling potential estimation need to be developed, taking into account the buildings' characteristics and, most importantly, behaviours of the buildings' occupants. Such tools and databases should have a sufficient time granularity to support sector coupling and energy recovery solutions and contain as well technical information, such as required temperature levels. Results of such tools should be made available, as done in the recent past for heating assessment, as a common base for further development. Mapping actions of available installed technologies can be encouraged also through public participation actions (e.g. PPGIS solutions).

Type of Action (Research/Innovation/Demonstration or TRL):
Starting from TRL 3-4 and reaching TRL 5-6

Key Performance Indicators:

- Decrease peak loads by minimum 20%
- Increased knowledge of end-user cooling requirements

Topic B.4 Accelerating innovative, renewable district cooling in emerging and developing countries

Objective:
Rising temperatures, population growth, increasing prosperity and urbanisation boost the demand for cooling, particularly in emerging and developing countries, thus accelerating climate change. While the use of innovative and efficient cooling equipment has grown in emerging and developing countries, the EU has the technological knowledge and capacity to leapfrog efficient and sustainable district cooling networks internationally.

CSAs in this field will contribute to the present R&I Partnership on Climate Change and Sustainable Energy of the EU/African Union High-Level Policy Dialogue on Science, Technology and Innovation, as well as the implementation of the Paris Agreement and the Kigali Amendment at large.

Key Actions:

B4.1 **EU-International District Cooling forum connecting policy-makers, industry, consumers, research institutes and NGOs**

The forum will cover different geographical areas with regional subgroups, including South-East-Asia, Africa, Central America and South America, supporting for example:

- Support of creation of national and regional cooling strategies and plans
- Facilitating policy dialogues between policy-makers, industry, consumers, research institutes and NGOs
- Knowledge transfer events on district cooling technology between EU and emerging and developing countries
- Enhancing R&I cooperation between EU research institutions and emerging and developing countries' academia

B4.2 **Market support for district cooling uptake in emerging and developing countries**

The European Union is leading the innovation of district cooling networks, but the greatest market potential of the technology lies outside the European continent. A key solution to tackle climate change, and provide efficient and clean cooling to communities, market support mechanisms are paramount to make these solutions accessible outside Europe. Existing innovative solutions and technologies generated for developed markets need to be adapted and tailored to the different geographical contexts and markets of emerging and developing countries. The goal is to bring not only economic, but also environmental, social and health benefits and co-creating solutions together with local stakeholders. To facilitate market uptake and sustained deployment of technologies, R&I policies need to be coupled with capacity building and appropriate financing solutions.

Type of Action (Research/Innovation/Demonstration or TRL):

CSA

Key Performance Indicators:

- Establishment of a DC Forum between the EU and emerging and developing countries with regular dialogue, exchange and meetings.
- Increased academic exchange between EU and emerging and developing countries on district cooling topics.
- 10% increase in the number of DC systems world-wide, especially in emerging and developing countries.
- Access to DC for vulnerable groups in emerging and developing countries.

C. Low-Temperature District Heating and Cooling

Current Status

The tendency of the evolution of district heating so far has been towards lower distribution temperatures, reducing heat losses and allowing for the integration of sustainable heat sources. This transformation from 3rd generation networks to 4th generation networks is essential for the decarbonisation of European cities. The concept of 5th generation networks operating at ultra-low temperatures has also emerged in recent years. This generational leap impacts all parts of the thermal energy flow, from generation to end-user consumption. Pipe dimensions will change, the way networks are constructed and installed will be altered and there will be changes on the consumption side as new substations are developed. This change enables the integration of new kinds of sustainable energy sources and network optimisation through digitalisation.

The transformation of 3rd generation networks into 4th generation networks will follow the transformation of the building stock towards high efficiency and reduced CAPEX and OPEX of components, to allow for lower network operating temperatures, with individual heat pumps in buildings to increase water temperatures, to supply district hot water, and eliminate the risk of legionella. The lower operating temperature of 4th/5th generation networks results in greater system efficiency, lower distribution heat losses and increased integration of locally-available renewable and waste heat resources. The development of these networks will promote a cost efficient and technically viable decarbonisation of the European DHC sector.

Topic C.1 Demand

Objective:

Enable the participation of prosumers in local energy markets and heat/cold exchange between buildings

Maximise the recovery of low temperature residual heat and high temperature cooling sources for building heating and cooling

Reducing the return temperature in networks by improved control of the building side (both room heating and sanitary hot water production)

Key Actions:

C1.1 **Develop local energy markets for heating & cooling to enable private and commercial participants to become prosumers**
Examine the impact on network operating temperatures of connecting pipelines between multiple prosumers and explore synergies with the electricity sector via prosumer interactions with both markets.

C1.2 **Develop technical solutions and policy frameworks in order to tackle the legionella risk for the use of very low temperature DHW.**
Using low temperature heat for sanitary hot water production can cause issues related to legionella. Different options are possible but each solution has advantages and disadvantages. Suitable technologies (or combination of technologies) are needed to reduce the legionella risk in low temperature heating networks by increasing the water temperature for DHW above 50°C (or via some other technical/chemical solution). New rules for distances between low temperature heating network piping and piping for potable water supply, due to the lower temperature of the water in the DHN piping, a smaller allowable distance between the DHN piping and the potable water supply piping in the underground should be considered.

C1.3 **Develop solutions for further reducing the return temperature in district heating networks by improved control of the building heating system and the sanitary hot water as well by identification of secondary faults (e.g. wrong heat exchanger design).**
e.g. lowering the primary return temperature by optimizing the room heating installation with respect to the return temperature.

C1.4 **Research on innovative solutions at demand level for the integration of local RES and waste heat resources** such as new kinds of heat exchangers with improved heat effectiveness, reduced pressure drop and reduced material usage for integration in substations, advanced sub-stations with smart controlled heat pumps supporting the grid.

C1.5 **Digital monitoring and analytics to increase network efficiency at demand side in single and multi family buildings.**
Low cost sensors to monitor:
- Indoor temperature, solar radiation in a room, presence of persons.
- Indoor distribution system (e.g. flow, pressure, leakage, corrosion)
- Substation (e.g. flow, temperature, pressure from both primary and secondary side)

Data analytics to support fault detection, fault diagnosis and automated correction.

Type of Action (Research/Innovation/Demonstration or TRL):

Research & Innovation: TRL from 4-5 to TRL 7-8

Key Performance Indicators:

- Share of prosumers in the heat supply >30%
- Decreasing LCOE (levelised cost of energy) for prosumers by >15% when participating in the market
- Decreasing the life cycle costs of DHW preparation at low temperatures by >10%
- >90% Identification accuracy of secondary faults leading to high return temperatures
- Reduce the return temperature in DH networks by 10°C

Topic C.2 Distribution

Objective:
Develop and demonstrate new solutions for DHC systems with local and centralised energy storage, integration of new components and management ICT systems.

Development of innovative components and infrastructure enabling the use of ultra-low temperatures in district heating networks and allowing high temperature district cooling (linked to Key Action B2.3).

Key Actions:
C2.1 **New design concepts for optimisation of LTDH distribution systems**
Advanced concepts allowing multiple heat sources and consumers at different locations with optimal short and long term storage integration. Hydronic and pump location optimisation to increase network efficiency at reduced pumping energy.

C2.2 **New pipe components for LTDH underground distribution and new high efficient pipe types for internal distribution in buildings.**
Low cost piping systems and components allowing for reduced cost of components and construction cost of LTDH.

C2.3 **Multi-temperature networks supporting high, medium and low temperature heating distribution and medium and low temperature cooling distribution.**
Advanced broad band district heating and cooling networks for exchanging heating and cooling atdifferent temperature levels between distributed sources and users allowing for minimisation of exergy losses.

C2.4 **Solutions to reduce pipe losses in DHN.**
The energy consumption of the pumps in district heating and cooling networks is depending on the pressure drop over the piping and components like valves, heat exchangers, metering equipment, etc. Pressure drop can be reduced in different ways, e.g. by increasing the piping diameter (costly), but also by reducing the roughness of the inner surface (e.g. by using coatings) or by adding DRA (drag reducing agents) to the circulation medium.

C2.5 **Advanced sensors for monitoring and analytics of the network.**
New sensor development for corrosion and leakage detection integrated in the piping network. Data analytics to support in fault detection, fault diagnosis and automated correction.

Type of Action (Research/Innovation/Demonstration or TRL):
Research, Innovation & Demonstration: TRL from 5-6 to 7-8

Key Performance Indicators:
- Reducing heat distribution losses by >20%
- Reducing fluid distribution leak by >20%
- Reducing electricity consumption for distribution by > 20%
- Demonstrate the concept of LTDH or multi-temperature levels in 2 - 3 demonstration projects

Topic C.3 Supply

Objective:
Increase use of low-grade local waste heat sources (e.g. data centers, cooling of buildings, metro stations, wastewater treatment plants) and local RES both centrally and on the consumer side.

Key Actions:
C3.1 **Optimisation solution for an optimal use of very low-grade heat sources such as innovative use of heat pumps/chillers.**
New type of heat pump systems that are capable to cope with variable heat/cold source temperatures and a high modulation degree.

C3.2 **Solutions to minimise daily and seasonal load variations such as the development of short term and seasonal thermal storage facilities.**
Linked to Topic F.2

Type of Action (Research/Innovation/Demonstration or TRL):
Innovation actions: TRL from 6-7 to 8

Key Performance Indicators:
- Decrease peak loads in DH networks by 20%
- Increase the share of renewable and waste heat sources in DH networks to 43% by 2027.

Topic C.4 Other / Non-technological priorities

Objective:
Support the large scale replication and the market uptake of solutions concerning low temperature district heating and high temperature district cooling

Key Actions:
C4.1 **Studies to raise awareness among local policy makers and consumers/citizens about the advantages deriving from an extensive use of low-grade heat surplus beyond traditional scopes**

C4.2 **Development of guidelines and recommendations for buildings preparation in the use of LTDH**
Renovation should be viewed as complementary to the roll out of DHC networks. The connection of well-insulated, energy-efficient buildings to modern heat networks will provide flexibility to the heat demand of buildings as well as enabling low supply and return temperatures. Through load shifting, generation from CHP and heat pumps can be used to provide flexibility to the electricity system.

Type of Action (Research/Innovation/Demonstration or TRL):
Coordination and Support

Key Performance Indicators:
- National awareness campaigns to promote LTDHC and the utilisiation of locally-available heat sources carried out in each EU Member State.
- DHC networks and building renovation considered together in local authority energy plans.

D. Energy System Integration

Current Status
Energy system integration – the coordinated planning and operation of the energy system 'as a whole', across multiple energy carriers, infrastructures, and consumption sectors – is the pathway towards an effective, affordable and deep decarbonisation of the European economy. DHC networks enable sector integration by creating linkages between different parts of the system and provide flexibility through the means of technologies which are both technically and commercially available. To reduce greenhouse gas emissions, energy system integration offers increased usage of waste heat and renewable energies in DHC. Modern low-temperature district heating systems connect local energy demand with renewable and waste energy sources, as well as the wider electricity and gas grid – contributing to the optimisation of supply and demand across energy carriers.

By increasing the synergies between electricity and heat networks, multi-energy carrier integration can support the usage of surplus renewable electricity, reducing curtailment and the need for direct electricity storage. RES development is supported by preventing the curtailment of variable renewable electricity. During times of high supply, when the price is low, surplus electricity can be integrated into heat networks through heat pumps and thermal energy storage.

Coupling the electrical and thermal grids plus the integration of energy storage will result in a significantly more stable electricity demand and a reduction of electrical peaks, maximizing the use of renewable energy sources and improving the efficiency of the whole energy supply. Coupling the gas and thermal grids can easily be done via using the excess heat from fuel cells (or other CHP processes involving hydrogen, biomethane etc.), and also by recovering the heat losses from electrolysis processes for hydrogen generation, increasing overall system efficiency. On the other hand, electricity and heating networks can be effectively coupled with state-of-the-art technologies such as heat pumps, cogeneration units and electric boilers.

The successful application of energy sector integration depends on optimal control of the system, to exploit fuel-shift capabilities and energy storage, to modulate the consumption of gas and electricity according to the needs of all sectors. Innovative business models and market designs are therefore required, to encourage stakeholders from the heating and cooling sector to develop new control strategies and benefit from the additional flexibility DHC systems could provide. At the same time, improved collaboration, transparency and communication between stakeholders from the different sectors is an essential condition to make all the sectors develop towards higher integration, through, for example, standardised monitoring systems and data sharing protocols and collaborative platforms.

Topic D.1 Short and long term flexibility

Objective:
Increase the short- and long-term flexibility of DH and DC networks enabling their efficient utilisation.

Key Actions:
D1.1 **Develop and implement measures for increasing the short term flexibility** (e.g. hours to days) of the DH network, in order to reduce the use of fossil fired peak load boilers, to decouple the heat and electricity production in CHP systems and to adapt to supply profiles with daily/ hourly variations (e.g. solar thermal energy, but also power-to-heat). This can be done via the integration of centralized and customer side storages, the utilization of the network as storage and customer side load shifting. These measures are state of the art, their penetration needs to be improved.

D1.2 **Develop and implement measures for increasing the long term flexibility** (e.g. weeks to month, also seasonal storages) of the DH network, in order to maximize the utilization of surplus heat in summer time, especially from solar thermal collectors and excess heat from cooling, but also from geothermal energy, heat pumps, industrial waste heat and waste incineration. Various long term flexibility measures are currently available (including aquifer, borehole, pit, tank storages). However, such systems have mainly been integrated in small/rural networks or building clusters in Germany, Denmark and Sweden. For integration in larger networks, the disadvantages of such storage, especially the space requirements and the high investment costs need to be overcome.

Type of Action (Research/Innovation/Demonstration or TRL):
TRL from 5-6 to 7-8

Key Performance Indicators:
- Reduce peak load boilers usage by minimum 80%
- Increase the share of volatile energy sources (solar thermal, direct electricity from PV/ wind etc.) and/or electricity provided by short term markets by minimum 50%
- Provide minimum 20% of the winter heat demand by using summer surplus heat via seasonal thermal storages
- Increase the number of annual load cycles of seasonal thermal storages to a value of minimum 4
- Decrease the life cycle costs of thermal energy storages by minimum 20%
- Increase the number of full load hours of heat supply from alternative heat sources by minimum 50%

Topic D.2 Integration constraints

Objective:
Identify the technological and systemic constraints of integrating multi-energy systems.

Enable and prioritise prosumer participation in a highly-integrated energy system (linked to Key Action C1.1)

Key Actions:
D2.1 **Development and testing of methods for creating cross-sectoral system models and integrated energy network infrastructure plans on a European/national level considering realistic representation of the H&C sector to enable a cross-sectoral and spatial differentiated optimization of the different energy infrastructures.**
These include: the realistic mapping of DHC networks and other H&C systems, including coupling points (CHP, power-to-heat, power-to-gas) and the respective flexibility potentials (especially long-term storage) and efficiency potentials (especially temperature levels) as well as consideration of current and future generation potentials. Special attention should be given to the utilization of waste heat from electrolysers.

D2.2 **Standardization and market entry for products/services for enabling an optimized sector integration** (e.g. planning tools, HEN controller); fostering an increased interoperability of the different systems and technologies as well as ICT security.

D2.3 **Identify and overcome the technical barriers preventing straightforward prosumer participation** and develop local energy markets with heat sharing between buildings, high shares of solar thermal generation (both centralised and decentralised) and electric and thermal storage. Develop synergies with the electricity sector, with prosumers playing an active role, to maximise system flexibility.

Type of Action (Research/Innovation/Demonstration or TRL):
TRL from 3-4 to 5-6 (TRL 8-9 for standardization and market entry projects)

Key Performance Indicators:
- Application of the tools and methods to minimum 3 different countries, considering the overall european energy system
- Involvement of minimum 2 experts from each sector (electricity, heat, gas), considering accademia, industry, network operators, associations

Topic D.3 Business models and market design

Objective:
Develop innovative business models to promote LTDH, that enable energy system integration and are favourable to all involved stakeholders.

Study innovative market designs and support schemes towards energy systems integration.

Key Actions:
D3.1 **Development of innovative business models to support use of LTDH at city/municipal level**
The business case for DHC must be improved to attract institutional investors to the sector.

D3.2 **Development of new and innovative business models and application of regulatory sandboxes for the optimization and operating of coupling points** e.g. optimizing the profits on different energy markets; using the concept of energy communities considering the sectors of heating & cooling (and mobility); use of coupling points and storage capacities; creation of synergies; local heating and cooling exchange/trading; counteracting limitations of the electricity network transfer capacity by local utilization of excess electricity from local intermittent renewable electricity production; reduce grid losses by maximizing local consumption of (renewable) electricity sources (close to the site of generation) instead of transporting the electricity to remote demand locations; (locally) adapting the temperature level to the demand side requirements to the available heat source.

D3.3 **Development of advanced methods to support investment decisions for integrated / hybrid energy infrastructure/decarbonization strategies** (including risk analyses and new financing models) considering future developments of the energy markets, coupling points and flexibility

Type of Action (Research/Innovation/Demonstration or TRL):
TRL from 4-5 to 6-7

Key Performance Indicators:
- Setup minimum 3 different energy communities, considering synergies to and opportunities for heat networks
- Increasing the utilization rate of locally generated energy (electricity and/or heat) by minimum 50%
- Decreasing the LCOE by minimum of 20%

Topic D.4 Stakeholder collaboration

Objective:
Develop frameworks for improving collaboration and transparency between stakeholders (e.g. standardised data sharing and storage, collaborative energy platforms).

Key Actions:

D4.1 **Development of advanced methods for planning and operation of hybrid energy networks** focusing on the reduction of the complexity due to a higher number of optimization parameters, different time responses and operating constraints, different metrics and KPIs for the multiple stakeholders involved as well as regulatory boundary conditions and constraints.

D4.2 **Capacity building and training for planning, installation and operation of integrated energy systems.**

Type of Action (Research/Innovation/Demonstration or TRL):

Coordination and Support

Key Performance Indicators:

- Successful development and operation of multi-sided, cross-sectorial platforms for stakeholder cooperation

E. Digitalisation

Current Status

Digital technologies are believed to make the whole energy system smarter, more efficient, reliable, and better integrated. It will also boost the integration of more renewables into the system. These technologies also enable increased access to data from the field and describe the actual assets in complete digital form. In the future, district energy systems are thereby enabled to fully optimise their plants and network operation while empowering the end consumer for mutual benefits and transparency, where energy communities can arise.

Technologies like IoT (internet of things), automation, AI (including augmented and explainable), and big data hold big promises and can be industrially packaged using the digital twin concept. Interoperability of systems enabling data integration still faces a number of challenges. Highly integrated large scale systems like district energy systems are systems of systems and are cyber-physical in nature. Any advanced solution improving design and operation relies on models describing the system and its behaviour (data-driven, physical or hybrid) requiring digital information not only from sensors and SCADA, but also detailed digital information on components and subsystems in the complete plant. Nonetheless, numerous pitfalls need to be avoided and new challenges arise, such as security and privacy as well as questions about data ownership. Additionally, new business models and policy interventions require market actors to adapt. The pace of change is fast and it is challenging both for the industry and regulators

Topic E.1 Integration of production, distribution and consumption

Objective:

Integrated approach to the control and optimisation of production, distribution and consumption to systematically exploit flexibility potentials on the system and subsystem level.

Key Actions:

E1.1 **Develop and demonstrate highly integrated monitoring and control of thermal energy provisioning from multiple production units to substation level at buildings considering flexibilities at all levels.**

Increased energy efficiency and integration of RES are attained through digitalising and integrated joint control and optimization of production, distribution and consumer substations. Digitalising the distribution system will facilitate a more balanced energy distribution, the integration of diffuse energy production (prosumer, heat recovery), leakage detection, minimisation of heat losses, and unlocking flexibility potentials in grid, thermal storages and consumer demands. Therefore methodologies and tools need to be developed and demonstrated comprising operational analysis, optimization-based control approaches on multiple system levels, resource availability prediction, and predictive maintenance using AI principles, while considering controllability of flexibility potentials.

E1.2 **Develop, demonstrate and implement quantification and assessment tools for exploiting flexibility in buildings and offering to grid and production operations.**

Digitalisation enables system-wide access to information and going beyond the substations in buildings, enabling further optimization of production and distribution where consumer behaviour and load flexibility can be exploited while delivering uncompromised comfort to consumers. Hence, methods and tools to quantify and assess the controllable load flexibility of consumers and buildings need to be developed and demonstrated along with the further deployment of sensing capabilities in buildings. To achieve this load prediction, schemes considering consumer load flexibility, fully digitalised and connected asset infrastructure with smart meters, smart substations, distributed control systems targeting local requirements are essential. New business models can therefore emerge providing heat-as-a-service, empowering energy providers to take more responsibility and end-users to actively engage, while considering all aspects circumferencing GDPR.

Type of Action (Research/Innovation/Demonstration or TRL):
E1.1 - Starting TRL 3-4 and reaching TRL 5-6
E1.2 - Starting TRL 4-5 and reaching TRL 6-7

Key Performance Indicators:

- Increased share of connected buildings providing near real-time updates on heat/cold demands and flexibility to centralized data warehouses or data lakes by 50%, with a minimum of 20% active connections
- Demonstrate use of consumption flexibility in buildings, specifically exploiting resident's thermal comfort flexibility
- Demonstrated use of fully integrated system wide control exploiting flexibility simultaneously at all levels in the grid, distribution, and buildings.and reduce peak load by 20%.
- Doubling the use and deployment of IoT devices in distribution and buildings for control and analytics to determine system states and condition for increased energy efficiency
- Benchmarked use of flexibility for increased energy efficiency showing the share of available flexibility used and the effect on load reduction.

Topic E.2 Planning and design

Objective:
Develop generation and update mechanisms for digital twins considering the complete life-cycle enabling co-design and optimal operational decision making

Key Actions:
E2.1 **Development and application of new digital twin based methodologies, tools and processes allowing for integrated energy infrastructure planning which supports the day-to-day decision making process in cities, energy utilities and other decision makers** (e.g. property developers) and finally leading to a socio-economic optimum and at the same time allowing for new business models (e.g. prosumer integration, heating and cooling as a service).

E2.2 **Develop and demonstrate methodologies and tools for the generation, update and operation of digital twins enabling planning, design and operation of an integrated energy infrastructure.**
This requires to establish new tools and methodologies for modeling and simulation, an integral part of a digital twin, which enable city scale simulation on varying time granularities (from low-level hydraulic aspects to high-level and long-term planning aspects) with sufficient accuracy for uses-cases supporting the planning, design and operation such as operator training, what-if analysis, scenario-based assessment, monitoring, control and optimisation, as well as maintenance and refurbishment. The developed tools need to be able to consider the system life-cycle and demonstrate automated mechanisms keeping the digital twin up to date and valid. It might be linked with geographical information systems (GIS). Further, to be relevant and useful in practical design and engineering, the digital twins need to be able to provide actionable insight fast requiring high simulation speeds in relation to real time.

Type of Action (Research/Innovation/Demonstration or TRL):
E2.1: TRL from 4-5 to 6-7
E2.2: TRL from 3-4 to 5-6

Key Performance Indicators:

- (E2.1 & E2.2) At least 6 months of continuous operation of the digital twin in parallel with the life system providing decision support with at least 95% validity of the insight.
- (E2.2) Proposed validation metric for large scale digital twin validation used in the generation, monitoring for triggering of updates, and calibration of embedded system models. This needs to include benchmarking of the metric with state of the art methodologies and considering aspects lite disturbance scenario and scalability.
- (E2.2) Reduction of the engineering efforts for generation and update of digital twin by 80% from current manual approaches.

Topic E.3 Data management and sharing

Objective:
Develop a policy supported data market and data governance model including open data to enable a wider data sharing while considering privacy and security aspects.

Key Actions:
E3.1 **Develop and demonstrate a data market for an integrated energy infrastructure on city-scale enabling service development and energy communities.**
Establish principles and prototypes for a data market enabling stakeholders to engage in development and service provisioning with utilities, including business models, routines and policies for data governance, open data and data sharing. Consumer engagement and the support of energy communities need to be specifically demonstrated.

Type of Action (Research/Innovation/Demonstration or TRL):
Starting TRL 3-4 and reaching TRL 6-7

Key Performance Indicators:
- Increased Ratio of buildings, components in production, and components in the grid providing data on at least hourly basis and offered to service providers in a market-like structure with established routines for governance and a business model.
- Targeted value: 50%

F. Thermal Energy Storage

Current Status

TES 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 gains to periods of greatest demand, each of them characterised by different specifications and specific advantages. By decoupling the availability of renewable energy from the time when it is needed, TES offers a major source of flexibility to the energy system. In addition, the same TES allows multifunctional usage for peak load shifting, enabling sector coupling between electricity and heating/cooling and raising efficiency of combined heat and power or biomass plants, enabling the efficient integration of heat pumps and can even store heat or cold seasonally for months. TES applications are at various stages of development, depending on the technology considered. The main developments in technology can be subdivided into large, sensible thermal energy storage and compact thermal energy storage technologies. Large scale TES applications are important for providing flexibility to DHC networks and enabling higher shares of RES usage.

Large thermal energy storage technologies for buildings, industry and DHC systems:
Above-ground realized steel tanks are a state-of-the-art technology spread in the European district heating and industrial heating market. These storages enable peak shifting between heat production and demand. The realized volumes reach up to 50,000 m^3 of water filling. For such large volumes thermal energy storage promises to be more cost effective if integrated underground. Most large thermal energy storage systems in the form of Pit Thermal Energy Storage have been realised in Denmark, with volumes up to 200,000 m3. Storage temperatures up to 80°C are being reached, and the storages are used for seasonal storage of solar thermal energy and for electricity peak supply uptake with heat pumps or directly. Tank Thermal Energy Storages are made of reinforced concrete containments that are partly integrated underground and filled with water that is heated up to 95°C. Several pilot storages with volumes of up to 12,000 m^3 were realized in different European countries. At lower temperatures to about 30°C, Aquifer Thermal Energy Storages are applied widely especially in The Netherlands, integrated in heat pump driven district heating and cooling systems for building blocks or districts. Borehole Thermal Energy Storage uses the upper layer of the earth to store heat with vertical, closed borehole heat exchangers and are applied both to small, domestic systems as well as for larger systems for building blocks or industry.

Compact thermal energy storage technologies for low temperature and medium to long term storage period:
A number of materials and concepts were developed for the compact thermal storage of solar energy, mainly with

solar thermal energy as the heat source and to provide space heating and hot tap water. These were developed up to TRL 6 (demonstration in a relevant environment). The concepts employ sorption materials, like zeolites, salt hydrates, for instance MgCl2, Na2S, KCO3 and SrBr2 and composite materials, being combinations of porous (sorption) materials and salt hydrates. The class of PCM can store a high amount of heat at a specific, constant temperature and is therefore applied in those situations where a constant temperature is needed. This applies to in-room comfort situations and also in combination with heat pumps and other technologies.

Compact thermal energy storage technologies for medium temperature applications in industry and in sector coupling:
The state of the art for these technologies is around TRL 4 despide water filled, pressurised storages or solid, sensible material storages. Materials research for PCM has led to a number of materials suited for medium temperature storage. Some sorption materials have been applied for storage of industrial waste heat, to be used in other applications at a later moment or in another location. Metal oxide-metal hydroxide reactions are being developed on prototype reactor scale for the storage of medium temperature heat from industrial or electricity grid sources. New materials from the classes of salt hydrates, carbonates, salt ammoniacates and composite materials are being studied for medium to high temperature applications.

Topic F.1 Large thermal energy storage technologies for DHC systems and industry

Objectives:
Improve the performance of above ground and underground thermal energy storages (energy efficiency, system lifetime, economic efficiency) by 25% (compared to 2015 levels): Enable TES technologies for a large bandwidth of heat sources in power and temperature to adjust them to a large bandwidth of DHC and industrial characteristics, increasing the long-term flexibility and the share of RES for district heating and cooling systems and for heating below 100 °C in industry.

Make storage systems suitable for a large variation of locations and for integration in a large range of energy production systems for local, district or industrial heating and cooling systems (large thermal energy storage based on sensible heat storage).

Boost the market deployment of large and cost effective sensible thermal energy storages in DHC systems and industry.

Key Actions:
F1.1 **Development and improvement of materials and storage design**
Improve building materials and construction technologies in order to increase storage density, the maximum temperature, lifetime and reduce overall costs (investment, operation and maintenance) of large thermal energy storage systems.

F1.2 **System development**
Improve the economic benefit of the thermal energy storage by further developed integration of the storage in the energy production and delivery systems of DH or DC networks. A multifunctional usage of the TES promises best economic benefits. This comprises on one hand the hydraulic interaction including the adaption of the TES to the DH or DC or industrial system and vice versa and, on the other hand, the interaction within the digital management of the overall system. For that purpose, further development of system simulation software is necessary.

F1.3 **Market acceleration**
Transfer the new findings and outcomes of the above key actions to the target groups of investors and decision makers. Train the bottlenecks like consultancies, approval authorities, general public etc.

Type of Action (Research/Innovation/Demonstration or TRL):
TRL from 3-5 to 6

Key Performance Indicators:
- 50% more R&D efforts for sensible TES in Europe.
- 25% lower cost for used heat of sensible TES in DHC and industrial systems compared to 2015 levels.
- 2 pilot storages for very large TES with a volume of over 200,000 m³ realized or at least in realization.
- 10 new demo systems with sensible TES realized in Europe with a usage of RES to more than 60% of the yearly heat demand.

- 2 new simulation softwares available on the European Market for simulating digital twins of systems with TES integration.
- 3 European technology transfer projects realized or ongoing for knowledge transfer about TES and their system integration to the market.

Topic F.2 Compact thermal energy storage technologies for low temperature and medium to long term storage periods

Objective:
For application temperatures between 40-120°C for domestic hot water and space heating purposes, the objective is to work on materials development and on component design and system optimisation towards an increase of energy storage density of about 200 kWh/m3 from the present 60 kWh/m3 (on storage system level).

Key Actions:
F.2.1 **Materials development and improvement:**
- Improved PCM for low temperature applications with attention to material cyclability.
- Development and improvement of thermochemical reaction materials for low temperature storage, with the aim of increasing the long-time performance.
- Development and improvement of novel combinations of porous and salt hydrate materials (composite materials), with the aim of increased storage density, long time performance and reduced costs.
- Development of measuring and testing techniques for the reliable and reproducible determination of compact thermal energy storage materials characteristics.

F2.2 **Component and system development**
Improve the performance of compact TES components and systems through better materials, geometries and controls. Develop methods to determine the state-of-charge of compact TES storages (see F3.2). Development of characterisation and test methods to effectively, reliably and quickly assess the materials performance under application conditions. (see F3.2) Demonstrate these concepts in a real environment, in systems for medium to long term, for instance for power to heat, for seasonal solar thermal or for biomass systems.

Type of Action (Research/Innovation/Demonstration or TRL):
F2.1: TRL from 2 to 5
F2.2: TRL from 5 to 7

Key Performance Indicators:
- At least 5 novel PCM and 5 TCM for low temperatures developed and tested
- Storage density at system level increased to 200 kWh/m3 from the present 60 kWh/m3
- Methods to determine the state of charge developed and demonstrated in practice
- 3 measurement techniques for PCM or TCM materials characteristics developed and assessed
- 2 methods for determination of the state of charge for TCM developed
- 10 systems for compact thermal energy storage for low temperatures demonstrated at TRL 6 or TRL 7

Topic F.3 Compact thermal energy storage technologies for medium temperature applications in industry and in sector integration

Objective:
At application temperatures from 120°C upward, the objective is to improve existing PCM and TCM materials and develop new materials and reactions that enable the storage of industrial waste heat or the coupling of the electricity and heating sectors by power to heat technologies on domestic, industrial and district heating network scale. Existing storage technologies for pressurized water volumes or solid materials have to be developed further to reduce their investment and O&M cost.

Key Actions:

F.3.1 **Materials development and improvement**

- Improved PCM for medium temperature applications with attention to material cyclability.
- Development and improvement of thermochemical reaction materials for medium temperature storage, with the aim of increasing the long-time performance.
- Other actions to linked to F2.1

F.3.2 **Component and system development**

- Development of characterisation and test methods to effectively, reliably and quickly assess the materials performance under application conditions (see F2.2).
- Develop methods to determine the state of charge of PCM and TCM storages (see F2.2).
- Study and improve the design methods for the main components (heat exchangers and reactors), test and demonstrate novel designs for these components.
- Develop new TES design for pressurized water volumes or solid materials that aim for a reduction in investment cost of at least 20% compared to the state-of-the-art.

F.3.3 **Integration of TES into systems**

Prototyping, demonstration and piloting of thermal energy storage technologies into energy systems, for a number of industrial processes and for power to heat. Key elements for the integration are accurate and fast system simulation, in connection to integrated system control incorporating state-of-charge determination and predictive techniques; development of novel business models incorporating dynamic pricing techniques to determine the added value of TES in a system.

Type of Action (Research/Innovation/Demonstration or TRL):

F3.1: TRL from 3-5
F3.2: TRL from 3 to 6
F3.3: TRL from 4 to 7

Key Performance Indicators:

- At least 5 novel PCM and 10 TCM for medium temperatures developed and tested
- 5 novel designs for heat exchanger or reactor demonstrated in the laboratory
- 2 novel designs for TES with pressurized water or solid material that reduce investment cost by at minimum 20% compared to the state-of-the-art on 2015 level.
- 10 systems for compact thermal energy storage for medium temperatures demonstrated at TRL 6 or TRL 7

IMPLEMENTATION PLAN

Budget

RHC-ETIP estimates that EUR 400 billion is the total investments required at the European level to substitute 50% of the yearly heating and cooling demand (200 Mtoe) from fossil fuels to renewables within the next 20 years. The related European R&D expenditure in the 2021-2027 period should amount to EUR 14 billion (50% industry, 25% EC, 25% MSs).

Gross domestic expenditure on R&D in Europe is approximately 2% of GDP, while the overall investment level in the EU is 20% of GDP. Each Euro spent for R&D therefore mobilises EUR 10 of investments. Given the need for EUR 400 billion within the next 20 years, EUR 140 billion will be required in the period 2021-2027. Those will be leveraged with 14 billion investments in R&D of which at least 25% could come from the EU R&D budget (i.e. Horizon Europe, Innovation Fund, and others), which amounts to EUR 3.5 billion.

Budget Overview (2021 - 2027)

	Funding needed (million euro)		
	Public	Private	Combined
Waste heat	55	135	190
District cooling	200	150	350
LTDHC	250	200	450
Energy integration	175	150	325
Digitalisation	125	150	275
TES	250	250	500
Total	**1,055**	**1,035**	**2,090**

Funding Needed to Implement the Research Priorities

Waste Heat

Topic	Indicative Budget (million euro)	Classification & TRLs
Integration of waste heat in decarbonisation strategies	60	Coordination and support
Business and financing models to boost waste heat recovery	30	TRL 6-9
Utilization of waste heat in district heating networks as well as within industrial processes	70	TRL 4-7
Evaluate and manage the risks related to waste heat recovery	30	TRL 4-7
TOTAL	**190**	

District Cooling

Topic	Indicative Budget (million euro)	Classification & TRLs
Operating temperatures in district cooling networks	100	TRL 4-7
Design of innovative cooling networks	110	TRL 3-8
Demand side response	90	TRL 3-6
Accelerating innovative, renewable district cooling in emerging and developing countries	50	CSA
TOTAL	**350**	

LTDHC

Topic	Indicative Budget (million euro)	Classification & TRLs
Demand	150	Research & Innovation TRL 4-8
Distribution	100	Research, Innovation & Demonstration TRL 5-8
Supply	150	Innovation actions TRL 6-8
Non-technological priorities	50	Coordination and Support
TOTAL	**450**	

Energy Integration

Topic	Indicative Budget (million euro)	Classification & TRLs
Short and long term flexibility	100	TRL 5-8
Integration constraints	100	TRL 3-6
Business models and market design	100	TRL 4-7
Stakeholder collaboration	25	CSA
TOTAL	**325**	

Digitalisation

Topic	Indicative Budget (million euro)	Classification & TRLs
Integration of production, distribution and consumption	100	TRL 3-7
Planning and design	100	TRL 3-7
Data management and sharing	75	TRL 3-7
TOTAL	**275**	

TES

Topic	Indicative Budget	Classification & TRLs
Large thermal energy storage technologies for DHC systems	200	TRL 3-6
Compact thermal energy storage technologies for low temperature and medium to long term storage periods	150	TRL 2-7
Compact thermal energy storage technologies for medium temperature applications in industry and in sector integration	150	TRL 3-7
TOTAL	**500**	

Financing DHC & TES

DHC & TES can be funded in many different ways, using both R&D public funding and private financing. Heating and cooling are influenced by a variety of local factors. There is no ready made solution and each project needs to be tailored to the local environment. However, there are European funding programmes available to get projects up and running. The main funding instruments are outlined in the section below. Member state public expenditure is also important for financing large energy infrastructure projects.

DHC projects are characterised by high CAPEX and long payback periods. This makes it difficult to attract private investment. Having the right funding scheme is crucial to maintain a reasonable overall cost; it requires finding investors who are willing to make long-term investments. Public guarantees are often needed to cover financial-related risks. Profitability can be low in some countries and so a clearly defined business model is essential to attract financial interest and attain a return on investment. DHC is in direct competition with individual heating solutions such as fossil fuel (gas, oil) boilers, while consumer protection laws mean that customers have the right to disconnect from DHC networks in favour of individual solutions, which can have a negative impact on projects where the margins are fine.

There are different risks associated with both small and large projects but bigger projects can exploit economies of scale and are less vulnerable to external shocks. Instruments are needed to enable the aggregation of small projects to leverage private investments, access more funding and reduce the risks involved. Innovative business models are needed to reflect the evolution of the sector towards low temperature DHC, where heat is sold as a service or through a pay-as-you-go model. These novel business models will leverage public and private investment into the sector, attracting institutional investors and placing increased emphasis on the green dimension of investing in renewable heating and cooling technologies. The inclusion of certain aspects can make projects more economically viable such as the exploitation of a reliable source of waste heat or having a mix of heating and cooling demands throughout the year.

Public funds and cities/municipalities are traditional sources of funding but there is also a need to engage the private sector. Institutional investors such as pension funds are expected to invest more in clean energy technologies in the future and may offer a novel financing method. Innovative financing schemes such as municipal green bonds, one-stop shops and standardisation of contracts (EPCs) constitute a renewed funding source for DHC & TES projects. It is important to maintain focus on grants and PDAs (project development assistance) as a way of de-risking instruments. By providing the majority of project funding up front, a large amount of risk can be reduced.

Funding Instruments

Further information can be found in the inventory of funding instruments developed by RHC-ETIP. According to this inventory, there are an estimated 26 funding instruments at EU level, outlined in the table below. At European level, DHC & TES projects are financed using grants (18) from public and private organisations, equity funds (3) from public authorities and financial institutions, financial schemes such as loans (5) and guarantees (6). Subsidy (1) and support schemes in the form of tax deductions and fiscal incentives also provide support. Grant-based financing and guarantees are the most common funding instrument and are especially useful for projects with higher risk such as in early stages of project development. Programmes such as the Innovation Fund can be useful to provide a bridge between R&I funding and revenue support instruments such as Member States' renewable energy and energy efficiency support schemes. The table below provides an overview of the European funding programmes available for DHC & TES.

GRANTS	LOAN	GUARANTEE	EQUITY	SUBSIDIES	OTHER
Green Deal	LIFE Private Finance for Energy Efficiency (PF4EE)	CEF – Energy	European Investment Fund	URBACT III	CEF Energy
Horizon Europe	European Energy Efficiency Fund	European Fund for Strategic Investments (EFSI)	InnovFin		LIFE Private Finance for Energy Efficiency (PF4EE)
SME Instrument	European Investment Fund	Smart Finance for Smart Buildings	COSME		
Fast Track to Innovation (FTI)	InnovFin	European Energy Efficiency Fund	EIT InnoEnergy		
Future and Emerging Technologies (FET) Open	COSME	European Investment Fund			
EIT Climate-KIC		InnovFin			

GRANTS					
INTERREG: European Territorial Co-operation (ETC)	CEF – Energy	ELENA	Urban Innovative Action (UIA)	NER300 / Innovation Fund	EUREKA
LIFE Climate Action	LIFE Environment	Eurostars	EIT InnoEnergy		

Renewable Heating & Cooling

European Technology and Innovation Platform

DISTRICT HEATING & COOLING AND THERMAL ENERGY STORAGE TECHNOLOGY PANEL

EUROHEAT & POWER

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