TECHNICAL ANNEX

1 S&T EXCELLENCE

1.1 SOUNDNESS OF THE CHALLENGE

1.1.1 DESCRIPTION OF THE STATE-OF-THE-ART

The proposed COST Action **Geothermal-DHC** deals with the integration of geothermal technologies into heating and cooling grids across Europe for lowering emissions, raising the share of renewables and hence mitigating the impacts of climate change. Energy production currently raises a lot of socio-economic and environmental challenges. To achieve low-carbon economies, an increasing proportion of energy is produced from renewable energy sources; shallow and deep geothermal systems are part of this energy mix. They meet the requirements of future environmentally friendly and economically efficient heating and cooling grids in urban as well as in rural areas. Hence, geothermal systems can play a major role to meet the energy demand in the housing sector in an emission free way and can strongly contribute to reach the Climate Goals of the Paris Agreement 2015. Among all renewable energy sources, geothermal systems present crucial advantages: energy supply is not volatile such as wind or solar based systems; large rock volumes allow provide large quantities of energy and allow the storage of heat (via cooling systems) to accommodate intermittency of the total energy demand and production.

Introduction to geothermal technologies for heating, cooling and underground storage

Medium to high temperature geothermal systems typically comprise reservoirs with temperatures usually higher than 50° C and are classified as hydrothermal and petrothermal systems (Fig. 1). Hydrothermal systems are developed in reservoirs where the natural permeability is high enough to circulate water between two bore holes in an open system. Petrothermal systems are developed in hot and dry crystalline or dense sedimentary rocks with very low natural permeability (Breede et al, 2015). Such systems require technical stimulation actions to produce permeabilities for the open water circulation (Hot-Dry-Rock (HDR) or Enhanced Geothermal Systems (EGS). If high water flow rates can be achieved in such systems, power production is economically reasonable.

Shallow geothermal systems operate at temperature levels below 50 °C and use the uppermost hundreds of meters of the subsurface (Figure 1). These systems are used in combination with closed loop heat exchanger systems or open loop systems (or groundwater heat pump systems) and heat pumps, also known as geothermal or ground source heat pump (GSHP) systems (Bayer et al, 2012). Such systems can be used in residential houses, building blocks, commercial buildings and industrial processes for heating and cooling.

Geothermal systems are increasingly utilised also for **underground heat/energy storage** approaches, which enables alternating storage and extraction of heat/cold as a function of heat demand and production. Seasonal heat storage may be provided by different underground thermal energy storage (UTES) concepts (Anderson et al 2003) based on borehole heat exchangers (BTES), aquifers (ATES) or subsurface caverns (CTES).

More recently, **synergies between geothermal systems and other subsurface technologies, such as** Geological Storage of CO2 (Carbon Capture Utilization Storage) and the re-use of abandoned subsurface infrastructures like hydrocarbon wells and mines, are being developed.

Research is also being undertaken to manage underground storage systems not only at seasonal but also at higher frequencies, which should allow to integrate the intermittent excess production from other renewable or classical energy sources leading to a new generation of **low temperature heating and cooling grids** (Bünning et al, 2018), i.e. sector coupling.

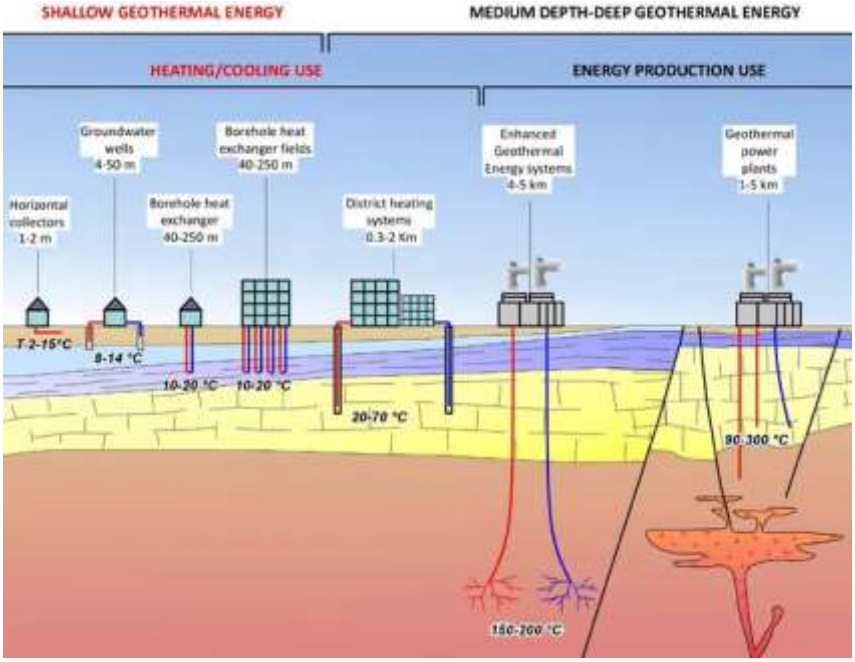

Figure 1: Geothermal technologies and approaches as a function of the underground reservoir properties, depth and temperature values (http://wiki.cesba.eu/wiki/Shallow_Geothermal_Energy/General_Public).

The current market situation in Europe with regard to the inclusion of geothermal applications into heating and cooling grids

The constantly growing market of geothermal applications for heating and cooling is quite heterogeneous among the different European countries.

Medium to deep geothermal: Referring to the current Market Report of the European Geothermal Energy Council (Dumas et al, 2018) 29 European countries are showing a growth of the number of deep geothermal heating and cooling systems. In 2017, 294 district heating plants were in operation in Europe with an installed capacity of over 4.9 GWth (1.7 GWth in the European Union). In 2017 the effective market growth of geothermal district heating reached around +3% with an average annual growth rate of up to +10% in recent years. Regarding the reported projects under development, almost every European country will utilize deep geothermal for heat supply by 2020.

Shallow geothermal: The use of shallow geothermal systems for heating or cooling purposes experienced a significant growth worldwide. Between 2010 and 2015, the world's total capacity of geothermal heat pumps installed increased at an annual rate of 13.2% up to 50 GW total capacity, with an annual energy use of 326 848 TJ/year. The equivalent number of installed 12 kW units is approximately 4.19 million, which represents a 52% increase over the number of installed units in 2010 (Lund & Boyd, 2016). In 2017, the total installed capacity reached around 20 GW in more than 2 million individual units (Dumas et al, 2018) at a growth rate of +5%, whereas annual growth rates exceed +10% in the European countries with emerging markets.

Regarding the overall heating and cooling market and the application of renewables, geothermal systems still represent a niche. Despite some countries having significant high enthalpy resources, such as Iceland, Turkey and Italy, the share of all geothermal technologies in the heating and cooling market is still below 2% and below 10% within the renewable heating sector.

1.1.2 DESCRIPTION OF THE CHALLENGE (MAIN AIM)

The current and expected future socio-economic boundary conditions demand a paradigm shift in district heating and cooling systems. The main drivers for creating a new generation of **decarbonized heating- or combined heating and cooling systems** are represented by:

- Adoption of Climate Change mitigation measures (Global Warming of 1.5 °C, IPCC, 2018);
- Fulfilling the policy requirements and legal regulations of the EU (e.g. 2020 & 2030 Climate and Energy Strategy; in particular “Renewable Energy Directive”, “Energy Efficiency Directive” and “Energy Performance of Buildings Directive”) and also the single national strategies to reach the Goals of the Paris Climate Agreement of 2015.
- Diversifying energy supply sources in the EU member states and reducing the dependency on energy imports;
- Improving air quality by reducing fossil fuel based energy sources;
- Reducing urban heat island effects and its negative influence on environment by seasonal thermal energy storage and use of otherwise wasted heat;
- An intelligent complementary energy demand side and resource management, integrating sector coupling, which reduces energy consumption and increase efficiency.

Future heating and cooling systems (HCS) will need to be more diversified and decentralized with regard to heating sources and sinks and they might consider seasonal heat storage to shift from capacity based to energy based systems. Furthermore, locally available energy sources emphasizing RES (renewable energy sources) should represent a major supply of HCSs to avoid energy import and transport and their related costs and energy losses. Geothermal technologies are able to provide a solution for efficient energy production and consumption, by overcoming the mismatch between intermittent renewable heating and cooling supply and fluctuating demand. In that context, the subsurface may play an important role by acting as an energy source, -sink and seasonal heat storage. Beyond well-known, operative and economically profitable very-high enthalpy (e.g. >100 degC) or low enthalpy (<50 degC reservoirs, hydrothermal and petrothermal systems cover vast regions of Europe based on recent estimations and may play a key role for supplying renewable energy to HCS at a medium term. However, despite its high potential, they have been explored to a much less extent compared to other renewable energy systems due to a low awareness of investors and higher economical risks linked to uncertainties in the exploration of suitable reservoirs.

Geothermal-DHC aims to addresses the integration of geothermal technologies to heating and cooling grids based on experiences from case studies across Europe. The overall ambition is to identify, evaluate and introduce solutions based on geothermal applications to **increase the share of RES** of up to **30% in 2030** and **50% in 2050 in heating and cooling grids across Europe**. This implies a boost of the market diffusion with regard to all geothermal technologies across Europe to leave the current niche in the heating and cooling sector.

To tackle this challenge, the Action addresses the following scientific questions:

- What can be learned from case studies or existing and new geothermal developments across Europe addressing the entire process chain from exploration, commissioning, implementation, operation and monitoring as well as socio-economic impacts and acceptance?
- Which knowledge gaps still prevail? How can they be addressed and which measures need to be undertaken to enhance investments in the inclusion of geothermal technologies?
- Which technical solutions are suitable to at least approach or reach the above listed 2030 and 2050 aims?
- What do policy makers, regulators and investors need from the research community to include geothermal energy in future energy roadmaps for heating and cooling in Europe?
- Which funding mechanisms can support the implementation of geothermal technologies in a cost-effective way?

1.2 PROGRESS BEYOND THE STATE-OF-THE-ART

1.2.1 APPROACH TO THE CHALLENGE AND PROGRESS BEYOND THE STATE-OF-THE-ART

Geothermal-DHC investigates the inclusion of geothermal systems in the heating and cooling market to shift this technology portfolio from a niche to a relevant player in Europe.

Past and recent projects like GeoDH (http://geodh.eu/), RESCUE (http://www.rescue-project.eu/) or CHEP GSHPs (http://cheap-gshp.eu/) as well as the COST Action GABI (https://www.cost.eu/actions/TU1405/#tabs|Name:overview) mostly address single sectorial aspects of geothermal use (e.g. the use of deep geothermal for district heating or the application in buildings and infrastructure).

In contrast, the proposed research network follows both, an open scale- and technology approach addressing the whole range from decentralized local grids to large scale urban district heating and cooling networks based on different case studies across Europe.

The network applies a technological and thematic bottom – up approach allowing monovalent or multivalent solutions for heating and cooling. The only limitation is given by the fact that geothermal applications, including underground thermal energy storage, must be a vital part of the technological concepts applied and that there is no focus on the production of electricity.

From a thematic and scientific point of view, the Action will address the whole process chain from exploring resources, characterizing sites, developing technical concepts below and across the surface for efficient inclusion of geothermal technologies, identifying and managing risks and analysing legal frameworks. From an intersectoral point of view, the Action addresses ecological and socio-economic impacts and possible rebound effects as well as social acceptance.

Geothermal-DHC will merge and connect knowledge from more than 50 national- as well as international projects in which the proposers have been or are involved in and will refer to:

- Methodologies, workflows and concepts on the inclusion of geothermal resources in general;
- Case studies for developing and evaluating concepts at real life conditions;
- Field Laboratories and in-situ experiments investigating detailed technical problems like the coupled thermal-physical behaviour of the subsurface or above surface technical solutions for next generation district heating and cooling systems;
- Existing demonstrators scientifically monitored and evaluated across Europe.

The proposing network already has access to at least 24 different sites in 9 European countries. will also increase the number of sites to more than 35 during the expansion phase of Geothermal-DHC. It comprises a representative cross section of the heterogeneous geothermal market of Europe to support knowledge transfer from market leaders to followers.

Furthermore, the network will connect decision makers at both, local, regional, national and international level to the research community inside and outside Europe to support a strong competence platform for geothermal based heating and cooling grids in Europe. Taking into account the need for new strategies and roadmaps after 2020, the current point in time is crucial to enable a shift of paradigm towards geothermal applications.

1.2.2 OBJECTIVES

1.2.2.1 Research Coordination Objectives

Geothermal-DHC will:

- Harvest and pool existing knowledge from more than 50 national and international projects linked to the network, which cover the following research sectors:
    - Assessment and characterization of resources as well as environmental impacts based on more than 20 case studies across Europe;
    - Technological research aspects of the inclusion of geothermal technologies in existing and new heating and cooling grids at an open scale in urban and non-urban areas. This includes operational and environmental monitoring of supplying and consumption structures;
    - Sector coupling possibilities will be evaluated especially in the focus of heat storage and cooling options
    - Economical evaluation of planned and existing heating and cooling grids supported by geothermal applications. This includes existing incentive and other supportive governmental measures like risk mitigation programs;
    - Legal framework and procedures for licensing and commissioning;
    - Socio economic rebound effects and social acceptance.
    - Development of a parameter catalogue for developing decision making support tools
- Evaluate the transferability of experiences and lessons learned between the different sites covered by the COST Action;

- Identify research gaps and measures to enhance the competitiveness of geothermally supported heating and cooling grids and develop proposals for follow up research activities taking into account the specific uncertainties related to legislation, economy, climatic and geological/site specific conditions across Europe compared to other energy solutions;
- Identify and characterize successful solutions for the integration in geothermal technologies in monovalent as well as multivalent heating and cooling grids;
- Compile the knowledge gained through the case studies to general technological catalogues, guidelines and fact sheets how to realize the inclusion of geothermal applications at its full technological range;
- Upscale the experiences gained at individual sites at European level to evaluate the chances for achieving the proposed 2030 (30%) and 2050 (50%) inclusion targets and compile them into a strategic roadmap for the decarbonization of heating and cooling grids by integrating geothermal resources.

1.2.2.2 Capacity-building Objectives

Geothermal-DHC will support a pan-European research and competence platform on the inclusion of geothermal technologies into heating and cooling grids including sector coupling by means of:

- Creating a physical web platform dealing with the present and possible future role of geothermal technologies in heating and cooling grids. The platform will offer:
    - Knowledge repositories covering the outcomes of national and international projects the Action consortium was and is involved in;
    - Compiled technological catalogues, fact sheets and guidelines based on the involved case studies and real life demonstrators;
    - Categorized links to international policies, regulations, initiatives and research projects;
    - Provide a strategic roadmap for enhancing the share of geothermal energy in heating and cooling grids for 2030 and 2050.
- Collaborating with already existing European and international organizations as well as EU institutions dealing with geothermal energy, heating and cooling supply and energy and climate mitigation policies;
- Collaborating with research groups in the previously mentioned thematic fields and interlinking research groups of different disciplines to cover all relevant thematic aspects;
- Interlinking local, regional, national and international stakeholders and decision makers of the involved countries to share the experiences gained at the covered case studies and real-life demonstrators;
- Promoting interdisciplinary education and supporting young careers in the research field of geothermally supported heating and cooling grids. This includes access to data from case studies, subsurface laboratories and real life demonstrators, short term staff exchange programs, technical workshops and scientific missions linked to academic theses as well as joint field trips, student conferences and training schools;
- Transferring knowledge from leading- to follow-up countries with regard to geothermal application and heating grids by supporting knowledge transfer workshops, scientific events linked to the covered sites, short-term staff exchange and joint scientific missions;
- To ensure gender balance in all planned activities (average share of at least 40% of each gender).
- To identify research gaps and prepare joint follow up research initiatives

Our special interest is to promote young scientists, who will be in charge to realize our concepts in the future and to involve partners from ITC countries, where the need for a decarbonisation of heating and cooling grids is very high.

2 NETWORKING EXCELLENCE

2.1 ADDED VALUE OF NETWORKING IN S&T EXCELLENCE

2.1.1 ADDED VALUE IN RELATION TO EXISTING EFFORTS AT EUROPEAN AND/OR INTERNATIONAL LEVEL

The geothermal resources are considered as a local, reliable and clean Renewable Energy Sources (RES) well suited for the heating and cooling grids. However, to our knowledge, no scientific pan-European initiative, organization, network or project has yet investigated the inclusion of the diverse types of geothermal technologies into the heating and cooling grids. Instead, in most cases individual technologies, process steps or disciplines have been targeted.

Several projects, like Ground-Reach, Heat and the City, BRUGEO, GeoPLASMA-CE, GRETA, MUSE, Geothermal4PL, TransGeoTherm refer to solving diverse issues of shallow geothermal energy application with a focus on the assessment of geothermal energy potential and land-use conflict mapping. The projects and networks dealing with diverse types of medium- and deep geothermal energy, such as: MATChING, GEMEX, ThermoDrill, Geothermal ERA-NET (GEOTERMICA), focused mainly on new drilling technologies, materials, improvement of performance and assessment of subsurface derisking.

It is also a priority to develop policies and strategies to ensure a quick and efficient deployment of shallow and deep geothermal as RES with a focus on the identification of the non-technical administrative and regulatory barriers at local and regional level. This has been elaborated in projects and initiatives like progRESsHEAT, ReGeoCities, STEP UP, Compact of Mayors, DECARB HEAT, Energy Cities, the European Technology and Innovation Platform on Renewable Heating & Cooling (RHC-ETIP), Geothermal Technology Panel. Some of them, like GRETA and GEOPLASMA-CE, established a project partner's network and a knowledge base to exchange the information and summarise the results.

Some former projects led to the development of European initiatives like "The Heat under your feet" (http://www.heatunderyourfeet.eu/) limiting its scope to the application of (shallow) ground source heat pumps for heating and cooling. Other European organization like the European Heatpump Association (EHPA) have a pure technological focus without giving special emphasis on geothermal technologies.

Geothermal DHC applies an intersectoral and technological bottom-up approach based on different case studies across Europe, instead of just tackling individual technical concepts, technologies or fields of applications. The added value compared to existing efforts is given by:

- Creating a network with a clear emphasis on the possible future role of geothermal technologies in heating and cooling grids with clear formulated targets for 2030 and 2050;
- An open, bottom up technological and strong intersectoral approach;
- By up taking experiences from individual case studies, field laboratories and real life demonstrators at more than 20 different locations across Europe;
- By capitalizing more than 50 national as well as international projects dealing with individual aspects of geothermal energy covering more than 20 countries inside and outside of Europe;
- By transferring research into a European roadmap for the inclusion of geothermal energy into heating and cooling grids;
- Integrating planning, legal and social science perspectives into the research network.

2.2 ADDED VALUE OF NETWORKING IN IMPACT

2.2.1 SECURING THE CRITICAL MASS AND EXPERTISE

To effectively address the challenges and objectives mentioned in section 1, the network will have the following characteristics:

I. Participants will have access to geothermal case studies, subsurface laboratories and demonstrators;
II. Participants involved in studies dealing with the inclusion of geothermal technologies into heating and cooling grids;
III. Participants from countries with developed and emerging geothermal markets and countries with a clear need to improve the share of geothermal (transfer of knowledge);
IV. Partners familiar with European policies;
V. Partners from research sectors covering the entire process chain from exploring – planning – licensing – developing – operating geothermal facilities as well as analysing the related socio-economic impacts.

The Network of Proposers already meets most requirements of the above-mentioned characteristics. It comprises more than 20 individual sites (criteria i.) and involves partners researching on the inclusion of geothermal technologies into heating and cooling grids (ii.) capitalizing from more than 50 national and international research projects. The network already covers more than 20 Countries including both, strong and weak geothermal markets (iii.), and comprises partners experienced in addressing European policies (iv.). All sectors listed in (v.) are represented by at least one researcher.

During the "networking expansion phase" in the beginning of the Action it wants to include participants from all European Countries with strong geothermal markets to enlarge the number of reference sites and to further balance the share of research sectors within the Action. Currently, the network is dominated by subsurface and environmental engineers (around 80%) and it aims to enhance the share of researchers dealing with surface technologies, grid design and simulation as well as economy, regulation and governance as well as social sciences.

2.2.2 INVOLVEMENT OF STAKEHOLDERS

The following stakeholder groups are identified as relevant for Geothermal-DHC:

Local stakeholders from reference sites (case studies, field laboratories and real life demonstrators)

- Operators of geothermal facilities;
- Operators of heating and cooling grids as well as heating and cooling suppliers;
- Policy makers;
- Local energy and spatial planners as well as Energy agencies;
- Local authorities involved in licensing;
- Investors in general;
- Secondary and tertiary education sector;
- Financial institutes and risk underwriters
- NGOs as well as the lay public.

International stakeholders and EU institutions

- International research groups
- International organizations (federations and associations) and existing platforms
- EU institutions like DG Energy and DG Climate

Geothermal-DHC comprises at least 24 different reference sites in at least 14 different countries relevant for diffusing the inclusion of geothermal technologies in heating and cooling grids.

Table 1: Definition of reference sites in Geothermal-DHC.

Definition of reference sites	
Field Laboratory: existing and planned at defined sites	A site not commercially used to investigate and simulate technical concepts, systems responses or specific technologies. Please note that the main focus needs to be on geothermal application
Demonstrator: existing or planned installations	Existing or planned commercial use. The site needs to fully or at least significantly developed within the lifetime of the COST Action (2019 - 2023). It can be independent of scale with regard to the size of the grid but needs to aim at heating or cooling supply.
Case Study: local to regional scale, no Demonstrator realized in lifetime of the Action	Represents feasibility studies, concepts and strategies for a real life study area. It is independent of scale (local to regional). The realization of the outcomes are not foreseen in the lifetime of the Action.

Stakeholders will be involved by the following activities:

- Local stakeholder workshops and events including field trips, regional scientific conferences and workshops aiming at transferring research knowledge to local decision makers (at least 10);

- Stakeholder interlinking events based on joint field trips to other reference sites and participation at knowledge exchange- and transferring workshops (at least 4). The network also plans to organize at least 2 stakeholder interaction events between local- and European as decision makers and international organizations ("Geothermal district heating and cooling day" events in Brussels);
- Stakeholder surveys and consultations to integrate them into the preparation of the Action's outputs. The stakeholder surveys address different topics of the process chain for the inclusion of geothermal applications into heating and cooling grids may base on interviews and online surveys (involvement of at least 20 stakeholders;
- Joint dissemination activities in terms of leaflets, press releases, public events, hosting of sessions at conferences and shared conference booths (at least 10 activities);
- Knowledge exchange- and networking workshops focusing on research groups (at least 4 workshops planned).

2.2.3 MUTUAL BENEFITS OF THE INVOLVEMENT OF SECONDARY PROPOSERS FROM NEAR NEIGHBOUR OR INTERNATIONAL PARTNER COUNTRIES OR INTERNATIONAL ORGANISATIONS

Geothermal-DHC aims at involving participants from international Countries, which already have a well-established or emerging geothermal market or a significant need to decarbonize heating and cooling grids. Of course, all other international partner countries are welcome to get involved into the planned Action on their interest.

During the preparation of the proposal, the Action already involved the Institut National de la Recherche Scientifique (Québec, Canada) as a co-proposer of the Action. The group of Prof. Jasmin Raymond is very active in the domain of both shallow and deep geothermal resources. A research chair funded by the Institut Nordique du Québec (INQ) has been awarded to Prof. Raymond to study the geothermal potential of Nunavik, the northern region of Québec populated by Inuit villages that rely on fossil fuels for both electricity and space heating production. His research group is currently evaluating the potential for geothermal resources (geothermal heat pumps, underground storage and deep borehole heat exchangers) for direct use of the heat. The consortium will benefit from the expertise of the INRS in the design of geothermal technologies in high-demand (8000 heating degree days) small communities in remote areas. Prof. Raymond's group will also bring in experience of an international project funded by UNESCO, wherein research activities on field methodologies, numerical simulations, public awareness and social acceptance of geothermal energy are addressed and shared among 8 countries in 4 different continents.

3 IMPACT

3.1 IMPACT TO SCIENCE, SOCIETY AND COMPETITIVENESS, AND POTENTIAL FOR INNOVATION/BREAK-THROUGHS

3.1.1 SCIENTIFIC, TECHNOLOGICAL, AND/OR SOCIOECONOMIC IMPACTS (INCLUDING POTENTIAL INNOVATIONS AND/OR BREAKTHROUGHS)

The proposed research network is expected to have the following impacts:

Short term perspective (within the duration of the COST Action)

- Research impacts: The network is pooling knowledge gained at more than 20 reference sites on geothermal energy use for heating and cooling as well as from more than 50 national- and international projects linked to the consortium. Accessible knowledge will be compiled and evaluated towards remaining research gaps. Based on this, the network aims at developing follow-up proposal on the research topics identified.
- Educational impacts: The network wants to establish young researcher and training programs focusing on the inclusion of geothermal in heating and cooling grids. Emphasis will be on access to knowledge from the different sectors involved in the process chain for developing geothermally supported heating and cooling grids, such as subsurface planning, management and engineering, surface engineering, governance and regulations, energy economics and social acceptance.

- Heat energy economy and market impacts: The network will establish an intersectoral platform on the use of geothermal in heating and cooling grids. The planned research and capacity building activities aim at transferring knowledge between leading- and follow up countries with regard to geothermal use. These measures will foster market diffusion of geothermal technologies across Europe. Learning from technological reference sites raises awareness of decision makers and disseminates suitable solutions. The network also aims to evaluate the current economic competitiveness of geothermally supported heating and cooling grids in the countries involved in the Action and proposes research and policy measures for supporting the profitability.
- Social and political impacts: On the one hand, the network interacts with local communities at the involved countries to identify non techno-economical barriers and addresses concerns. On the other hand, the interaction with European policy- and decision makers as well as European organization may raise the awareness towards future strategies for decarbonization of heating and cooling grids and reducing the dependency on energy imports. The planned upscaled roadmap document transfers the research findings of the Geothermal-DHC to European stakeholders for providing inputs for adapting long term strategies and measure in the time frame of 2030 and 2050. The roadmap also supports other relevant initiatives such as the Heat Roadmap Europe, the Covenant of Mayors and Sustainable Energy Action Plans.

Long term perspective (beyond Geothermal-DHC):

- The network supports the establishment of a permanent competence platform to accompany the roadmap prepared during the Action.
- The network aims at joint follow up research initiatives to strengthen the coherency of the platform and keep the impact at a high level.
- The young careers supporting programs developed within the Action will be a continuous part of the competence platform and will be linked to joint research initiatives and training programs developed during the Action.

The results of the Action will contribute to raising awareness and acceptance for the inclusion of geothermal energy in heating and cooling grids at stakeholders at local, national and European level. The scheduled roadmap will support decarbonization, resilience and climate change strategies and action plans and stimulates market incentives to raise the share of RES in general and geothermal in particular towards the aimed 30% in 2030 and 50% in 2050 targets.

3.2 MEASURES TO MAXIMISE IMPACT

3.2.1 KNOWLEDGE CREATION, TRANSFER OF KNOWLEDGE AND CAREER DEVELOPMENT

In order to maximize the scientific, technological and social impacts of the COST Action, specific activities will be carried out to produce new and useful knowledge, facilitating its diffusion among societal actors and to support young researchers in developing their careers. Regarding the production of new and useful knowledge, attention will be paid in providing new information combining the different research sectors involved in creating a strong knowledge basis for supporting private and public decision makers in designing effective policies and strategies.

Regarding stakeholder interaction the network plans (see also chapter 2.2.2):

- Stakeholder interlinking events and joint reference site visits (at least 6);
- Local events to inform the wider public about the opportunities represented by geothermal technologies in terms of: local stakeholder workshops and events including field trips to demonstrators (at least 10);
- Stakeholder surveys at identifying expectations, opportunities and barriers for the inclusion of geothermal applications into heating and cooling grids (at least 20 surveys in terms of interviews and online surveys);

Regarding the transfer of knowledge, widely recognized as the main shortcoming in exploiting innovations, the network plans:

- An international assessment on the state-of-the-art of geothermal application at diverse scales: micro (single building blocks), meso- (local grids) and macro- (district heating and cooling grids). The focus will not only be on developed solutions but also on projects (EU and national funded)

targeting at least a TRLs 6 to 7. The outcomes will be published in through fact sheets via the web portal (at least 20 fact sheets);
- Knowledge exchange, knowledge transfer and networking workshops with local- as well as international research groups and actors in the research topics of Geothermal-DHC;
- A web based knowledge platform providing repositories and categorized web links to relevant European and international initiatives, directives and organizations (at least 4).

Regarding the support for developing career the network plans:

- Personal support of the Action participants to facilitate the active engagement of young researcher in organizing and carrying out the activities of the network;
- Institutional support by organizing young researcher conferences, training schools, staff exchange programs and short term scientific missions linked to academic theses;
- Access to information: The network provides access to data and summarized information from the investigated reference sites (see also chapter 2.2.2) and offers a knowledge repository on the Action related web platform.

3.2.2 PLAN FOR DISSEMINATION AND/OR EXPLOITATION AND DIALOGUE WITH THE GENERAL PUBLIC OR POLICY

The Communication, Dissemination and Exploitation (C-D-E) plan of Geothermal-DHC consists of the following elements:

- A general communication strategy;
- Key messages to be communicated to external audiences
- The initial C-D-E plan specifying objectives, target audiences, channels and targets (Table 2)

Who? The dissemination of the results of the Action is aimed at researchers and the higher education sector, planners, industry and administration in general working in geothermal and renewables technologies, district heating and cooling systems and thermal storage. These are the major target group, being the most direct user of the Action's results.

Specifically, the COST Action intends to communicate with**:**

- stakeholders dealing with operation, design or plan the transformation or building new smart and efficient district heating and cooling systems by disseminating and transferring knowledge gained within the COST Action;
- researchers from universities and research centres working in the different scientific disciplines involved in the field of geothermal energy, renewables and thermal grids;
- policy makers at local, national and European level;
- the general public that needs to be informed about the potential of geothermal technologies in for decarbonizing district heating and cooling systems.

What and how? The Action will adopt means to ensure visibility, impact and create awareness of its achievements in the use of geothermal technologies combined with heating and cooling grids, underground thermal storage and RES as outlined in the previous chapters.

The following key messages have been defined for Geothermal-DHC:

- "The use of geothermal energy combined with other RES in heating and cooling grids, linked to subsurface storage systems, has a significant potential for the decarbonization of the energy market."
- "Geothermal applications represent key technologies for the transformation of old heating and cooling grids based on fossil fuels into future smart and efficient grids."
- "Geothermal cooling and seasonal underground heat storage may become a key technology to mitigate urban heat-island effects"

The planned external communication will regard the key messages defined above. If relevant, the key messages may also be adapted or expanded during the project lifetime of the COST Action.

The C-D-E plan shown in Table 2 organizes the activities planned in this COST Action with regard to objectives, target audiences, planned communication channels and measurable communication targets.

The preliminary plan will later be expanded to a periodically updated living document during the execution of the Action. The coordination of the communication activities and maintenance of the updated C-D-E plan will be governed by the COST Action communication manager. Geothermal-DHC follows an open data access approach as far as possible.

Compliance with IPR rules will be organized in the MoU and will also be at the responsibility of the Communication Manager.

Table 2: Preliminary C-D-E plan.

C-D-E- objective	Type of action	Target audience	Planned activities, channels	C-D-E targets
Inform about the Action, its objectives and activities and dissemination of the outcomes and results of the COST Action	C	All groups	Website Leaflets Corporate identity and logos	>1.000 unique visits at website >300 downloads of the leaflets
General knowledge exchange on cross- cutting topics and knowledge transfer	C,D	Action participants International projects or Actions EU & national stakeholders Higher education	Events Workshops	>10 Knowledge Exchange and Knowledge Transfer Workshops
Disseminate the results of the COST Action to scientific and expert communities	D	International research groups (young careers) Higher education	Cumulative research paper (special journal issue) Present the COST Action at conferences and expert workshops	>1 cumulative research paper in internationally recognized journal >10 presentations
Raise the awareness on geothermal inclusion at heating and cooling grids	D	EU & national stakeholders	Fact-sheets on reference sites covered by the Action Local stakeholder workshops and events	1 catalogue of fact-sheets covering > 15 different
Promote strategies and measures for the inclusion of geothermal energy	E	European and international stakeholders	Roadmap for the inclusion of geothermal energy in heating and cooling grids for the period 2030-2050	1 roadmap

(*) C - communication / D- dissemination / E – Exploitation

4 IMPLEMENTATION

4.1 COHERENCE AND EFFECTIVENESS OF THE WORK PLAN

4.1.1 DESCRIPTION OF WORKING GROUPS, TASKS AND ACTIVITIES

Management structure and working groups:

The Action Implementation Office, located at the Grant Holder, will support the administrative coordination of the Action including internal progress control and communication to COST. It will furthermore provide internal communication tools (e.g. e-mail groups, web conferences and internal file exchange servers) and organize management meetings.

The Action MC (Action Management Committee), as described in the COST SESA guidelines, will be the decision making body. It is led by a Chair and supported by a Vice-Chair. The Action MC meets on a regular basis including annual physical meetings and web meetings at an interval of 3 months.

The Chair and the Vice-Chair are responsible for the scientific and innovation management inside the network and will be supported by Executive Committee (ExCo) consisting of the leaders of the Permanent Working Groups (PWGs). Both positions will be selected by vote of the Action MC. The Chair position will be elected twice in the running time of the Action (Action MC Kick-Off Meeting and Midterm Meeting). The Vice-Chair will be elected on an annual basis. The Chair and Vice-Chair can be re-elected. This flexibility in leading positions is allowed to enable a certain dynamical development of research emphases during the implementation of the Action.

The Executive Committee (ExCo) supports the Action MC and consists of the leaders of Permanent Working Groups (PWGs). The ExCo will have regular web meetings in a one to two month interval. The PWGs cover the following Working Groups (WGs):

- WG Technology coordinates all activities related to technological research including subsurface geothermal and surface heating and cooling grid topics (see also Figure 3, green column).
- WG Outreach and Communication coordinates all external communication activities including C-D-E and IPR. It applies the tools listed in the yellow column of Figure 3 and is led by the Communication Manager of the Action.
- WG Promoting Young Careers coordinates all activities related to education and inclusion of young researchers into the Action activities.
- WG Capitalization and Uptakes coordinates the harvesting and pooling of knowledge inside the network, the identification of research gaps and the organization of follow-up and spin-off research projects.

The PWGs will be active during the entire COST Action. In addition, Ad-Hoc Working Groups will be established during the Action within a framework of research topics, Action tools, Study areas and Technologies as shown in Figure 2. Ad-Hoc Working Groups are intended to allow a dynamic bottom-up approach with regard to research topics and technologies. They support the role of the PWGs and will be approved (opening and closure of WGs) during the Action MC meetings.

Tasks and Activities

Geothermal-DHC differs between Tasks, linked to the PWGs and Activities, linked to the Ad-Hoc WGs. While Tasks have an already defined time frame, shown in Figure 2, Activities will have flexible time frames and will be allocated to Tasks. Tasks and Activities will be organized and monitored in an Action Work Plan, which will be set up at the beginning of the Action and updated on a regular, at maximum 3-monthly basis. The Action Work Plan will also organize the distribution of responsibilities inside the network regarding Tasks, Activities and Deliverables.

Considering its objectives in chapter 1.2.2, Geothermal-DHC includes the following Tasks:

- T1 Coordination and Management of the Action (Action MC supported by the Action Implementation Office): Approving and monitoring the individual WGs, financial planning and monitoring;
- T2 Sharing knowledge inside the network (WG Capitalization and Uptakes): assessment of methods and concepts as well as building the joint knowledge repository.
- T3 Learning from reference sites and successful technical concepts across Europe (WG Technology): organization of workshops and site visits as well as publication of technical fact sheets.
- T4 Implementation and maintenance of the Action-related web platform (WG Outreach and Communication)
- T5 Fostering young careers and female researches linked to the Action (WG Promoting Young Careers): Organization of all trainings and educational events.
- T6 Stakeholder interaction and networking (WG Outreach and Communication): Organization of all activities related to the involvement of stakeholders including events, workshops and surveys.
- T7 Upscaling of outcomes to a European level and follow-up measures (WG Capitalization and Uptakes): Identification of research gaps and preparation of follow-up activities.

- T8 General dissemination and exploitation of results (WG Outreach and Communication): Including preparation of dissemination material and contents for the website as well as publishing of the Action's outcomes in various channels.

The updated Action Work Plan and C-D-E plans will provide the basis for the allocation of budgets to the detailed Activities on a 6 to 12 month basis. The planning of funds will refer to the intersection of a bottom-up approach (proposed activities by the WGs) and a top-down financial framework assigned by the COST framework.

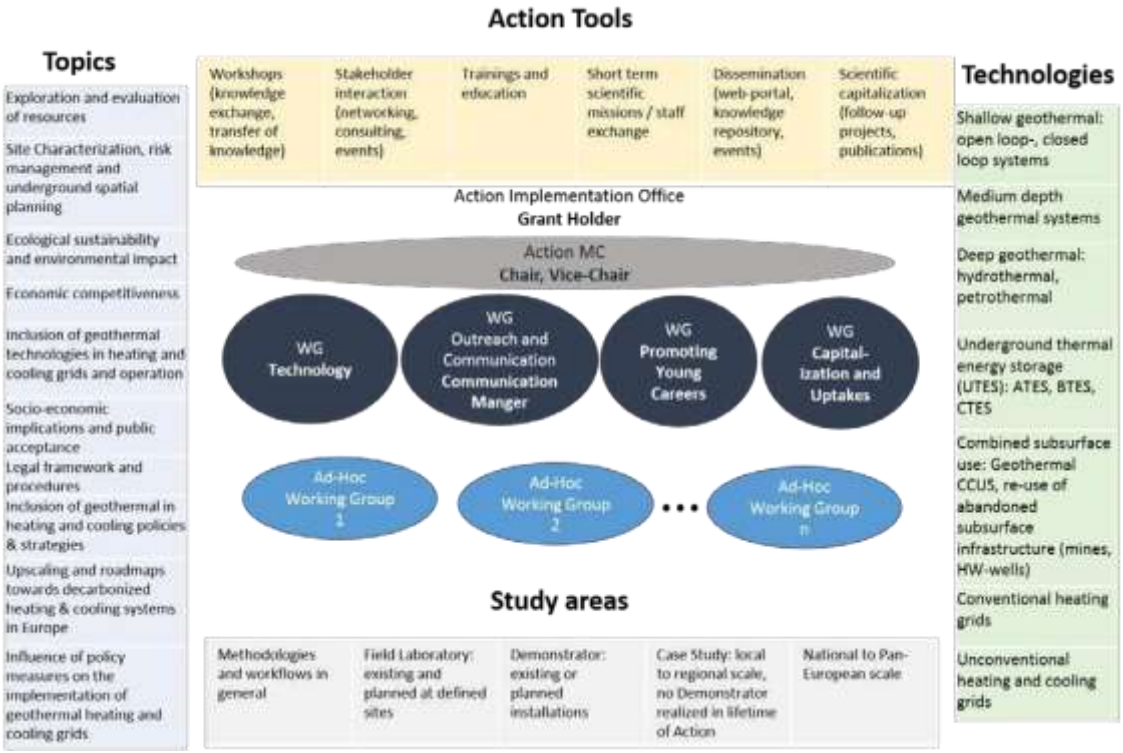

Figure 2: Organisational structure of Geothermal-DHC.

4.1.2 DESCRIPTION OF DELIVERABLES AND TIMEFRAME

The planned deliverables of the Action are listed below including the targeted outputs, delivery time in project months (PM) and links to the Tasks (T) described in the chapter before.

- **D1** Initial Action implementation plan including management and monitoring documents like the Action Work Plan (internal deliverable, 1 document; PM 3; T1)
- **D2.1 to D2.3** Updated Action implementation plan (internal deliverables, 3 documents; PM 12, 24, 36; T1)
- **D3.1 to D3.4** Annual management summary report on the activities performed by the Action network (internal deliverables, 4 documents; PM 12, 24, 36, 48; T1)
- **D4** Electronic Knowledge Repository ready for operation, stored at the Action related web platform. The KR will later be regularly updated during the Action (1 tool; PM 18; T2)
- **D5** Catalogue of workflows and methodologies for the inclusion of geothermal technologies into heating and cooling grids based on problem – solution fact sheets (1 document; PM 36; T2)
- **D6** Fact Sheets on the investigated reference sites and study cases across Europe for the inclusion of geothermal technologies (15 documents, PM 38; T3)
- **D7** Technical report on promising concepts for the inclusion of geothermal energy in heating and cooling grids in Europe (1 document; PM 42; T3)
- **D8** Interactive web platform on the inclusion of geothermal technologies in heating and cooling grids across Europe including deliverable D4 (1 tool; PM 8; T4)
- **D9.1 to D.9.4** Annual progress and impact report on the activities performed to foster the integration of young careers and female researches into the network and its achievements (internal deliverables, 4 reports; PM 12, 24, 36, 48; T5)

- **D10** General educational concept for training related to the inclusion of geothermal technologies in heating and cooling grids based on the experiences gained in the Action (1 document; PM 44; T5)
- **D11.1 to D.11.4** Annual progress and impact report on the involvement of stakeholders and transfer of knowledge (internal deliverables, 4 reports; PM 12, 24, 36, 48; T6)
- **D12.1 to D.12.4** Annual progress and impact report on knowledge exchange and networking activities (internal deliverables, 4 reports; PM 12, 24, 36, 48; T6)
- **D13** Stakeholder feedback report on the expected and aimed role of geothermal technologies for the decarbonization of heating and cooling grids in Europe, including analyses of opportunities and barriers (1 document; PM 34; T6)
- **D14** Summary report on the legal and social boundary conditions in the countries participating at the COST Action for the inclusion of geothermal technologies in heating and cooling grids (1 document; PM 36; T6)
- **D15** European Roadmap for the inclusion of geothermal technologies and market diffusion measures to reach the proposed 2030 and 250 inclusion targets in the heating and cooling sector (1 document; PM 42; T7)
- **D16.1 to D16.3** Updated C-D-E plan (internal deliverables, 3 documents; PM 12, 24, 36; T8)
- **D17.1 to D17.4** Annual summary report on the achieved dissemination and exploitation activities (internal deliverables, 4 documents; PM 12, 24, 36, 48; T8)
- **D18** General dissemination materials including leaflets and periodic newsletters (10 documents; PM 46; T8)

4.1.3 RISK ANALYSIS AND CONTINGENCY PLANS

The initial and updated Action implementation plans (D1, D2) will also contain detailed risk and contingency plans. At the moment, the Action identified the following implementation risks:

Table 3: Risk and Contingency analysis

Risk	Likelihood	Impact	Strategy	Response
The number of network participants exceed the available funds	Medium to high	Medium	Mitigate	The funding rate of individual activities will be prioritized and reduced if necessary, to avoid a narrowing of activities.
Withdrawal of participants with major roles in the consortium	Low	Medium	Mitigate	The network ensures to have the critical mass of participants and to organize a quick formal change of roles.
Lack of interest of national and European stakeholders	Low to medium	High	Avoid	Adaptation of the communication strategy and greater engagement with stakeholders
Violation of IPR rules	Low	High	Avoid	The Communication Manager performs compliance checks measures and raises awareness on IPR rules inside the network.
Not all relevant topics are covered by working groups	Low	Medium	Avoid	Gaps in competence and interests are planned to be closed by involvement of further (regular and ad-hoc) participants during the expansion phase of the Action.
Deliverable or milestone delay	Medium	Medium	Avoid-mitigate	The ExCo oversees Work Group progress for timely delivery. Any delays will be assessed and amendments made by the Action MC.

4.1.4 GANTT DIAGRAM

Geothermal-DHC contains three major phases: during the initial (network expansion) phase, activities focus on involving further participants to optimize the aimed balances regarding competences and views as well as involving more reference sites into the network. During the scientific expansion phase, activities will focus on research and targeted communication to complete the scientific deliverables. In the final dissemination and uptake phase, the consortium will focus on the accomplishment of the communication-based deliverables and on follow-up measures.

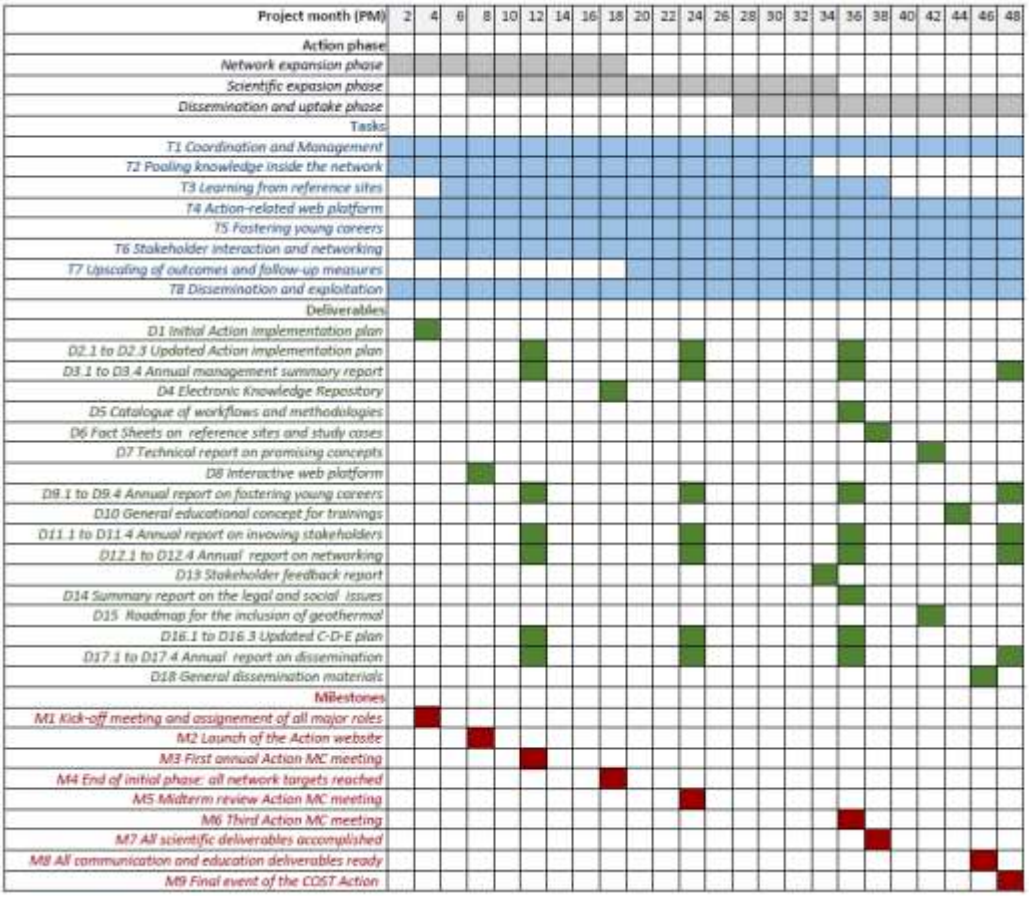

Figure 3: GANTT chart of Geothermal-DHC.

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